UNIVERSITY “DŽEMAL BIJEDIĆ” MOSTAR
FACULTY OF MECHANICAL ENGINEERING

1st International Conference on Engineering

MAT 2010

Manufacturing and Advanced Technologies

PROCEEDINGS

Edited by: S. Rahimić, S. Isić

18th-20th September 2010. Mostar, Bosnia & Herzegovina

Title: "MAT 2010 – Manufacturing and Advanced Technologies"

Editors: S. Rahimić, S. Isić

Reviewers: V. Doleček, M. Behmen, S. Sedmak, V. Višekruna, Z. Burzić, H. Đukić, J. Kevelj, D. Tiro, R. Dedić, S. Pašić, A. Sedmak, S. Klarić

Publisher: University "Džemal Bijedić", Faculty of Mechanical Engineering Mostar

Corrector: S. Isić

Technical assistance: Edin Šunje, Emir Nezirić

Issue: 300 copies

Printed by: FAMIS Mostar

International Scientific Comittee:

Organising Committee:

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Supported by:

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PREDGOVOR

Proizvodnja u razvijenim zemljama je zasnovana na modernizaciji i optimizaciji proizvodnih procesa uz primjenu naprednih tehnologija koje su rezultat naučno-istraživačkog rada. Primjenom novih tehnologija preduzeća imaju efikasniju proizvodnju te konkurentnost na svjetskom tržištu, gdje je važna sprega sa naučno-istraživačkim institucijama. Mašinski fakultet pokreće prvu međunarodnu konferenciju „MAT 2010 – Proizvodnja i napredne tehnologije“ kojom želi doprinjeti implementaciju novih tehnologija u proizvodnim procesima. Upravo ova misao vodilja je inicirala organizacioni odbor da uz odluku naučno nastavnog vijeća organizuje ovaj skup, kao i želja za boljim ostvarenjem saradnje između naučno-istraživačkih institucija i privrednih subjekata.

Prva međunarodna naučna konferencija o naprednih tehnologijama MAT 2010 održava se u Mostaru 18.20. Novebra 2010. godine

Naučna konferencija “MAT2010 – Proizvodnja i napredne tehnologije” se sastoji od četiri sekcije:

1. Informacione tehnologije
2. Obnovljiva energija
3. Proizvodne tehnologije
4. Integritet i dizajn konstrukcije

Na ovom skupu uzet će učešće XX autora i koautora iz Bosne i Hercegovine, zemalja regiona i Evropske Unije. Prijavljeno je XX radova od čega je XX originalnih znanstvenih radova, XX prethodnih saopštenja, XX pregledna rada i XX stručnih radova.

Nadamo se da ćemo ovim skupom doprinijeti kako razvoju naučno-istraživačkog rada na našem faultetu, kao i omogućiti privrednim subjektima da poboljšaju svoju konkurentnost na domaćem i stranom tržištu te tako doprinijeti razvoju privrede Bosne i Hercegovine.

Zahvaljujemo se svim autorima, koautorima, pokroviteljima i svim drugima koji su pomogli i doprinijeli da se konferencija MAT2010 održi te se nadamo da će naredni skup biti na još višem nivou.

dr. Senad Rahimić
Prcdsjednik Organizacijskog odbora

dr. Alija Pičuga
Predsjcdnik Naucnog odbora

INTRODUCTION

Production in developed countries is based on modernization and optimization of manufacturing processes by using advanced technologies as a result of scientific research. By the application of new technologies, companies have more efficient production and competitiveness in the global market, where connection with important scientific and research institutions is indispensable. Faculty of Mechanical Engineering is launching its first international conference "MAT 2010 - Manufacturing and advanced technology," with the goal to contribute to the implementation of new technologies in production processes. Precisely this was considered as a guiding principle, which has motivated the Organizational Committee to organize this Conference based on the approval of our Teaching - Scientific Council. We also wanted to establish better cooperation between scientific research institutions and businesses corporations.

First international scientific conference on advanced technologies MAT 2010 will take place in Mostar from November 1, to November 20, 2010.

Scientific conference „MAT 2010 – Manufacturing and Advanced technologies" has four main topics:

1. Information technologies
2. Renewable energy
3. Manufacturing technology
4. Integrity and design of constructions

XX authors and co-authors from Bosnia and Herzegovina, region and European Union will participate in the conference. There are XX papers, out of which XX are original scientific papers, XX are preliminary reports, XX reviews and XX are professional works.

We hope that this meeting will contribute to the development of science and research at our faculty, and allow businesses to improve their competitiveness on domestic and foreign markets and therefore contribute to the economic development of Bosnia and Herzegovina.

We would to thank all authors; co-authors, sponsors and everybody who have helped and contributed to MAT 2010 and we hope that our next meeting will be even more successful.

dr. Senad Rahimic
President of Organizing Committee

dr. Alija Picuga
President of Scientific Committee

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Structural Integrity and Design:

1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

PRIMJENA INDUSTRIJSKIH ROBOTA U MALIM I SREDNJIM PODUZEĆIMA

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SAŽETAK

Analizirana je primjena industrijskih robota u malim i srednjim poduzećima u zemljama Evropske unije. Analiza je napravljena u šest evropskih zemalja: Francuskoj, Njemačkoj, Španjolskoj, Švedskoj, Italiji i Poljskoj. Anketa je urađena u ovim zemljama, te došlo se do zaključka da 67% malih i srednjih poduzeća još uvijek nisu automatizirale proizvodni proces i uvele industrijske robote, a 33% MSP već koristi industrijske robote, dok 11% ima namjeru instalirati industrijske robote u naredne dvije godine. Možemo zaključiti da su u Italiji mala i srednja poduzeća manje automatizirali proizvodni procesi od malih i srednjih poduzeća u Njemačkoj, Španjolskoj, Francuskoj, Poljskoj i Švedskoj. Najveća je zainteresiranost za robote "uključi – i – proizvodi" a najmanja zainteresiranost za robote sa više alata. Kroz analizu je uzeta upotreba industrijskih robota, planiranje povećanja njihovog korištenja, zatim razlozi nekorištenja industrijskih robota u malim i srednjim poduzećima, te procjena različitih mogućnosti primjene istih. Analizirana je procjena budućih potencijalnih korisnika industrijskih robota u malim i srednjim poduzećima.

Ključne riječi: MSP (mala i srednja poduzeća), primjena, industrijski robot, automatizacija, instalacija.

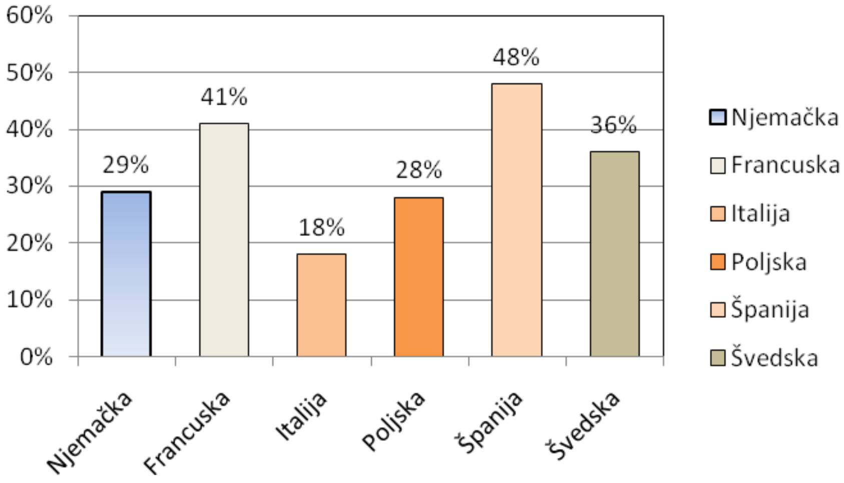
1. UVOD

Kao što je u World Robotics Report 2008. prikazana primjena industrijskih robota u svijetu u svim industrijskim granama, interesantno je da se prikaže i primjena industrijskih robota u malim i srednjim poduzećima. Anketirana su mala poduzeća do 49 zaposlenih radnika i srednja preko 50 zaposlenih radnika. Anketu ispitanika evropskih malih i srednjih proizvodnih poduzeća proveo [1], te napravio statistiku za primjenu industrijskih robota. Analiza primjene industrijskih robota u malim i srednjim poduzećima je napravljena za slijedeće evropske zemlje: Španjolsku, Francusku, Njemačku, Švedsku, Italiju i Poljsku. Kroz analizu je uzeta upotreba industrijskih robota, planiranje povećanja njihovog korištenja, zatim razlozi nekorištenja industrijskih robota u malim i srednjim poduzećima, te procjena različitih mogućnosti primjene istih. Analizirana je procjena budućih potencijalnih korisnika industrijskih robota u malim i srednjim poduzećima.

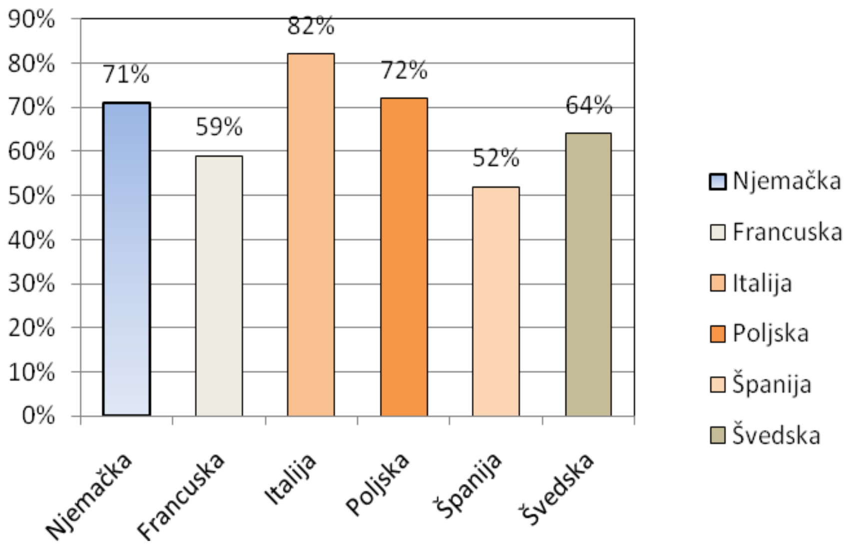
2. PRIMJENA INDUSTRIJSKIH ROBOTA U MSP

Provođenjem ankete došlo se do zaključka da 67% malih i srednjih poduzeća još uvijek nisu automatizirale proizvodni proces i uveli industrijske robote, dok 33% poduzeća već koristi industrijske robote, a 11% ima namjeru instalirati industrijske robote u naredne dvije godine.
Sa slike 1. možemo zaključiti da je stopa korištenja industrijskih robota u Njemačkoj 29%, Francuskoj 41%, Italiji 18%, Poljskoj 28%, Španjolskoj 48% i Švedskoj 36%[1,3]. Mala poduzeća s do 49

zaposlenih radnika imaju nižu stopu korištenja robota oko 30%, dok kod većih poduzeća koja imaju 50 i više zaposlenih radnika ima veću stopu korištenja industrijskih robota 37%. Možemo zaključiti da su u Italiji mala i srednja poduzeća manje automatizirani proizvodni procesi od malih i srednjih poduzeća Njemačke, Španjolske, Francuske, Poljske i Švedske.



Slika 1. Korištenje robota u 2008 godini u MSP



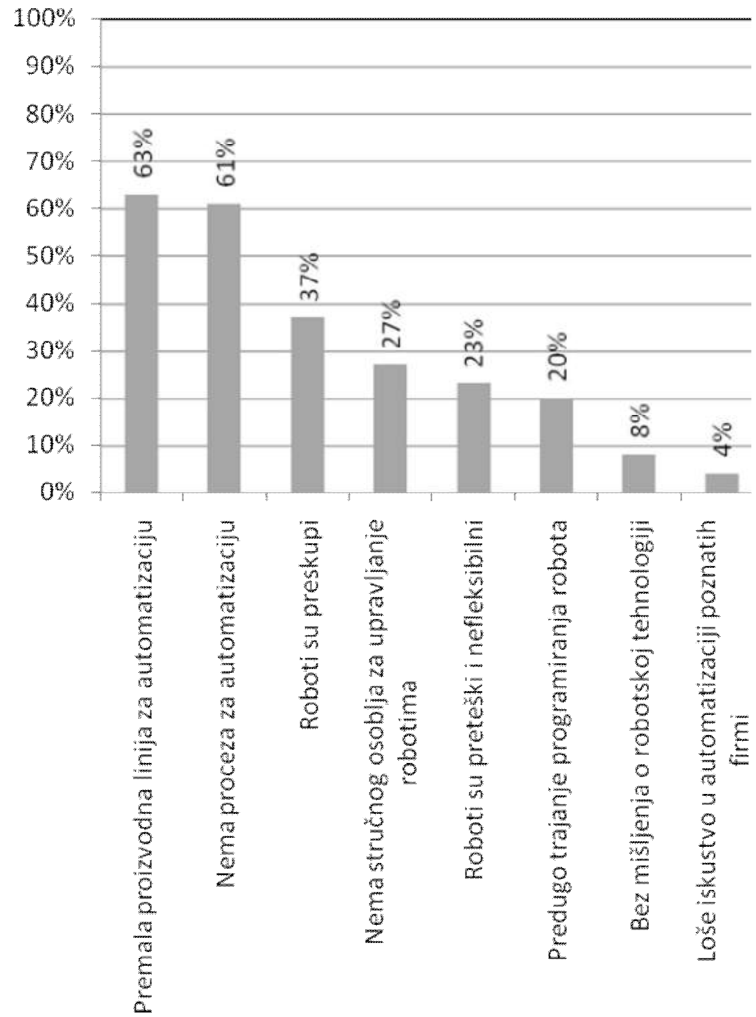
Slika 2. Nekorištenje robota u 2008 godini u MSP

Na osnovu slika 1. i 2., dolazimo do zaključka da se sve više industrijskih robota primjenjuje u Španjolskoj i Francuskoj 48% i 41% u MSP, dok je daleko niža upotreba industrijskih robota u Italiji 18%. Većina MSP koriste industrijske robota u proizvodnim procesima za transport i komisioniranje, a današnja istraživanja pokazuju slične rezultate, tako da 44% SMP koriste robote u procesima za transport, zatim slijedi industrija za obradu sirovina (kao što su hemijska, plastika i guma) 40%, industrija pretovarivanja robe 35%, elektronska industrija 31%, te proizvodna metalna industrija 27%.

3. RAZLOZI ZA KORIŠTENJE INDUSTRIJSKIH ROBOTA U SMP

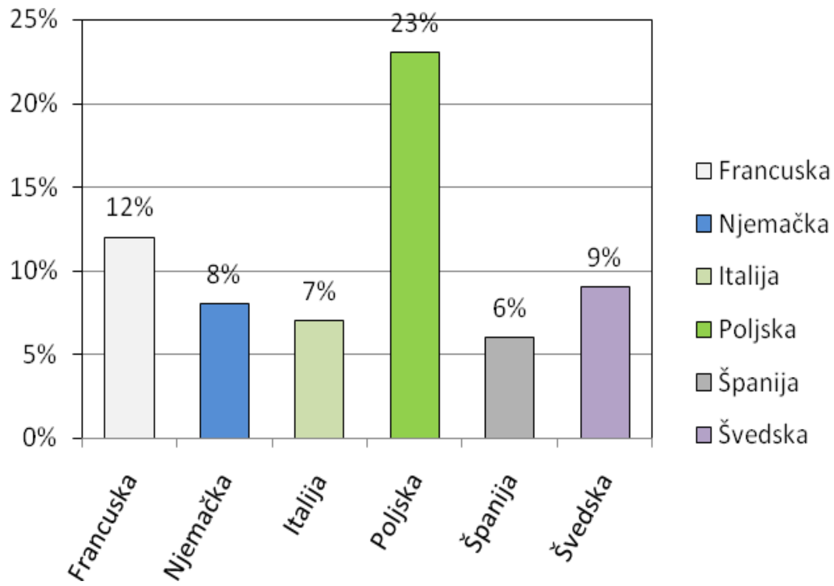
Većina anketiranih ispitanika MSP obično navode najmanje jedan od dva navedena razloga kao najznačajnija za nekorištenje industrijskih robota. Jedan razlog je mala proizvodna linija, misli 63% ispitanika, dok 61% ispitanika misli da se njegov proces ne može automatizirati uvođenjem industrijskih robota.

Ova očekivanja nisu iznenađujuća jer MSP radije proizvode sa malim proizvodnim linijama, te zbog toga misle da nije moguće automatizirati njihov proizvodni proces.



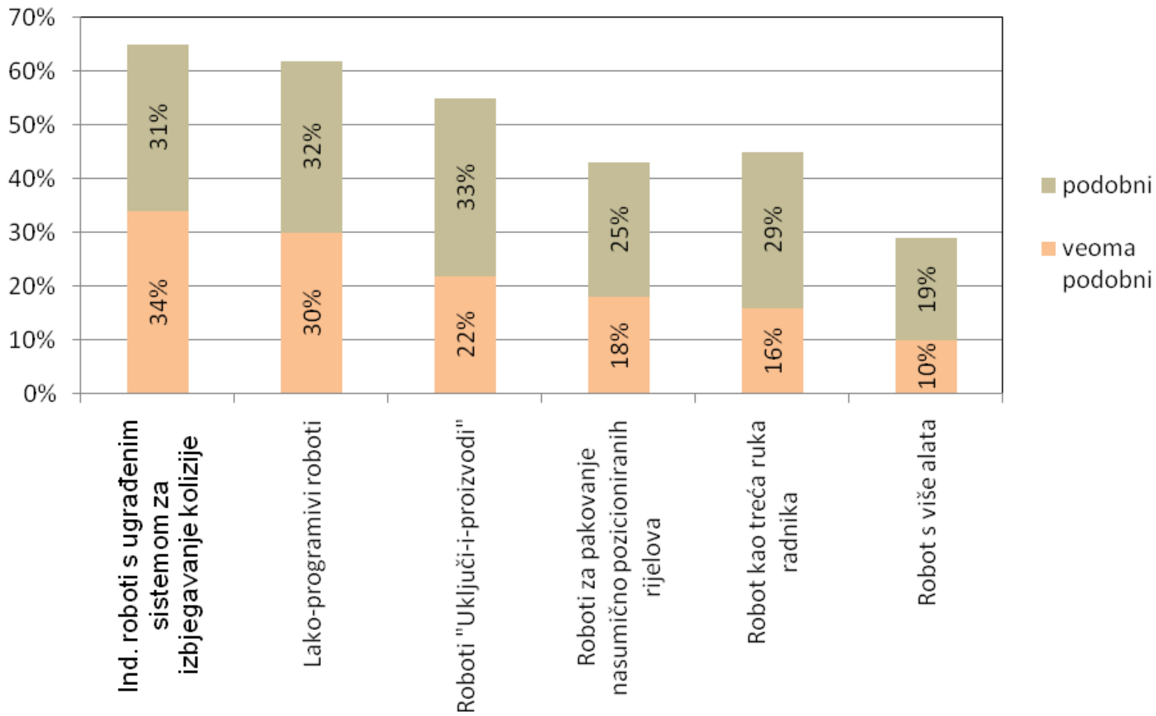
Slika 3. Razlozi nekorištenja industrijskih robota u SMP[11]

Kod analize procjene instaliranja robota u budućnosti u obzir su uzeta ona poduzeća koja su konstatirala da primjena industrijskih robota može biti veoma korisna. Na slijedećoj slici prikazane su mogućnosti instaliranja industrijskih robota u MSP u budućnosti.



Slika 4. Planiranje instaliranja industrijskih robota u budućnosti

Kao što vidimo najveći udio u planiranju instaliranja industrijskih robota u MSP u naredne dvije godine imaju Poljska 23%, zatim Francuska 12%, te Švedska 9% i Njemačka 8%[1,11]. Anketama se ustanovilo da MSP u Poljskoj i Francuskoj su oduševljena s instaliranjem konvencionalnih industrijskih robota, dok su im manje privlačne nove robotske tehnologije. Razvojem robotske tehnologije postigla se velika mogućnost da se MSP ponudi šarolikost u lepezi industrijskih robota. MSP izrazila su mogućnost primjene industrijskih robota kao što je prikazano na slijedećoj slici.



Slika 5. Primjena različitih industrijskih robota u MSP

Na osnovu prethodnog grafikona dolazimo do zaključka da u MSP najveću prednost imaju roboti s izgrađenim sistemom izbjegavanja kolizije. MSP zainteresirana su za industrijske robote koji se lako programiraju putem navođenja, glasovnim ili grafičkim komandama. Isto tako ova poduzeća su zainteresirana za robote "uključi – i – proizvodi".
Najmanja zainteresiranost je za robote sa više alata što je i očekivati jer MSP su za što manja ulaganja i teško se odlučuju da ulažu u edukaciju svojih kadrova, te uvođenje novih tehnologija.

4. PRIMJENA INDUSTRIJSKIH ROBOTA U MSP BUDUĆNOSTI

Procjena budućih instaliranja industrijskih robota [1] u MSP dobijena je spajanjem izjave MSP koja plasiraju instaliranje industrijskih robota i izjave poduzeća koja naglašavaju jednu mogućnost potrebe industrijskih robota za njihovo poduzeća i procjene buduće primjene, date su tabeli 4.1.

*Tabela 4.1. Procjena instalacije industrijskih robota u MSP odabranih zemalja Evropske Unije**

Korištenje robota / Zemlje (EU)	Roboti se koriste s planiranom budućom upotr.(2god)	Roboti se ne koriste s plan.b. upotrebom (2god.)	Ukupna planirana upotreba robota	Plan.upotr. robota (2god) i najmanje jedna SME robot mogućnost koja je	Broj MSP u odabranim zemljama	Broj potencij. SME robot korisnika (godišnje)	Procjena broja kompanija s realiz. budućih planova	Smanjeni broj potencijalnih SME robot korisnika (godišnje)
Francuska	11,3%	11,9%	23,2%	12,0%	22.476	1.349	60%	809
Njemačka	10,6%	8,0%	18,6%	17,6%	32.701	2.878	75%	2.158
Italija	8,3%	6,9%	15,2%	10,2%	34.610	1.765	70%	1.236
Poljska	17,7%	23,4%	41,1%	17,9%	14.141	1.266	35%	443
Španjolska	22,3%	6,1%	28,4%	25,5%	23.038	2.937	50%	1.469
Švedska	27,3%	9,1%	36,4%	29,6%	3.294	584	60%	350
				Σ	130.909	**10.778**	60%	**6.465**

* Izvor: Praunhofer ISI istraživanja 2008

Na osnovu tabele 4.1. i svih istraživanja broj budućih korisnika industrijskih robota u malim i srednjim poduzećima MSP, svodi se na 6500 instalacija. Vidimo da je u Poljskoj i Španjolskoj taj broj instaliranja industrijskih robota ohrabrujući.
Očekivanja su da će razvoj tehnologije i razvoj svijesti o novim tehnologijama dovesti do značajnog povećanja korištenja industrijskih robota u evropskim MSP. Iako nova dostignuća u tehnologiji nisu bila dostupna na tržištu do sada, ovaj broj zainteresiranih MSP za instaliranje industrijskih robota je ohrabrujući.
Kao što vidimo da je više od jedne četvrtine MSP u Francuskoj, Njemačkoj, Italiji, Poljskoj, Španjolskoj i Švedskoj planira buduća investiranja u instaliranju industrijskih robota. Postoji značajan korisnički potencijal MSP za instalaciju industrijskih robota.

5. ZAKLJUČAK

Primjena industrijskih robota u malim i srednjim poduzećima analizirana je u šest evropskih zemalja: Francuskoj, Njemačkoj, Španjolskoj, Švedskoj, Italiji i Poljskoj. Anketa je urađena u ovim zemljama, te došlo se do zaključka da 67% malih i srednjih poduzeća još uvijek nisu automatizirale proizvodni proces i uvele industrijske robote, a 33% MSP već koristi industrijske robote, dok 11% ima namjeru instalirati industrijske robote u naredne dvije godine. Procjena je da se godišnje 6500 jedinica industrijskih robota instalira u MSP u ovim zemljama. Možemo zaključiti da su u Italiji mala i srednja poduzeća manje automatizirali proizvodni procesi od malih i srednjih poduzeća u Njemačkoj, Španjolskoj, Francuskoj, Poljskoj i Švedskoj. Najveća je zainteresiranost za robote "uključi – i – proizvodi" a najmanja zainteresiranost za robote sa više alata.

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RAZVOJ CAD SISTEMA KORIŠTENJEM OBJEKTNO ORJENISANE MEDODE

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SAŽETAK
U radu će se prikazati analiza razvoja CAD sistema korištenjem objektno orjenitasnom metodom - OMT.Pojedini faktori igraju važnu ulogu u implementaciji ovih pojava, kod kojih su najvažnije: planiranje metodologija, arhitekturu sistema i informatički model korišten za razvoj naprednog CAD sistema. U ovom rad predlaže se OMT metodologija koja preko API komandi obezbjeđije pristup u CAD sistem i na osnovu usvojene kalsifikacije osnovnih oblika parametarskim programiranjem generiše komad. U radu će se koristiti programski jezik Visual Basic koji je pogodan za OMT metodu programiranja.

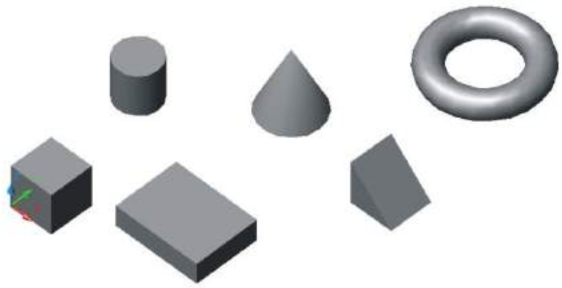
Ključne riječi: CAD sistemi, API, objektno orjentisana metoda

1. UVOD
Današnja industrija ne može preživjeti svjetsku konkurenciju osim ako ne predstavljaju nove proizvode sa boljom kvalitetom, manjom cijenom i sa kraćim vremenom isporuke. Nastoji se upotrebi ogromnog kapaciteta računarske memorije, brzi procesori, prilagodljivo korisničko grafičko okruženje za automatizaciju i objedinjavanje ovih aktivnosti za inžinjerske i proizvodne aktivnosti. U procesu konstruisanja vrši se "geometrijsko modeliranje" proizvoda uz pomoć nekog CAD sistema. Geometrijskim modeliranjem se na pogodan način u memoriju računara unose podaci sa geometrijskim karakteristikama dijelova. Ti podaci služe za vizuelizaciju proizvoda na ekranu kao i za čuvanje informacija o proizvodu. Kao izlaz iz CAD sistema dobijaju se crteži dijelova u pogodnom formatu. Paralelno sa tim može da se dobije, u određenom formatu, i baza podataka o geometrijskim i tehnološkim karakteristikama dijela, tj. model proizvoda.

2. CAD MODELIRANJE [1]
CAD (Computer Aided Design) je tehnologija koja uzima u obzir računarske sisteme koji pomažu u modeliranju, modifikaciji, analizi i optimizaciji konstrukcije. Bilo koji program koji sadrži računarsku grafiku i aplikacijski program primjenjen inžinjerskim funkcijama u procesu konstruisanja je klasificiran kao CAD program. CAD može varirati od od geometrijskih alata, analize tolerancija metode konačnih elemenata i vizuelizaciju alanliziranih podataka. Osnovna uloga CAD-a je da definiše geometriju, jer je geomerija osnova za sve ostale aktivnosti u krugu proizvodnje. CAD sistemi obezbjeđuju visok kvalitet i tačnost projektovanja. Sistemi punog modeliranja se koriste za modeliranje oblika koji ima zapreminu. Matematički opis oblika kreiranog u punom modelu sadrži informacije koje određuju bilo koje mjesto unutra, vani ili u zatvorenom volumenu. Aplikacijski program može automatski generiasti konačne elemente i NC putanju alata. Ove mogućnosti su

utvrđene kada se kreira model kao potpuno puni. Ako sistem punog modela zahtijeva direktno unošenje svih informacija za matematički opis, korisnik će osjećati da je to previše koplikovano i neće ga koristiti. Umjesto toga proizvođači softvera se trude da ponude jednostavne i prirodne funkcije modeliranja tako da korisnik može mijenjati oblik kao i na fizičkom modelu bez puno razmišljanja o detaljima matematičkih opisa.
Osnovni oblici za modeliranje za puni (solid) model su (slika 1):

- Kocka
- Kvadrat
- Valjak
- Kupa
- Klin
- Prsten



Slika 1. Osnovni geometrijski oblici punog modeliranja

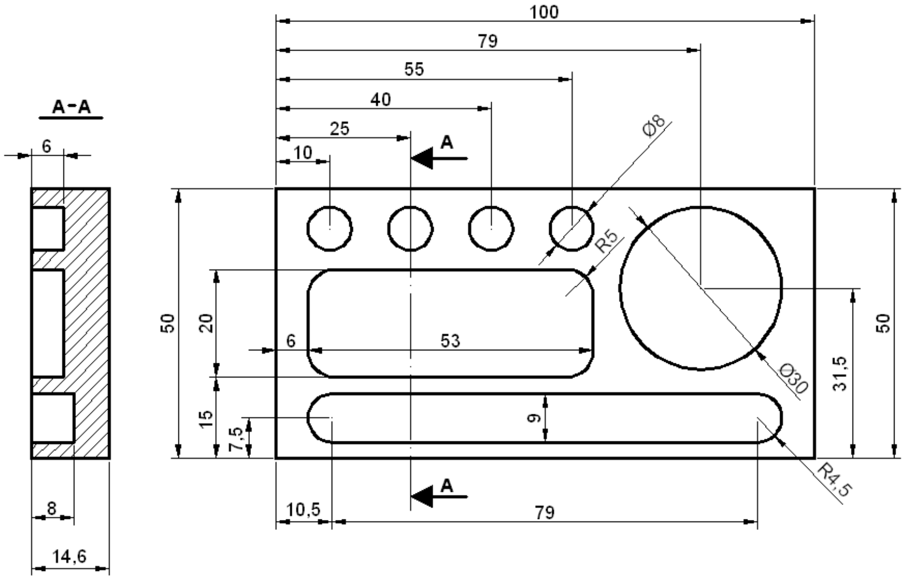
Boolean-ovim operacijama (dodavanje, oduzimanje, presjek) moguće je dobiti složene modele. Geometrijski sistemi modeliranja ne koriste se za oblik ili model kao pojedinačni dio, nego za skup dijelova, gdje CAD sistem dolazi do velikog izražaja. Vjerovatno najveća upotreba mogućnosti sklopnog modeliranja je u automobilskoj i avio industriji. Modeliranje ovih visoko kopleksnih proizvoda mora biti usklađeno na svim nivoima proizvodnje. Modeliranje sklopova omogućava konstruktoru da utvrdi pojedinačne dijelove, prati i održava vezu između sklopova i podsklopova. Održavanje ovih veza u modeliranom sklopu je najvažniji dio povezivanja podataka. Modeliranje sklopova takođe nudi opciju kreiranja parametarskih veza između dijelova, mjerene veličine i dimenzionisane informacije jednog dijela i primjene na drugi dio. Ove veze su od velike pomoći kada puno dimenzija u sklopu zavise od neke dimenzije. Kada se ovaka relacija unese, konstruktor mora promjeniti samo jednu vrijednost dimenzije a sistem automatski prilagođava druge povezane dimenzije.

3. OMT (Objektno orjentisana metoda) [2]
Objekti baze podataka su modeli baza podataka koji prestavljaju oblik informacija u obliku objekta koje se koristi u metodi objektno orjentisanog programiranja. Objekti baze podataka su polja unutar sistema za upravljanje bazom (Database management system - DBMS) koji su povezani relacijskim vezama sa drugim bazama. Kada su ove baze podataka povezane sa sposobnostima objektno orjentisanim (OO) programskim jezicima, rezultat je objekat upravljanja sistema baza podataka (ODBMS). Današnji trend razvoja u programskim jezicima je korištenje objekata, te je time ODBMS idealan za OO programere. Moguće razviti baze, spremiti ih kao objekte, a mogu replicirati ili modifikovati postojeće objekte za kreiranje novih objekata unutar ODBMS. Kroz integraciju sa programskim jezikom, programer može održavati jedinstvenost unutar jednog okruženja za dva ODBMS. Projekti relicajskih DBMS koji koriste složenje vrste podataka bi trebala biti podjeljenja u dva zasebna zadatka: model baze podataka i aplikacije. Korištenje DBMS koji je posebno dizajniran za pohranu podataka i daje prednost za one firme koje su usmjerene prema multimedijalnim prezentacijama ili organizacije koje koriste CAD projektovanje.
API(Application Programming Interface) [3] je programsko okruženje namjenjeno za interakciju sa drugim softverom putem komunikacije sa operativnim sistemom. API podrazumjeva da su neki programski moduli dustupni na računaru za obavljanje operacija ili moraju biti povezani u postojeći

program za obavljanje zadataka. API komande sadrže specifikacije strukture podataka, objekte, klase i protokole za komunikaciju između programskih modula.

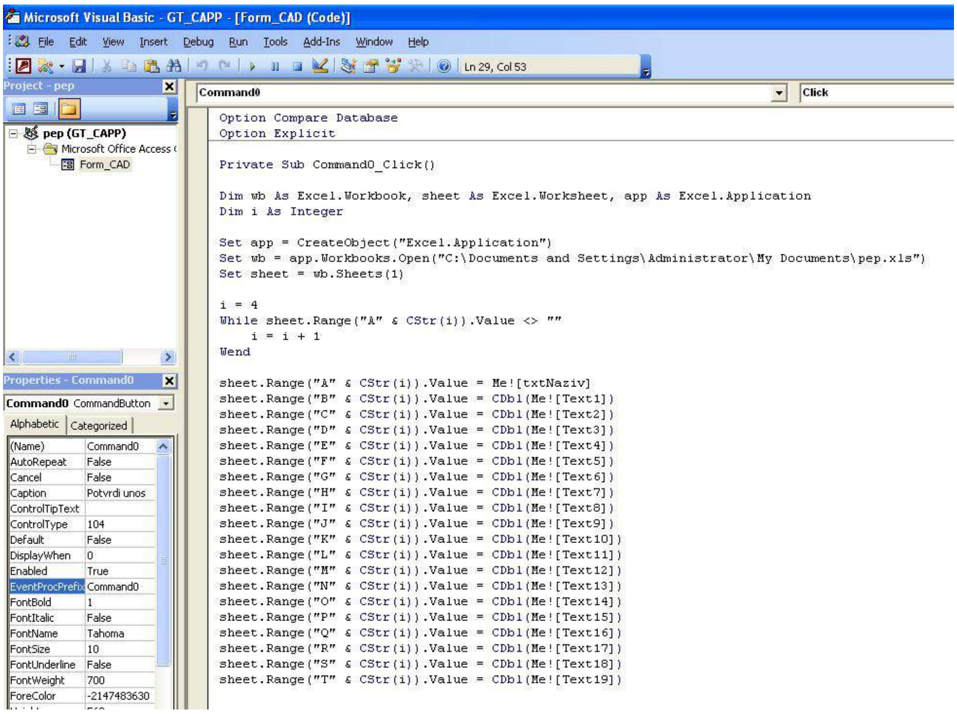
3.3. RAZVOJ CAD SISTEMA KORIŠTENJEM OMT

Za ovaj rad je urađena eksperimentalna aplikacija koja koristi MS Access kao bazu podataka, SolidWorks kao CAD modul i MS Excel kao vezu između ova dva programa. Radni komad je prikazan na slici 2. predstavlja osnovni (polazni) oblik za definisanje ulaznih parametara za ostale grupne tehnologije.



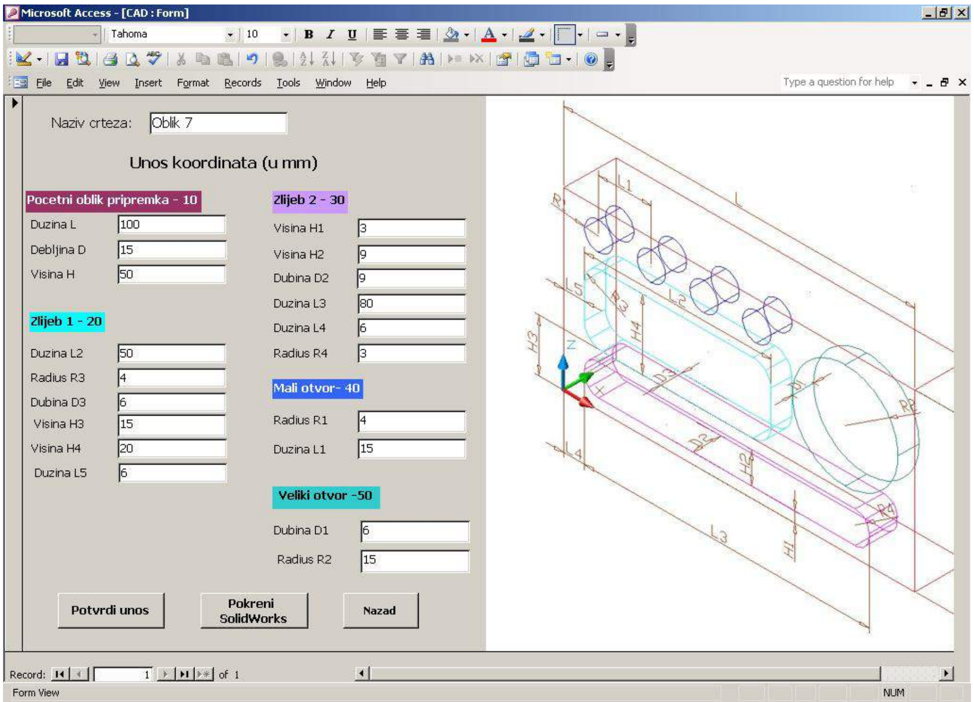
Slika 2. Radni komad

Definisanjem dimenzija u MS Asscess-u, generisanjem istih, u SolidWorks-u automatski dobijamo oblik radnog komada sa mjerama unešenim u bazu. Forma "CAD" u MS Access-u je prilagođena da se automatski unešeni podaci upisuju u Excel tabelu. Ovaj automatizam je urađen preko API komandi koristeći VBA kod. U samom kodu je postavljena i "IF" petlja da bi aplikacija znala gdje je početak, a gdje kraj zapisa o unešenim geometrijskim podacima (Slika 3). Geometrijski podaci ostaju zapisani sve vrijeme, tako da se kreirana familija (varijante) proizvoda mogu pozvati u bilo koje vrijeme.



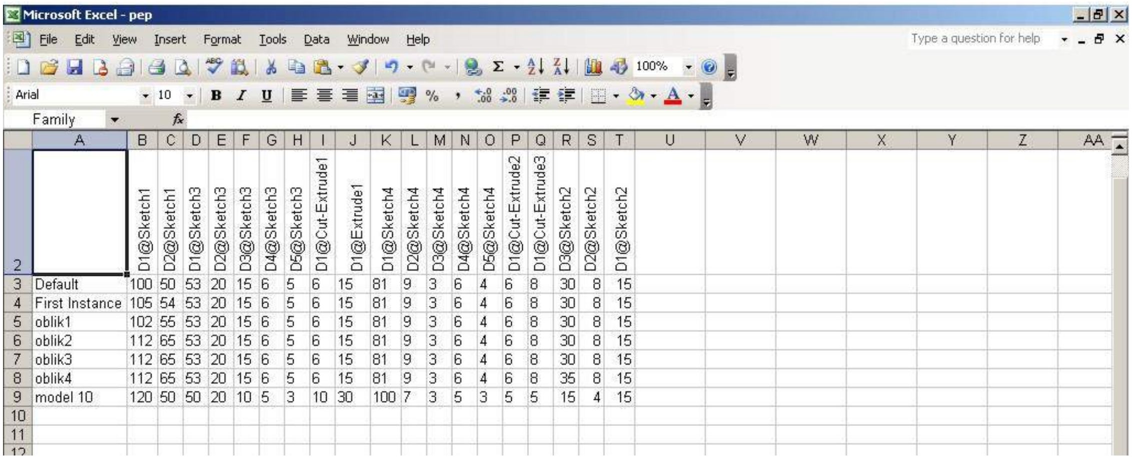
Slika 3. Prikaz VBA koda aplikacije.

Postupak unosa podataka počinje u Access-u, slika 4.



Slika 4. Prikaz unosa podataka

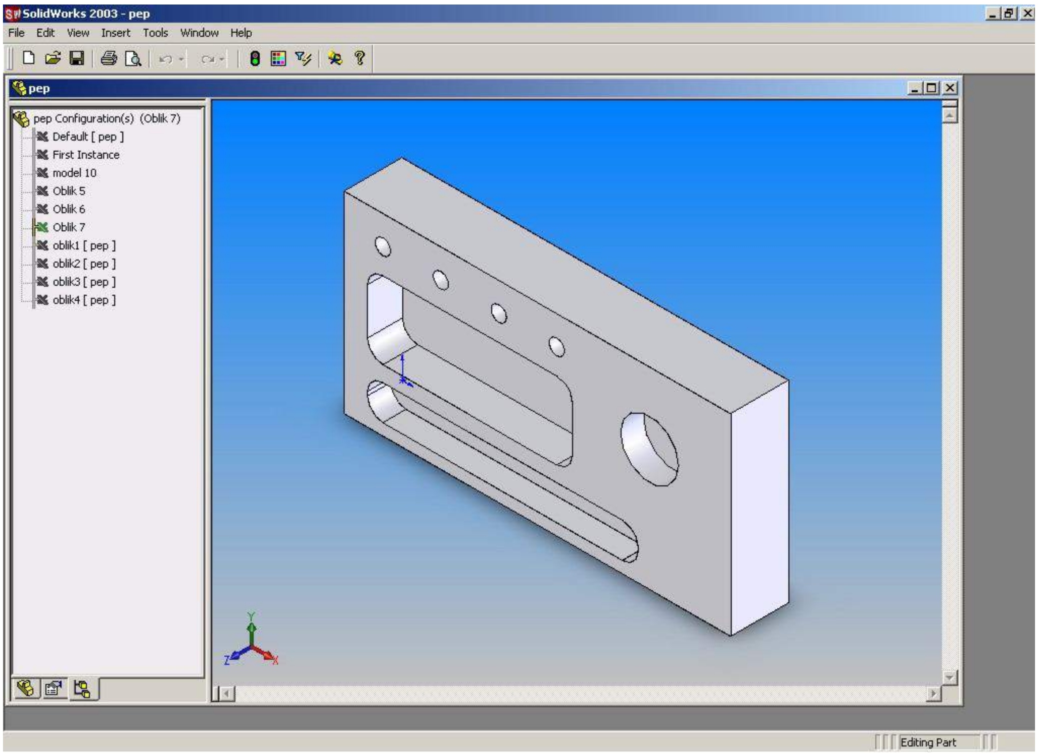
Unosimo "Naziv crteža" koji će se kasnije prikazati kao oblik u SolidWorks-u. Radni komad je vizuelno obilježen različitim bojama, radi lakšeg pregleda unešenih podataka, ali i zbog daljnjeg definisanja tehnološkog postupka. Nakon unesenih podataka kliknemo na dugme „Potvrdi unos". Podaci se automatski upisuju u Excel tabelu (Slika 5), koja je „linkovana" (povezana) sa Solid Works-om.



	D1@Sketch1	D2@Sketch1	D1@Sketch3	D2@Sketch3	D3@Sketch3	D4@Sketch3	D5@Sketch3	D1@Cut-Extrude1	D1@Extrude1	D1@Sketch4	D2@Sketch4	D3@Sketch4	D4@Sketch4	D5@Sketch4	D1@Cut-Extrude2	D1@Cut-Extrude3	D3@Sketch2	D2@Sketch2	D1@Sketch2
Default	100	50	53	20	15	6	5	6	15	81	9	3	6	4	6	8	30	8	15
First Instance	105	54	53	20	15	6	5	6	15	81	9	3	6	4	6	8	30	8	15
oblik1	102	55	53	20	15	6	5	6	15	81	9	3	6	4	6	8	30	8	15
oblik2	112	65	53	20	15	6	5	6	15	81	9	3	6	4	6	8	30	8	15
oblik3	112	65	53	20	15	6	5	6	15	81	9	3	6	4	6	8	30	8	15
oblik4	112	65	53	20	15	6	5	6	15	81	9	3	6	4	6	8	35	8	15
model 10	120	50	50	20	10	5	3	10	30	100	7	3	5	3	5	5	15	4	15

Slika 5. Excel tabela sa generisanim podacima

Sledeći korak je da kliknemo na tipku „Pokreni SolidWorks“, da bi vidjeli dobijenu varijantu radnog komada u „solid“ (punom) obliku. Prilikom unosa dimenzija, mora se paziti da nebi došlo do „preklapanja“ vrijednosti dimenzija (predimenzionisanja), jer u tom slučaju program će nas obavjestiti da je radni komad nemoguće izvesti. Ako su dimenzije unešene tačno, program nas obavještava da je pronađena nova varijanta komada i da će se komad automatski generisati u SolidWorks-u. Dobijeni komad odabiremo iz opcije „Configuration Manager“ s duplim klikom za odabrano ime koje smo zadali u ulaznoj formi (Slika 6).



Slika 6. Okruženje SolidWorks sa radnim komadom

Generalno posmatrano, prikazani sistem za automatizovano projektovanje, omogućuje praktičnu primjenu tehnologu u izradi tehnoloških postupaka grupne tehnologije. Sistem skraćuje vreme izrade dizajna komada i tehnološkog procesa, a time se smanjuje i cjena izrade proizvoda uz povećanje kvaliteta.

4. ZAKLJUČAK

Na početku novog vijeka bili smo svjedoci nastanka internet inženjeringa na tržištu, gdje inženjeri, dizajneri i proizvođači iz malih i velikih firmi sarađuju putem Interneta i sudjeluju u razvoju proizvoda i marketinškim aktivnostima. To će dodatno obogatiti sljedeće generacije proizvodnog okruženja, koji će se sastojati od mreža inženjerskih aplikacija, gdje će se najsavremenijim multimedijskim alatima i tehnika unaprijediti saradnja između distribuiranih aplikacija, virtuelnim alatima omogućit vizuelizaciju i simulaciju u realnom okruženju, i pri tome olakšati razmjenu informacija.

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[2] *Object Oriented Programming and CAD E. A. Warman Journal of Engineering Design*

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METODOLIGIJA RAZVOJA EKSPERIMENTALNOG SOFTWARE-A ZA ROTACIONE ELEMENTE ZASNOVANOG NA WEB TEHNOLOGIJAMA

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SAŽETAK
Razvoj aplikacija zasnovanih na Web tehnologiji je težak zadatak, jer te aplikacije uključuju razne osobine, kao što je grafičko okruženje, strukturu pristupa podacima, poslovne osobine, opsluživanje više korisnika i potrebe za kraće vrijeme razvoja proizvoda. Za prevladavanje tih složenosti neophodno je korištenje aplikacije zasnovane na Web tehnologijama, odnosno klijent/server arhitekture. Osnovna ideja u ovom radu je razvoj aplikacije za podršku proizvodnje rotacionih elemenata preko baze znanja, koja sadrži metode i postupke tehnološkog procesa, kao što su materijal proizvoda, klasifikaciju oblika, dimenzije, tolerancije, i dr.. Tehnolozi će moći koristiti ovu bazu znanja a povratne informacije mogu dobiti preko Web servera putem Internet preglednika.
Ključne riječi: CAD/CAM sistemi, WEB tehnologije, ekspertni sistemi

1. UVOD

Trenutni CAD i CAM sistemi obično rade na samostalan način. Za povećanje mogućnosti tih sistema, potrebno je uključiti druge softverske sisteme, alate, postojeće baze podataka, ili baze znanja. Najveći troškovi proizvoda sadržani su u preliminarnoj fazi projektovanja. Neki od problema koji uzrokuju poteškoće u integraciji oblika proizvoda i planiranja proizvodnje su:

1. nekompatibilnost između softverskih sistema i alata,
2. nekompatibilnost WEB-baziranih aktivnosti postupaka planiranja i aktivnosti idejnog projekta,
3. nemogućnost pružanja informacija modela koji se integrišu u proces planiranja i projektovanja

Kritični element u integraciji CAD/CAM sistema je baza znanja koja ima svoja pravila za specifikaciju oblika i procesa za proizvodnju različitih vrsta dijelova. Ova pravila se koriste od strane inžinjera, koji su povezani u računarsku mrežu, te su u interakciji sa korisnicima putem web preglednika. Korisnici mogu viditi status radnih mjesta i prenijeti poruke sa jednog mjesta na drugo. Baze znanja pomaže u definisanju pravila u odabiru oblika i planiranja procesa. Ova tehnologija omogućuje inžinjerima da se više softvera poveže u jednu cjelinu.
Ovaj rad opisuje metodologiju razvoja softvera za rotacione elemente zasnovanog na web tehnologijama. Korištenjem ovog softvera bi se integrisali programski alati, baze znanja, baze podataka preko web preglednika koji bi pružao uslugu u procesu planiranja.

2. RAZVOJ SOFTVERA [1]

Za ovaj softver predviđen je programski jezik PHP i MyQSL DataBase.

Zašto PHP? PHP (Hypertext Preprocessor) je skriptni jezik (ne treba se kompajlirati kao npr. programski jezik C/C++) koji se pokreće na serveru (server-side), ne na klijentovom računalu. Dizajniran da se koristi zajedno s HTML-om. Pruža puno više fleksibilnosti nego sam HTML koji je po prirodi statičan, dok je PHP dinamičan – sadržaj stranice se može mijenjati. PHP sintaksa je slična onoj u C, Java ili Perl-u, također PHP je sličan ASP-u (Active Server Pages) koji je na neki način Microsoftova verzija PHP-a.

Mnogo je razloga zašto koristiti PHP umjesto drugih web-tehnologija. PHP je Open Source (otvoreni kod je dostupan svima na pregled, modificiranje i sl.), besplatan softver, cross-platform – funkcionira na Windows/Linux/MAC serverima bez imalo problema, te također korisnici ga mogu razvijati i koristiti u bilo kojem navedenom operativnom sistemu, moćan, robustan i skalabilan – to što je besplatan ne znači da nije stabilan ili pouzdan – naprotiv PHP je od početka razvijan kao isključivo web-tehnologija – sve funkcije su namijenjene za web, sjajna dokumentacija u mnogo jezika (*http://php.net/docs.php*).

Zašto MySQL DataBase. MySQL je sistem za upravljanje relacionim bazama podataka (Relational DataBase Management System - RDBMS). Pored toga što čuva sve baze, tabele i njihove elemente i podatke, MySQL upravlja njima kao jednim entitetom. Korisnicima su pridruženi nivoi pristupa i dozvole. Osim toga, MySQL bilježi akcije ovih korisnika i upravlja odgovorima na upite. Upiti su komande napisane u SQL-u (Structured Query Language), koji se šalju sistemu za upravljanje bazama podataka, (u ovom slucaju to je MySQL), da bi se kreirale baze i tabele, dodali podatke u njih, izmjenili pojedine slogove, obrisali ili preuzeli informacije koje će se koristiti u aplikaciji. MySQL je najpopularnija Open Source baza podataka, sa nekoliko miliona korisnika, od pojedinačnih, do velikih korporacija, koje opslužuju web stranice sa izuzetno velikim saobraćajem.

Kao i svaki drugi projektni zadatak i ovaj počinje sa analizom zahtijeva. Za vrijeme analize zahtijeva, potrebno je prikupiti neophodne informacije od naručioca i budućih korisnika sistema vezane za sadržaj, strukturu, pristup i izgled. Zahtijevi vezani za sadržaj definišu informacije specifične za domen aplikacije koje moraju biti raspoložive na samoj Web stranici.

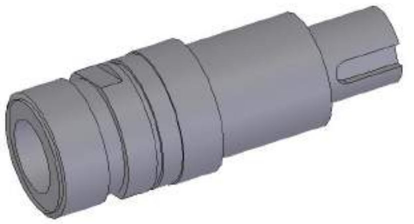
3. PROJEKTOVANJE [2]

Bazirana na zahtjevima, faza projektovanja definiše cjelokupnu strukturu Web stranice, opisujući način na koji će ona biti organizovana i kako će se korisnici kretati kroz nju. Pažljiva projektna aktivnost treba da istakne osnovne sastavne elemente stranice i omogući projektantu da identifikuje neophodne strukture i šablone za navigaciju koji može višestruko da koristi. Kao posljedica prethodno rečenog, dobar projekat može da preživi česte promjene u implementaciji, prouzrokovane pojavama novih tehnologija. Zbog toga što ne zavisi od implementacije, identifikovanje gradivnih elemenata stranice se može izvesti notacijama i metodologijama koje nisu izričito definisane za primjenu na Web tehnologije.

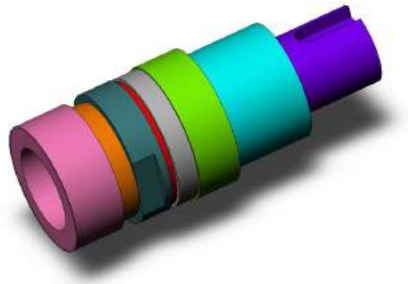
Okvirni sistem objedinjava modeliranje baze znanja, baze podataka, proces zaključivanja i korisničko okruženje.

- Server baze znanja sastoji se od više tabela koje sadrže određena pravila za rješavanje postavljenih uslova. U pravilu, znanje je prestavljeno IF – THEN strukturom. Baza znanja se obično sastoji od baze pravila, biblioteka referentnih funkcija, pravila klasifikacija, funkcijskih biblioteka.
  - Parvila baze uključuju uslov IF – THEN i opisuje ponašanje svake strukturne komponente u ovom pravilu.
  - Biblioteka referentnih funkcija će biti pozivanje putem weba, ali ne i sama funkcija. Funkcija će pohraniti zadate vrijednosti unutar predviđenih lokacija, imena definisanih klasa i putem web preglednika ih prikazati korisniku.
  - Pravila klasifikacija primjenjuju se u spašavanju baze podataka prilikom promjene podataka.
  - Funkcijska biblioteka se može razviti kao C# Web Services, koja sadrži sve funkcije koje se traže po pravilima

4. KREIRANJE BAZE PODATAKA I BAZE ZNANJA [2]
Prije svega potrebno je definisati osnovni oblik rotacionog tijela. Jedan takav oblik je prikazan na slici 1. Za ovaj osnovni oblik potrebno je definisati osnovne i dopunske forme oblika (Slika 2.) Oblici i forme se povezuju sa formiranim tabelama baze podatka. Baza podataka se kasnije relacijski povezuje sa upitima i formama od kojih će zavisiti redosljed tehnološkog procesa.



Slika 1. Osnovni oblik rotacionog tijela



Slika 2. Rotaciono tijelo podjeljeno na osnovne i dopunske oblike

Da bismo izveli neki SQL-upit sa PHP-om, moramo prije svega otvoriti bazu podataka - odnosno povezati se s njom. Nakon toga bi se poslala SQL- naredba bazi podataka, bio bi preuzet odgovor od baze. Ova veza nas dovodi do formiranja baze znanja, odnosno ekspertnog sistema.
Baza znanja je sistem koji koristi umjetnu intelegenciju za rješavanje problema. Povezuje se sa bazom podataka radi dobijanja povratnog odgovora o specifičnom upitu. U principu, sistem se fokusira na tehnikama podrške odlučivanja. Sistem je u mogućnosti rješavati probleme i asistirati u odabiru ponuđenih odgovora.

5. FAZE IZGRADNJE EKSPERTNOG SISTEMA [3]

Problem izgradnje ekspertnih sistema je dosta kompleksan pa sam postupak izgradnje nije dovoljno razvijen i razlikuje se od oblasti do oblasti. Takođe faze izgradnje ekspertnih sistema nisu jasno razgraničene, strogo definisane i nezavisne. Dostizanje dobrih osobina ekspertnih sistema zahtjeva eksperimentisanje, pa je neophodno da se oni razvijaju postupno. Ključni proces u izgradnji ekspertnih sistema je baza znanja, jer direktno utiče na kvalitet i primjenljivost samog sistema.
Mogu da se izdvoje sljedeće faze u izgradnji ekspertnih sistema:

1. identifikacija,
2. orjentacija,
3. konceptualizacija,
4. formalizacija,
5. implementacija,
6. testiranje, i
7. korištenje i održavanje.

- Prva faza u izgradnji ekspertnih sistema je **identifikacija** područja problema i identifikacija ciljeva. Potrebno je izvršiti identifikaciju odgovarajućih entiteta i atributa.

- U fazi **orjentacije** se definišu konkretni ciljevi, i definiše se šta se želi od ekspertnog sistema. To je važno jer se poslje identifikacije problema mogu se neki ciljevi dodatno postaviti ili neki korigiarti.
- **Konceptualizacijom** se određuju karakteristike informacionog toka potrebne za opis procesa rješavanja problema u datom području, tj. definišu se odgovarajuća pravila i relacije potrebne za rad sistema.
- **Formalizacijom** se na bazi uspostavljenih koncepata u prethodnoj fazi vrši projektovanje strukture za organizaciju znanja. Projektovanje strukture u ovoj fazi obuhvata preslikavanje ključnih koncepata, podproblema i karakteristika tokova informacija u pogodnije oblike.
- U fazi **implementacije** vrši se unošenje pravila i njemu pridruženih struktura upravljanja (mehanizma za zaključivanje). Kroz proces implementacije se kombinuju i reorganizuju formalizovana znanja, kao i karakteristike toka informacija o problemu. Prilagođava se sintaksa programskog okruženja izabranog za izgradnju ekspertnog sistema.
- **Testiranjem** se ocjenjuje valjanost pravila kojima se pretražuju znanja tj. testiraju se performanse programa-prototipa. Vrši se korekcija da bi se njegove performanse prilagodile potrebama projekata. Kada prototip prođe i fazu testiranja dodaju mu se željene mogućnosti, proširenja i osobine radi lakšeg korištenja.
- Zadnja faza **korištenje i održavanje** je permanentan proces u kome se u toku eksploatacije nadgleda sistem, da bi se korigovao i usavršavao novim saznanjima. Treba shvatiti da jednom završen sistem ne predstavlja i konačnu verziju. Nju treba dinamički prilagođavati novim dostignućima u određenoj oblasti.

6. ZAKLJUČAK

Pošto softveri imaju sve veću primjenu u proizvodnoj industriji tokom proteklih godina sve veća je naglašenosti iskorištenja internet tehnologija. Ovaj rad opisuje konceptualni razvoj softvera u procesu projektovanja rotacionih elemenata. Svrha razvoja ovog softvera je pristup bazi znanja putem web tehnologija u procesu planiranja koji utiče na materijal, oblik, tolerancije…

Komunikacija putem web-a omogućuje interaktivno korištenje projektanata putem internet preglednika, kao i povratne informacije u samoj fazi projektovanja. Sam softver je zasnovan na open source-u, što omogućava obnavljanje i nadogradnju baze znanja i baze podataka novim informacijama.

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TECHNOLOGICAL PRODUCTION PREPARATION OF NON-CUTTING PROCESSES AREA WITH ASPECT TO ARTIFICIAL INTELLIGENCE

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ABSTRACT
The technological production preparation for area of the non-cutting technologies, namely forging and casting needs analyse of the wide spectrum parameters that influence on production process. It is result of the specific disciplinary areas conjunction and high variable sub-technologies within the frame of the design and realisation process. We can simply state: „Technologist must or should dispose of the wide-spectrum knowledge in given field ".For all that the computer support, adequate databases of the knowledge and their consecutive exploitation by means of the optimal defined algorithms for solution is important matter. Nowadays is manifested wide spectrum progressive technologies of the computer support application in individual stage of process design. Among others it is application of "cognitive systems (artificial intelligence) those using requests the deep analyse too. It is necessary to consider everything positive and negative in order to improve activity and to not involve the futile complexification of the work. The article goal is the presentation of the cognitive methods exploitation in areas of non-cutting technologies with aspect on expert' systems, fuzzy expert systems or application of Petri nets.
Keywords: technological production preparation (TgPP), group technology, artificial intelligence, expert system (ES), fuzzy approach, Petri nets, databases, non-cutting technologies

1. INTRODUCTION
The computer systems as instruments of the production process design in frame of the non-cutting technologies should not solve only exact tasks. This area can not be in a matter of fact only elimination of routine works in design process. The digitalisation of experience and computer support of the human thinking is also the indubitable fact in production process design. It is conditional by necessity of the frequent using of hard - determinable (*"fuzzy"*) process parameters *(e.g. manufacture ability, ability of deformation, pourability, etc. - parameters of forging, casting process*).

2. PREMISES OF USING ARTIFICIAL INTELLIGENCE IN TgPP FRAME
Artificial intelligence is relative wide term including the large area for solving tasks according to the quality engineering calculation improvement and partial human elimination *("this is perhaps too superlative term, convenient term can be cognitive systems")*. For technical problems that technical departments are solving it is not simple to choose optimal tool suitable for this query. That means that complex problems analyse should be first step.

3. BRIEF VIEW OF ARTIFICIAL INTELLIGENCE USING AREA
The base equipment of the human thinking simulation so as expert systems, fuzzy sets, neural nets are common known [1, 3]. The question is their optimal application for solving of the concrete practical

problems. The digital simulation of the technician skills and experiences must take account of interactive factors that affect the production process. In frame of the mechanical engineering with aspect to non-cutting technologies (*forging, casting,*) it can be convenient to use expert systems or fuzzy expert systems in relation with database systems (*InterBase, MS Access, e.g.*) and group technology principles. The database system choice is specific task (*in many cases is sufficient spreadsheet, e.g.*).The meaningful product classification code can be suitable source of the information in digital form and database filtering tool.

3.1 Expert systems and fuzzy approach

An important question is existence of the problem-oriented ES, respectively the filling of the empty ES shell possibility [1]. It is subject to expert – knowledge engineer quality communication.
Of course the main task is creating of the adequate database (*e.g. relation database, spreadsheet…*) and effective sequence of the rules on the base of gained knowledge (*it is not simple matter*).
One of the effective ES putting with relation to fuzzy approach can be using of the group technology principles (*products coding*), that is built on suitable products grouping according to their key

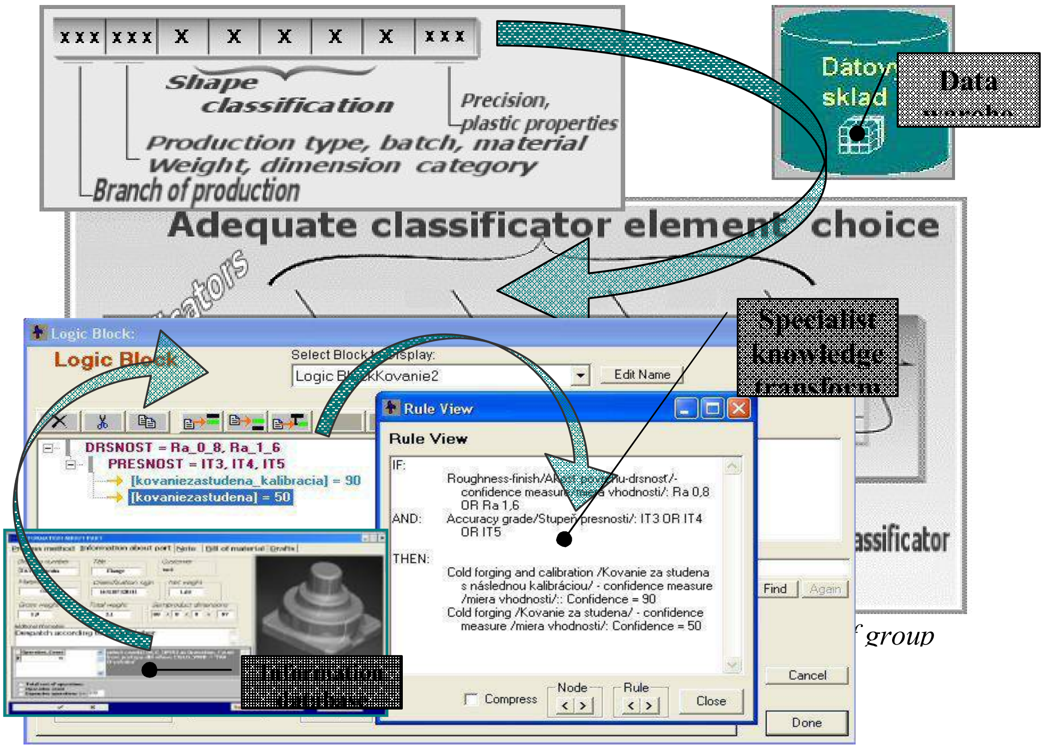

Figure 2. Example of expert system rules definition

properties and production type [6]. The convenient way is the product classification and coding in combination with computer support and the product classification standards. The purposeful classification code treatment that contains high number of the elements (*count is continual proportion with description exactness*) is relatively difficult task.The classification code using as static mark (*chain*) is not every time optimal. Advisable it can be treatment every element separately with possibilities of change its priority (Fig.1.). The significance measure (*importance*) of the classification code elements is not always constant and it is dependent on the character of other elements (*describing of the component and its production*).For example, in the case of the high-alloy steel using, material can be priority property according to high effect on the production process character (*e.g., specific requirement on heating way of input semiproduct*). That can be solved by means of the dynamic classification – classificatory relations inclusion. The knowledge measure of the products (*production*) properties is not equivalent to every design stage. Some properties and parameters of forging or casting process can not be described expressly / *shape complexity, pourability, formability, plasticity…*/ [4, 5, 7]. Therefore it has to be applied linguistic variables, confidence variables expressed by membership degree for example.

3.2 Possibilities of Petri nets using

The Petri nets can be understood as the suitable tool of definition (*graphical description*) of distributed system and the mathematical modelling their concurrent behaviour.

Petri net is triplet N= (P, T, F), where:
P= $\{p_1, p_2, p_3 \dots p_n\}$ is set of places (states),
T= $\{t1, t_2, t_3 \dots t_n\}$ is set of transitions,
$F \subseteq (PxT) \cup (TxP)$ is set of oriented arcs;

P and T are not-empty, disjunctive and finite sets.
F is set of arcs among places and transitions (*respectively transitions and places*) expressive the flow relations of net N. The model is described by places that contain information in mark form (*tokens*), by transitions that express possibly changes of the state and by arcs that interlink places with transitions each other [2].
An example of this is model of the robotic production cell (Fig.3.). The detail (*casting*) entering to the production cell by means of the input band conveyer is transferred to the milling machine.
For the finished casting transition to the milling machine input zone the detail has to be present on input conveyer for machining operation, both robot and milling machine has to be free. After milling operation the detail removes to milling machine output. If the robot is free the detail movement to output conveyer begins. In ever subsystem only one detail can be present in same time moment.

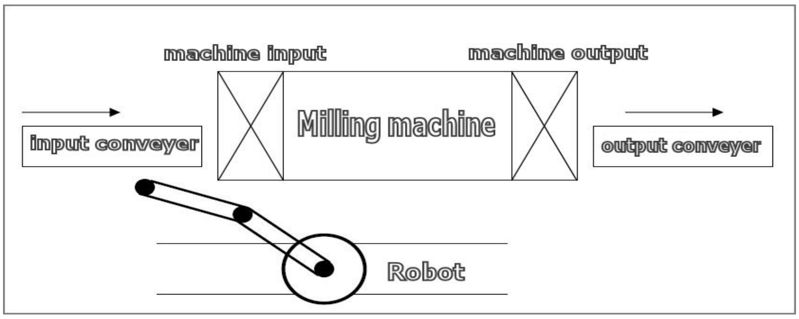

Figure 3. Robotics production cell

The system function is simulated by Petri net on Fig.4. The marks p_1, p_2, p_5, p_7 corresponds to four partial states: input conveyer – p_1, robot – p_2, milling machine – p_5, output conveyer – p_7.
Other marks correspond with next operations: the detail transfer by robot to milling machine input – p_3, milling operation – p_4, machined detail transfer to output conveyer – p_6. The detail presence (*accessibility*) on cell input is modelled by spot (mark) in point p_1. Similarly, the mark in point p_2 represents the robot disposition for detail transfer. Figure 4 represents state when milling operation is

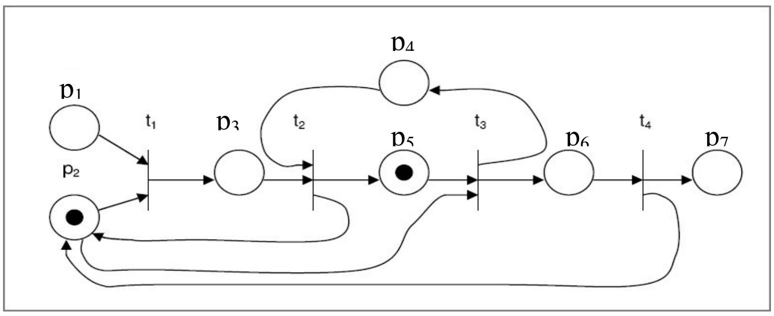

Figure 4. Production cell Petri net

realized and robot is free. Petri model for discrete dynamic system (Fig.3) responds to real system in that case as the Petri net elements properties are correct used. The presented model brings specific risk, for example, milling operation is realized and to the production cell new detail enters. The robot is free and can begin the detail transfer (*according presented Petri net*), that means robot is reserved. On the other side robot is needed for the detail transfer to machine output. System comes in deadlock when it is impossible to continue by next state change. The deadlock appearance depends on time conditions. If the detail inputs to place p_1 in good time which means that intervals between two the detail inputs are not less as certain permissible deviation, the deadlock is not occurred.

Table 1. Places status in Petri net

P_1	detail (casting) on input
P_2	detail transfer to input by robot
P_3	detail transfer to machine input
P_4	milling operation running
P_5	milling operation ending – milling machine is free
P_6	machined detail transfer to machine output
P_7	detail on output
t_1	transfer operation start
t_2	transfer ending and start of milling operation
t_3	milling operation ending
t_4	detail (casting) transfer ending

Nowadays Petri nets represent extensive model of the parallel and distributed systems in various spheres. Petri nets are wide class of discrete mathematics models that enable the control flows and the information relations describing by specific instruments in simulated systems. The using of Petri nets is not specific for computing systems. It can be also using in area of production processes (*automated forging or casting lines, e.g.*) for analysing and description of parallel processes (*their synchronization*) in technological process optimalization frame

4. CONCLUSION

It is needed to note that analysing and solving of the wide-spectral task with large number of variables sometimes demands specific simplification. That can lead to relative differences according to real processes [8]. In frame of the forgings (*castings*) production technology design is not every time possibly to use ancestral empirics. It is necessary to apply exact methods (*multi-factors mathematic optimalization, finite element method, etc.*). According to complexity these technologies (*information that the technician has to handle in decision process are not always sharp or consistent)* the selected instruments of cognitive systems (*artificial intelligence*) can be effective tool of technological preparation rationalization.

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The article was processed in frame of KEGA 216-007ŽU-4/2010 and KEGA 090-010ŽU-4/2010 project

1st International Scientific Conference on Engineering
”Manufacturing and Advanced Technologies”
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

DEVELOPMENT OF MATHEMATICAL MODELS FOR THE CAPP SYSTEM

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ABSTRACT
The Mathematically model devolpment for minimum cost per piece, which have all parameters of process planning. For determining machining and manufacturing tims imoprting for maximum profit, what is leading aim all manufacturing of industry. The optimal of cutting speed determining which to recive maximum profit. The maximum profit introducing combination of criterion minimum cost per piece variant process planning and criterion optimal of cutting speed. In this paper will be show model for optimizataion varinats process planning with minimum cost per piece in function to cutting speed. The numbers varinats depends of resource by manufactured system, machine labor and overhead rate and tools. The optmization model will be use in generative CAPP system for rotation parts The physical layout of manufacturing systems is a major determinant of a firm's efficiency. With the rapidly-changing environment facing most firms today as well as the shortened life cycles of many products and process technologies, facility rearrangement and redesign become critical in sustaining productivity and competitiveness. Consequently, operations managers and researchers have recently focused on the dynamic aspects of facility design.
Keywords: Facility design; dynamic models; optimization.

1. INTRODUCTION

It is a well established fact that products and processes exhibit life cycles evolving through initial development, growth, maturity, and decline stages. The understanding of these life cycles can be quite beneficial in determining appropriate marketing and manufacturing strategies for an organization. Schmenner [1] proposed that facilities also progress through life cycles and that the knowledge of this concept can be exploited to plan the use and change of the facility, leading to improved productivity and prolonged facility life. The throughput, the number of products, the capacity utilization, and the process technology all of which have an effect on the design of the facility at any particular stage of the life cycle change throughout the life of a facility which, in turn, necessitates the redesign of the facility. In general, manufacturing facilities tend to be quite capital intensive and have long-range implications for the organization, which underscores the importance of dynamic facility design in response to the changing demands placed on the facility. Nicol and Hollier [2] reported on the results of a field study of [3] manufacturing companies in the United Kingdom. One of the aspects investigated was the stability of the firms' facility layout. One of the facilities management practices that was identified as being in serious need of improvement was that of "planning horizon" for major buildings and facilities; over 80 percent of the respondents categorized their organization with poor or inadequate performance on this dimension. Furthermore, three of the eight key findings that were identified are:

(i) Rearranging for cells and continuous flow: This was the greatest management concern, cited by 60% of respondents, including a number in government, insurance, health care, and other non-manufacturing facilities,
(ii) Many facilities organizations lack readiness: They are playing 'one-move chess' with no plan beyond their next major project.
(iii) Planning horizons are still too short among manufacturing organizations: The most common practice is still calendar-based, typically three to five years, rather than being tied to industry cycles or the life cycles of key products and process technologies.

Obviously, facilities managers see the rearrangement and redesign of facilities as an important part of their organizational efficiency and competitiveness, yet this is one aspect of their planning efforts that is apparently underemphasized. The purpose of this paper is to investigate various approaches of analyzing and solving the dynamic facility layout problem. Current formulations of the problem and techniques for determining the optimal solution are presented. We present a linearization of the problem, such that a commercially-available, linear-programming computer package can be utilized, either in conjunction with a CAD system or as a stand-alone package for a facility manager solving relatively small problems. Bounding techniques are demonstrated to make the problem more tractable. Finally, implementation issues concerning the understanding and application of the dynamic facility layout problem are presented.

2. IMPLEMENTATION ISSUES

We now turn our attention to several issues that may arise during the analysis, optimization, and implementation of the dynamic facility layout problem. The dynamic facility layout problem (DFLP-1) has as its special case the quadratic assignment problem (when $T = 1$) and, since the QAP is known to be NPcomplete, we can conclude that the DFLP is also NP-complete. Thus, the development of heuristics is necessary to solve even moderately-sized instances of the dynamic problem. Rosenblatt[15] proposed a class of heuristics for the DFLP in which the dynamic programming algorithm is used, but with fewer states considered than necessary to determine the optimal solution. The intent is to determine a good, although small, set of layout arrangements (states) to be considered in each period (stage). He proposed using the static optimal QAP solution from each period (thus, requiring N layouts) under a heuristic approach to generate a number of layouts, or randomly generating the layouts. While this approach obviously may not result in the optimal solution, it becomes computationally feasible for larger problems, although it still requires the use of a dynamic programming algorithm.

A heuristic that utilizes the popular steepest-descent, pairwise-interchange procedure (used in Craft), was developed by Urban.[4] To adapt it for use with the DFLP, the concept of "forecast windows" is used. That is, the workflows for a varying number of periods are evaluated at any one time. The heuristic first analyzes the workflows one period at a time, and the associated rearrangement costs are incurred. The heuristic then considers a forecast window of two periods, assuming the same layout will be used over this time frame, and determines appropriate layout arrangements. The length of the forecast window is increased, the layouts determined, and the solution is obtained from the forecast window that provides the minimum total cost. Lacksonen and Enscore modified and evaluated five existing algorithms to solve the DFLP: (1) a pairwise exchange heuristic that also evaluates exchanging pairs of locations in consecutive time periods; (2) a heuristic utilizing a cutting-plane routine to identify initial solutions for the static problem followed by an exchange routine; (3) a branch-and-bound algorithm limited to the most promising partial solutions and limited in program run length; (4) a dynamic programming algorithm with a limited number of states identified using an exchange routine; and (5) a heuristic based on cut trees including "rearrangement avoidance" costs. Of these five methods, the cutting-plane algorithm identified the best solutions for all test problems considered. Since then, several authors have used various metaheuristics to solve the dynamic facility layout problem. Genetic algorithms have been used for the DFLP with additional constraints and with a two-period, multiple-floor problem.[5] Kaku and Mazzola developed a tabu search heuristic procedure for the DFLP. Urban utilized a greedy randomized search procedure (Grasp) for the special case of the DFLP with fixed rearrangement costs. Recently, Bozer and Wang presented a simulated annealing algorithm. Due to the computational requirements for identifying the optimal solution to the DFLP, the development of effective heuristics is a fruitful area of research.

2.1. Discrete efficient frontier

The formulation of the total cost of the dynamic facility layout problem (Eq. 1) assumes that we can derive explicit values for the workflow costs *(fikt)* and the rearrangement costs *(su* and *rt)* in comparable terms. However, in practice, static facility layout analyzes typically minimize the distance traveled, not the associated cost. It may be difficult to obtain comparable costs that could be used to solve the DFLP as formulated. The DFLP generally has two conflicting objectives: to minimize material handling and to minimize the rearrangement "effort" of the facility over the planning horizon. A useful approach to situations with incommensurable objectives is the concept of a discrete efficiency frontier (DEF), which is the set of efficient (nondominated) solutions, such that a given solution is at least equally as good as another solution on all measures (objectives) and strictly better on at least one measure. Rosenblatt and Sinuany-Stern[6] and Malakooti addressed the notion of identifying efficient layout arrangements for the static, multiple-criteria (workflow versus closeness rating) facility layout problem and developed algorithms to identify the DEF. Urban proposed a method of identifying the DEF for the dynamic facility layout problem with no variable rearrangement costs comparing the volume of material flow and the number of rearrangements made using the information obtained from the solution to the problem. When we include variables, as well as fixed, rearrangement costs, the measure of the rearrangement effort may no longer simply be the number of rearrangements. It may be necessary to use another measure, such as the total number of departments moved, the total rearrangement cost (if it can be determined), or the number of rearrangements (if that is still the primary concern for rearrangement). To illustrate the process, let us use the following objectives:

(i) **Material handling**

Minimize the total workflow over the planning horizon,

$$\sum_t \sum_j \sum_k \sum_l \quad \text{...(1)}$$

f_{ikt} d_{ji} x_{ijt} x_{kit}, where f_{ikt} is not expressed as a cost but measured simply as the volume of material flow, subject to the typical assignment constraints,

(ii) **Rearrangement**

Minimize the total number of departments moved over the planning horizon,

$\sum_t \sum_i y_{it}$ again, this could be replaced with other appropriate measures. A typical efficient frontier is illustrated in Fig. 2. The two extremes of the frontier are easily determined: (1) *the minimal rearrangement point* is determined by utilizing the same layout arrangement during the entire planning horizon, hence no departments are moved, which is determined by minimizing the material handling, as with the Batta upper bound; and (2) *the minimal material handling point* is

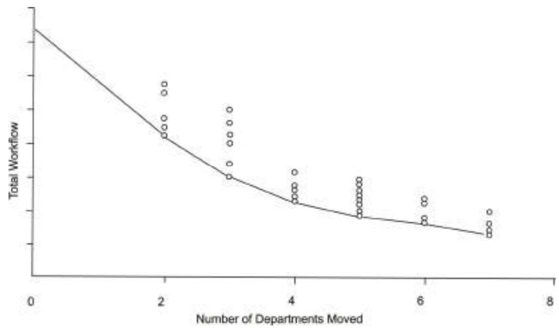

Fig. 2. Discrete efficient frontier for the DFLP

determined by minimizing the material handling for each time period incurring the necessary rearrangement (number of departments moved) of the facility. We can then find the intermediate points in the following manner:

Step 1: Using the formulation DFLP-1, remove the rearrangement cost portion of the objective function, leaving only

$$\sum_t \sum_j \sum_k \sum_l \qquad ...(2)$$

$f_{ikt}d_{jl}x_{ijt}x_{klt}$, and solve. This will provide *the minimal material handling point* as described above.

Step 2: From this solution, define γ to be the number of departments that are moved over the planning horizon.

Step 3: To the formulation in *Step 1,* include the constraint:

$$\sum_{i\varepsilon N}\sum_{t\varepsilon T} y_{it} \leq \Psi - 1 \qquad ...(3)$$

and solve.

Step 4-' Repeat *Steps 2* and *3* until γ = 0. At this time, we will have *the minimal rearrangement point.*

Theoretically, there could be as many as NT — 1 iterations required to identify the entire efficient frontier. To reduce the calculations, we may wish to replace the right-hand side of Eq. 3 with γ — k, where k is some fraction of the number of departments moved. We could also use heuristics to solve the mixed integer program, particularly for larger problems; however, we are not assured that all of the points on the efficient frontier will be identified.

2.2. Flexible facility layout

An interesting perspective regarding dynamic facility design is the concept of flexible facility layouts. The flexibility of a layout arrangement is the ability to accommodate changes in the production requirements, either by the insensitivity of the layout to those changes (reactive flexibility) or by the ability of the layout to be easily and rapidly changed (adaptive flexibility). Several papers have been written in this area since the publication of the paper by Shore and Tompkins; however, we will limit our discussion to those that explicitly consider the rearrangement of the facility. Bullington and Webster[6] evaluated the adaptive flexibility of a layout by considering the rearrangement costs of a change from that layout to one of several potential future layouts. The present layout with the smallest expected rearrangement cost, using the probability of each of the potential future layouts, was considered to be the most flexible. Savsar extended this approach by incorporating reactive flexibility considerations, measured using both material flows and closeness ratings, with the expected rearrangement cost. Each of these approaches assume that there is only one opportunity for rearrangement. The flexibility of this approach is such that once (in the first period) a decision is made concerning the family of layouts to be used, the only irreversible decision is that the location of the monuments and a near-optimal layout arrangement can then be identified for each period.

2.3. A quick-and-dirty test of optimality

Balakrishnan and Cheng10 noted that the importance of considering the dynamics of facility layout problems is diminished in two situations: (1) when the rearrangement cost is negligible, we need to focus only on the material handling cost and can rearrange the facility as needed; and (2) when the rearrangement cost is prohibitive, we can use the same layout arrangement for the entire planning horizon. The results from Urban's [6] lower bound calculations provide a test of optimality for the second case; in particular, we can make the following claim:

$Claim: If\ \min_t \{T_t + \min_i \{s_{it}\} + \min_i \{s'_{it}\}\} > Q_{1,T}^{.} - \sum t \in TQ_t^{.}$, then it is optimal to avoid facility rearrangement, $\sum_t z_t = 0$, incurring a total cost of $Q_{1,T}^{t}$.

This observation makes it unnecessary to solve the DFLP in those situations with relatively large rearrangement costs.

3. DETERMINING MACHINING CONDITIONS AND MANUFACTURING TIMES

Having specified the workpiece, machine too, and question is what can be controlled to reduce cost and increase production rate. The controllable variables are cutting speed (v), feed (f), and depth of cut (d). Jointly, v, f, and d are referred to as machining conditions. There are a number of models for determining the optimal machining conditions. In this paper we present simple models. The average cost per piece to product a work piece consists of the following costs: [3]

Cost per component, C_u = nonproductive cost per piece
+ machining time cost per piece ...(4)
+ tool changing cost per piece
+ tooling cost per piece

Mathematically, this can be expressed as

$$C_u = c_o t_1 + c_o t_c + c_o t_d \left(\frac{t_{ac}}{T}\right) + c_t . \left(\frac{t_{ac}}{T}\right) \quad ...(5)$$

The tool life equation as function of cutting speed (v) is expressed as

$$vT^n = C \quad ...(6)$$

where:

c_o= cost rate including labour and overhead cost rates (km/min)
c_t= tool cost cutting edge, which depends on the type of tool used (km)
C=constant in the tool life equation, $vT^n = C$
v= feed rate (m/min)
f= depth of cut (mm/rev)
d= exponent in the tool life equation (mm)
n= exponent in the tool life equation
t_l= non-productive time consisting of loading and unloading the part other idle time (min)
t_c= machining time per piece (min/piece)
t_d = time to change a cutting edge (min)
t_{ac}= actual cutting time per piece, which is approximately equal to t_c (min/piece)
T= tool life (min)

Consider a single-pass turning operation. If L, D, and f are the length of cut (mm), diameter of work piece (mm), and feed rate (mm-rev), respectively, then the cutting time per piece for a single-pass operation is

$$t_c \approx t_{ac} = \frac{\pi LD}{1000vf} \quad ...(7)$$

Upon substituting these values as well as the tool life equation in the cost per piece equation (5), we obtain

$$C_u = c_o t_1 + c_o\left(\frac{\pi LD}{1000vf}\right) + c_o\left(\frac{\pi LD}{1000vf}\right)\left(\frac{v}{C}\right)^{1/n} t_d + c_t\left(\frac{\pi LD}{1000vf}\right)\left(\frac{v}{C}\right)^{1/n} \qquad ...(8)$$

The feed rate and depth of cut are normally fixed to their allowable values. Therefore, the cutting speed v is the decision variable. Upon partially differentiating C_u with respect to v, equating to zero, and solving, we obtain the minimum unit cost cutting speed v_{opt} as follows equation (6)

$$v_{opt} = \frac{C}{\left[\left(\frac{1}{n}-1\right)\left(\frac{c_o t_d + c_t}{c_o}\right)\right]^n} \qquad ...(9)$$

On figure 2. Showed graph function cost per component, we obtain minimum unit cost with cutting speed v_{opt} .

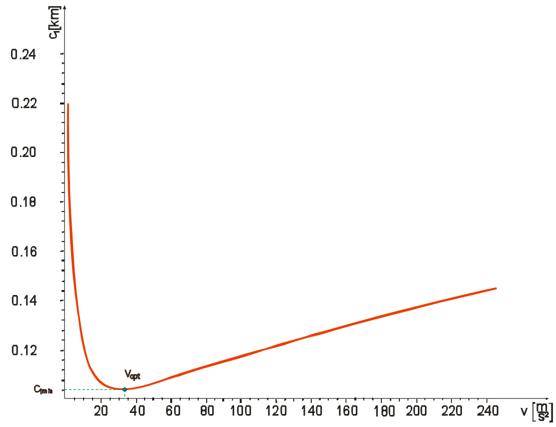

Figure 2 – The function cost per component with v_{opt}

4. CONCLUSION

This paper has described a process planning activity development of mathematical models for the CAPP system. Each manufacuring activity can be one of many processing activities, such as setup, load/unload, handling, processing, and idling. The object model defines classes used in process planning. The main purpose of developing this model is initiate the devolpment of standard interface specifications that are neccessary for design and process planning integration.

Given the strategic importance of maintaining efficient and productive facilities in a rapidly changing environment, the consequence of incorporating the dynamics of facility design is obvious. Furthermore, the use of CAD/CAE/CAM systems makes it quite straightforward to incorporate this type of analysis into a comprehensive facility design program.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

DESIGN OF INTELLIGENT LEARNING MANAGEMENT SYSTEM FOR HIGH SCHOOL MATHEMATICS

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ABSTRACT
The basic goal of an "intelligent" Learning Management System (iLMS) is to improve the learning experience by personalizing and adapting the instruction, based on what the system knows about the student. Noticing that huge part of our students are having trouble with standard way of learning and teaching high school mathematics, we decided to try to improve our results using an web based iLMS underpinned by an powerful, explanatorily coherent theory of learning. In this paper we will state our starting point in building an iLMS for this purpose.
Keywords: iLMS, AI, Mathematics, Education, e-Learning

1. INTRODUCTION
In recent years, university professors, more than ever, encounter the obvious problem of growing deficits in math skills among students. Mathematics is a specific science, which often generates dissatisfaction among some students, because they are "afraid" of it. Although it is clear that most problems have their origins in early education, universities must deal with several problems, such as different levels of mathematical knowledge (and yet attending the same "one-size-fits-all" class) and not recognizing the importance of mathematics to their profession. All these problems make additional support (such as tutorials, formative assessment, etc.) difficult and, in conjunction with the increased intake of students, time consuming [2].
Given the need for a kind of balancing the level of mathematical knowledge of our students, with the present restrictions on the number of teachers and school hours, considering the results of our previous research in which we showed a statistically significant advantage of using advanced computer technology in teaching mathematics [1], we want to ensure the ability of the individual learning the necessary mathematical skills and knowledge using an intelligent computer tutor. In this way, students will get a lecture adapted their level of mathematical knowledge and will, each with their pace, to complement the needed skills.
In this paper, we explain why we choose an intelligent Learning Management System (iLMS), among numerous computer-based learning paradigms, as a solution to our problem. We will mention its comparative advantages over other paradigms of computer-based learning and possible pitfalls into which we could fall.
We want to develop a system designed so as to be "educationally intelligent". In other words our system should be soundly based on a viable theory of learning. We hope that such a system will help us in more efficient teaching university mathematics, and enable our students' successful learning of scheduled teaching content, using the intelligent functions built into the system itself.

COMPUTER-BASED LEARNING PARADIGMS

Computer-based Learning (CBL) is the use of computers as a basic element of the educational environment. It is not limited to the use of computers in the classroom, but we use a broader meaning of the term, which is structured environment in which computers are used for teaching purposes. In the field of computer-assisted learning, different systems are proposed to support various educational methodologies. The most popular paradigms are: Computer-Based Training (CBT), an Intelligent Tutoring System (ITS) and Computer-Supported Collaborative Learning (CSCL).

1.1. Computer-Based Training (CBT)

Computer-Based Training (CBT) is a self-paced learning activity available through an electronic device. CBTs are often used for teaching structural processes, such as solving mathematical equations or using of software tools, because their linear approach to its content, similar to reading a book. In the case of using a web browser for content delivery, the term Web-Based Training (WBT) is used.

Assessment of learning content in CBT usually comes in the form of multiple choice questions, radio buttons, or similar forms that the computer can verify and evaluate using the algorithms embedded in system. The user thus gets the feedback and is able to print the final evaluation in the form of certificate.

CBTs provide the possibility of learning beyond traditional learning methodology from textbooks, manuals and classroom instruction. They offer the advantages of learning through visual contents, animation or video, and represent a good alternative to printed learning material.

However, typically the creation of effective CBTs requires enormous resources. Software for CBTs development is complex can hardly be used effectively by subject matter expert or a teacher. In addition, the lack of human interaction causes an actual limitation of the type of content that can be present and the type of assessment that can be made.

1.2. Intelligent Tutoring System (ITS)

Intelligent Tutoring System (ITS) is a computer system that gives students personalized guidance and feedback during performance of tasks, without human intervention. ITSs implement the theory of learning-by-doing. They are usually designed as Artificial Intelligence expert systems, designed to simulate aspects of human tutors.

ITSS consist of four different modules: an interface module, expert module, student module, and mentor module. Interface module provides interaction between the student and the ITS, usually through a graphical user interface. Expert module or domain model contains a description of knowledge or behaviors that represent expertise in the domain of ITS subject. Student module uses a student model that contains descriptions of students 'knowledge or students' behavior, including its errors and gaps in knowledge. The disagreement between the behavior and knowledge of students and professionals is a signal to tutor module to initiate some corrective action, such as providing feedback or remedial classes.

Creating ITSs requires careful preparation in terms of describing knowledge and possible behavior of experts, students and tutors. These descriptions should be in a formal language, so ITSs could process information and draw conclusions to generate a comment or instruction. Therefore only description is not sufficient. The knowledge described in the model should be organized and linked to the inference engine.

1.3. Computer-Supported Collaborative Learning (CSCL)

Computer Supported Collaborative Learning (CSCL) is a method to support collaborative learning with computers and the Internet. It follows researches in psychology, computer science and education. CSCL supports the communication of ideas and information between students, collaboration in accessing information and instructor's feedback about learning activities. CSCL also supports and facilitates the process of group work in a way which cannot be achieved by communicating face-to-face. These tools are increasingly used, but significant parts of the teachers are still insufficiently informed about their availability on the Internet and its efficient use.

Key characteristics of CSCL research is the diversity of their methodologies. CSCL researchers apply methods of laboratory experiments, quasi-experimental approaches, discourse analysis, or case studies. Qualitative data showed high efficiency of these tools to help in the traditional classroom teaching.
However, there are problems that are common to all processes of learning and cannot be solved by any of the above paradigms. Problems of using resources, such as hardware devices, software applications, educational materials, or information about the course, are generally present. It is necessary to determine how to use them, in a unique, easy and convenient way. Learning Management System (LMS) is traditionally used to solve such problems.

2. LEARNING MANAGEMENT SYSTEM (LMS)

In recent years, developers of educational content focused their work on the design of Learning Management System (LMS). These general-purpose systems tend to provide a series of student interaction with text and audio-visual material, through reading, listening and viewing, a variety of tasks and participating in discussions. Programmers strive to provide "intelligent" support for these activities and provide teachers with information about students' progress. Although LMSs sometimes provide interesting learning opportunities, they are rarely backed up by a strong, coherent learning theory. Routine channeling of students through a series of e-learning activities, more likely results with actual knowledge by chance than by design
LMS is a software application for administration, documentation, monitoring and reporting on training programs, classroom or on-line events and e-learning programs. LMS can be considered an "operating system" for e-learning in the educational institution. It automates the delivery of educational content, facilitates communication between students and between students and teachers, and monitoring and reporting on student progress and test results.
Some LMSs are enhanced with tools for the delivery and management of synchronous and asynchronous online training based on learning object methodology. This gives them the functions Learning Content Management System (LCMS) (Figure 1.). Providers of LCMS functionality are developing their objects in accordance with the applicable standards, such as SCORM (Sharable Object Content Reference Model), IMS (Instructional Management System) or XML (eXtensible Mark-up Language).

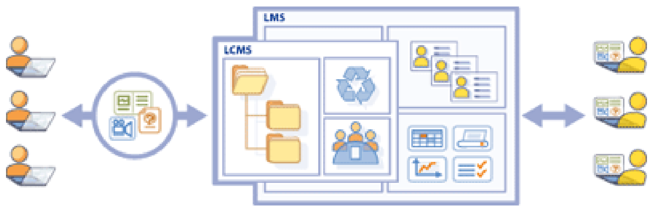

Figure 1. LMS with LCMS functionality

2.1. Learning content management system (LCMS)

Learning Content Management System (LCMS) is a technology focused on the development, management and publishing content that will largely be delivered through the LMS. LCMS is a multi-user environment where developers can create, store, reuse, manage and deliver digital educational content from a central repository of objects (Figure 2.).
LCMS does not create nor manage courses. Its function is the creation, import, manage, search and reuse of smaller units or "chunks" of digital learning content, also called learning objects. This includes media files developed in other authoring tools, simulation, text, graphics or any other object that represents content within the course. Objects stored in a centralized repository can be made available to developers of courses and experts in selected areas for potential reuse.

3. INTELLIGENT LEARNING MANAGEMENT SYSTEM (iLMS)

Using web-based applications in education is becoming increasingly popular, from online tools to supplement traditional online education to the online campus. Providing the computer technology by using the techniques and concepts of artificial intelligence to support teaching and learning in an intelligent way [3] are the foundation of Artificial Intelligence in Education (AIED). The aim of the research is to develop principles of design intelligent systems that will be used in teaching.

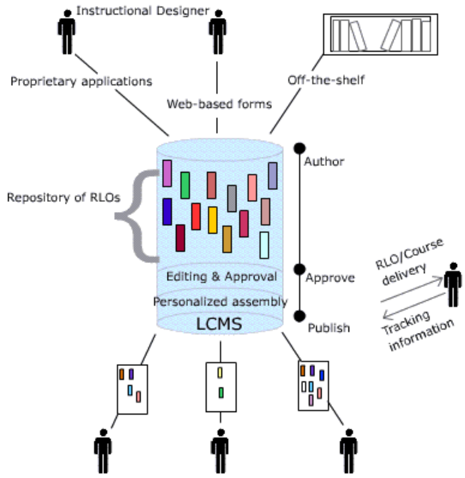

Figure 2. Central object repository of LCMS

AIED community has devoted much effort in developing the principles and tools to enhance individualized learning. Model of individual mentoring is not a major interest in Education because it really does not give solutions to their basic problems. Human teachers know how to do a good job in one-on-one teaching. They are more interested in the methods and principles in the classroom, which usually corresponds to their reality. In addition, AIED research favors precise models of learning, whereas Education specifically dismisses precise theory and promotes practical understanding based on rich conceptions of learning.

Intelligent Learning Management System (iLMS) has the potential to bring education and AIED closer. Integrating the principles of AIED with LMS technology can have a synergetic effect on the benefit to education and AIED. In addition to LMS features iLMS provides adjustment of learning according the actual state of the student's knowledge. This means that iLMS should have some knowledge about how students learn and what his learning difficulties [4]. Most importantly, iLMS should be an instrument that teachers use in the design and management of classes.

4. CONCLUSION

Our goal is to create a software application that will be used on our University as the nucleus of the future widely applied iLMS. With inclusion of "intelligent" function, based on solid learning theory which came from recent insights into neuroscience, evolutionary epistemology and self-organising, dynamic systems [5], we will achieve optimal utilization of this system in the teaching process, first in the teaching of mathematics, and then beyond. Construction of the teaching content will be left to experts of domain knowledge. They will, naturally, have support of authoring tools for making such contents

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

PRIMJER RAČUNARSKE APLIKACIJE U INŽENJERSKOJ PRAKSI

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ABSTRACT

Practice in the company of Mine and Thermal Power Plant Gacko, to entrust problems of preventive, current and remount maintenance, most frequently without or on bases of outdated documentation to other companies, from drafting new construction documentation to creation and control of mechanical elements, is, under new working conditions, necessary to change gradually and relay more on own forces. This work is an example of application of computer in such an engineering practice - calculation of geometry of bevel gear. A short theoretical discussion has been covered and it resulted in creation of a program with necessary data named Calculation of BG (Calculation of bevel gear). Data base is created in ***Microsoft Access 2007, main form of the program is made in*** *CodeGear™ RAD Studio 2007, program code is written in Borland Delphi Object Pascal, quaries in SQL, while for creation of the report was used FastReport 3.4 „Add-Ins" a program application of an indepenent producers.*

Keywords: engineering practice, program, calculation of bevel gear

1. UVOD

Zaostajanje privrede većine zemalja „bivše nam domovine" u odnosu na privrede razvijenih zemalja je prilično što se očituje u skoro svim njenim dijelovima. Vidljivo je u nesavremenosti mašina i opreme, u organizaciji i ukupnoj produktivnosti, u primijenjenoj tehnologiji i materijalima a u oblasti korištenja savremenih informatičkih tehnika, to zaostajanje je posebno veliko, i sa posebno teškim posljedicama. Kao posljedica dugogodišnjeg nepostojanja tržišne privrede i zanemarivanja marketing koncepcije poslovanja, razvoj proizvoda je potiskivan u drugi plan. To se posebno odrazilo na vrlo usporeno i otežano uvođenje novih metoda, postupaka i tehničkih sredstava, posebno u slučajevima kad je to zahtijevalo dodatna investiciona ulaganja. Uvođenje računara u proces projektovanja i konstruisanja je upravo jedna od takvih oblasti, tako da se danas može bez sumnje tvrditi da je ova, u razvijenom svijetu već potpuno rutinska metoda, u našoj privredi veoma rijetko u primjeni.

Mnoga preduzeća se danas bezizlazno vrte u tom začaranom krugu, nepovratno gubeći vrijeme i zaostajući sve više. Kao i obično kad su u pitanju "Gordijevi čvorovi", ni u ovom slučaju ne postoje univerzalna rješenja, a još manje recepti. U našim preduzećima i kod pojedinaca, u poslednje vrijeme ima sve više personalnih računara, a sa njima često pored „nelicenciranog Windowsa", igrica i uobičajenog Microsoft Office-a i nažalost, tek „pokoja" kopija AutoCAD-a.

Dosadašnju praksu, u preduzeću Rudnik i Termoelektrana Gacko da se rešavanje problema u toku preventivnog, tekućeg i remontnog održavanja, a najčešće na osnovu dotrajale „papirnate" dokumentacije, počev od izrade nove konstrukcione dokumentacije do izrade i kontrole mašinskih elemenata, povjerava drugim firmama, nužno je u novonastalim uslovima rada preduzeća postepeno mijenjati i sve više se oslanjati na sopstvene snage. Rudnik i Termoelektrana ima dobro opremljenu zajedničku radionicu sa izuzetnim kadrom - inženjeri, tehnolozi i majstori na mašinama. Velik posao, koji oni mogu uspješno obavljati, je održavanje termoenergetskog pogona i rudarske opreme sa stanovišta održavanja mašina.

Cilj ovoga rada je da na primjeru iz prakse, približi mogućnost primjene računara kao multifunkcionalnog alata za prikuplanje informacija, memorisanje, obradu i proračine u mašinskoj industriji, jednog velikog termoenergetrskog postrojenja.

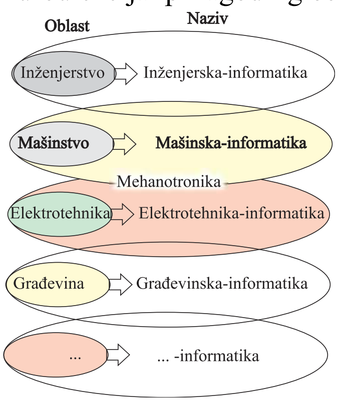
2. INŽENJERSKA-INFORMATIKA

Inženjerstvo predstavlja primijenjenu disciplinu i kao posledicu te pretpostavke imamo potrebu stvaranja u prisustvu ograničenja nametnutih od strane okruženja u kome se to stvaranje dešava. **Kako riješiti inženjerski problem?** Odgovor na pitanje je vrlo teško generalno dati, ali je moguće izolovati određeni broj koraka, koje je iskustveno potrebno izvršiti da bi se problem, kao odraz nepoznatog, doveo u domen rješivog. Inženjerstvo se zadovoljava isljučivo efikasnim rješavanjem problema [3].

Inženjer se treba naći i u problemskoj situaciji, dakle, npr. imate oštećen ili polomljen zupčanik sa koga treba premjeriti polazne parametre (što često nije moguće, pa je potreban „proračun od nule") i na osnovu njih dobiti kompletne podatke sa dokumentacijom potrebnom za izradu zupčanika u radionici. U praksi je to proces, u kome inženjer u skladu sa vlastitim sposobnostima, vještinama i stručnosti dolazi do rješenja. Tu se stvaraju temelji za mnoga pitanja, a samim time i za motivaciju i želju za daljim radom, istraživanjem i vlastitim stručnim napretkom [2,4].

Nekad, ne tako davno, smo to radili ovako: Na osnovu „papirnate" literature rađen je „pješke" proračun geometrije i provjera nosivosti konusnih zupčanika. Ulazni parametri, postupak proračuna i podaci potrebni za isti, izimani iz jednog ili više izvora su često nepotpuni i različiti, kao i tablice, dijagrami, ili preporučene vrijednosti (opšte ili proizvođačke). Sve je to „trošilo previše inženjerskog kreativnog vremena" i bilo dugotrajan proces, sa veoma čestim greškama.

Brzi razvoj nauke i tehnike zahteva permanentno i fleksibilno obrazovanje sa imperativom praćenja novih tokova razvoja nauke i tehnike, a da se pri tome, uz sve obaveze na radnom mjestu, sa što manje turbulencija prilagodi globalnom okruženju. Inženjer se prilikom rada na računaru kontinuirano usavršava, brzo osposobljava i koristi gotova softverska rješenja koja omogućavaju lakše savladavanje nastalog problema. Zato je potrebno da sa jedne strane poznaju tehnologiju mašinogranje i osnove konstruisanja mašina, a sa druge strane osnove programiranja i softver [1].



Sl.1. Specijalizovane oblasti izvedene iz opšte

Stalno rastući značaj informatike za pojedine oblasti tehnike neizbježno je doveo do toga da su nastale nezavisne naučne oblasti i teoretske strukture kao preciznije i specijalizovane oblasti „opšte" informatike. Ovaj razvoj doveo je do takozvanih „-informatika" *(slika 1.)*:

Za inženjerske nauke naročito je od interesa inženjerska-informatika, u mašinstvu označena kao **mašinska-informatika**. S obzirom na opšti značaj, nazivu „**inženjerska-informatika**" daje se prednost u odnosu na „mašinsku-informatiku".

Rad više stručnjaka, različitog profila ne donosi rezultate kao rad svestrano obrazovanog stručnjaka inženjerske-informatike. Dakle, inženjerska-informatika je budućnosti inženjerstva, koja će koristiti računar za projektovanje, modelovanje, analizu i simulaciju rada komleksnih mašina i uređaja.

Inženjerska informatika je informatika koja je stručno-specifično priključena inženjerskim naukama, a obuhvata tehničko-naučne osnove kao i praktična stručna znanja za adekvatno korišćenje računara u svim oblastima inženjerskih nauka. Izraz „inženjerska-informatika" je odgovarajuće proširenje i nova formulacija tradicionalnih izraza, kao što su, na primer, „Obrada podataka", „Računarske metode", „Numeričke metode", „Konstruisanje pomoću računara". Prema svom sadržaju, inženjerska-informatika se bavi teorijom, metodama i primenama modernih informacionih i komunikacionih tehnika, posebno strukturom, radom i upravljanjem inženjerskih postupaka (procesa) i njihovim realizacijama na računarima, tj. računarskim sistemima [1].

Inženjerska informatika je racionalna osnova za računarski orijentisane modele mišljenja u inženjerstvu, tj. nije u prvom planu interesa inženjerske-informatike „rukovanje” hardverom i softverom, već „mišljenje”, tj. rad sa „modelima mišljenja”.

3. KONCEPTI INŽENJERSKE-INFORMATIKE / MODELI MIŠLJENJA

Osnovni princip rešavanja problema u klasičnom algoritamskom modelu mišljenja je **algoritam**, kojim se označava **tačan opis šematski/mehanički izvršivog računskog postupka**. Algoritam se označava kao niz naredbi (= elementarni nalozi ili imperativne operacije). Zbog upotrebe naredbi govori se takođe o **imperativnom** modelu razmišljanja [5,6].

Evidentno da su u veoma bliskoj prošlosti za rad na računaru u prvom redu korišćeni modeli mišljenja koji su bili orijentisani na „računanje”, tj. na numeričke operacije, a time i na algoritme. Stoga je klasični model mišljenja informatike/inženjerske-informatike postavljen algoritamski.

Algoritam se sastoji od više potpuno uređenih koraka. U algoritmu se može skakati sa naredbe na naredbu a moguće su i iteracije. Kod velikih problema se odgovarajući algoritmi dobijaju koristeći **analizu problema** koja predstavlja editovanje odgovarajuće postavke problema s obzirom na algoritamsko rešenje. Preporučljivo je algoritme ili dijelove algoritama povezati u pregledne, veće cjeline, koje se često nazivaju „Procedure”. Zato se, pored algoritamskog, tj. imperativnog načina mišljenja, govori i o **proceduralnom** načinu mišljenja.

Tek transformacija algoritma u jedan oblik razumljiv računaru pomoću nekog programskog jezika, vodi konačno izrazu **Program.** Kako se pri izvršenju programa obrađuju podaci (brojevi, znakovi, simboli). Dakle: **Program = Algoritam (izražen u nekom programskom jeziku) + Podaci.**

Prvi korak u korišćenu računara na našem primjeru iz prakse je zamjena „proračuna pješke” sa programom, koji je na osnovu algoritma proračuna bio urađen u proceduralnom Turbo-paskal-u. Linijski izvršavan postupak proračuna je koristio podatke, koji su „pješke” birani iz papirnih tablica i dijagrama. Sve je to ubrzalo proces proračuna, ali je proces odabira podataka i dalje bio naporan „manuelni” proces sa veoma čestim greškama.
U algoritamskom modelu mišljenja su algoritmi centralni element modelovanja. Sa manje-više sekundarnim podacima se „nešto obavlja”: algoritam se koncentriše na operacije, preuzima ulazne podatke na obradu i generiše rezultate, ali preuzeti podaci nisu direktno sastavni dio algoritma: prema tome, podaci se „samo“ obrađuju. Algoritam je „trajan”, dok su podaci „prolazni”. Algoritamska paradigma (tj. koncept i metodika rješenja) je stoga uvek primjenljiva kada se postavke problema mogu riješiti tako da se iz unaprijed datih podataka (ulaznih podataka) po jednom tačno utvrđenom postupku traženi rezultati mogu „izračunati”. Vrlo mnogo matematičkih, inženjersko-tehničkih ili čak komercijalnih primjena je u suštini tako formulisano (numerička postavka problema).

4. DRUGI KONKURENTNI MODELI MIŠLJENJA

Računari su se poslednjih godina značajno promijenili. Oni više nisu „računske mašine” već su više multifunkcionalno primjenljivi sistemi za radno mjesto (oblasti primene su obrada teksta, grafika, banke podataka, sistemi bazirani na znanju, itd.)[3]. Zato je razumljivo da su se pored klasičnog „algoritamskog modela” razvili i drugi modeli mišljenja. Različiti, trenutno međusobno konkurentni modeli mišljenja moraju moderno obrazovanom inženjeru biti poznati; ovi će stoga u nastavku biti kratko predstavljeni. Pogled na inženjerske probleme pokazuje da u toj oblasti postoji značajan broj drugačije postavljenih problema za koje je algoritamska paradigma samo djelimično, ili nikako podesna. U tim slučajevima su pogodni drugi modeli razmatranja npr.:
Održavanje velikih struktura podataka - Kao zamena za tradicionalne stokove akata sređene u obliku registratura, uvedene su u inženjerstvu, u mnoge oblasti, banke podataka, u poslednje vreme zvane „Databank-Management-Systems", skraćeno „DBMS”[5]. Ovde se radi o dijametralnoj situaciji u odnosu na algoritamski model: podaci su dugotrajni i primarni, dok se algoritmi za održavanje i obradu (traženje, brisanje, memorisanje, izmjenu, preuređenje) koriste, ali su od sekundarnog značaja, dakle „prolazni” su. Saglasno tome, ovde se govori o „modelu orijentisanom ka podacima”[6].

tblHLIM_1

ID	HLIM	JUS	DIN	TE	TVR_JEZ	TVR_BOK	DI_BOK	DI_POD	STAT_TVRD
1	1	SL200	EN-JGL-200	lam-grafit	180 HB	180 HB	300	40	190
2	1	SL250	EN-JGL-250	lam-grafit	220 HB	220 HB	360	55	245
3	1	SL300	EN-JGL-350	lam-grafit	230 HB	230 HB	375	70	350
4	2	NL 400-12	EN-GJS-400-S5	feritni	180 HB	180 HB	370	185	700
5	2	NL 600-3	EN-GJS-600-3	ferit. perlit	250 HB	250 HB	490	215	840
6	2	NL 800-2	EN-GJS-800-2	perlitni	275 HB	275 HB	600	225	1100
7	2	NL 1000	EN-GJS-1000-2	-	330 HB	330 HB	640	235	1300
8	3	CTEL350	EN-GJMB-350-10	feritni	150 HB	150 HB	320	165	780
9	3	CTEL650	EN-GJMB-650-2	perlitni	220 HB	220 HB	460	205	980
10	4	ČL 0501	GS52.1	-	160 HB	160 HB	320	140	460
11	4	ČL 0601	GS60.1	-	180 HB	180 HB	380	160	510
12	5	Č0460	S 275 JR	-	125 HB	125 HB	290	150	440
13	5	Č0545	E295	-	160 HB	160 HB	370	160	560
14	5	Č0645	E335	-	190 HB	190 HB	430	175	650
15	5	Č0745	E360	-	210 HB	210 HB	460	205	710
16	6	Č1531	C45R	normalizovan	190 HV-10	190 HV-10	530	205	740
17	6	Č1731	C60R	normalizovan	200 HV-10	200 HV-10	530	220	880
18	6	Č4131	37Cr4	poboljšan	250 HV-10	250 HV-10	530	245	930
19	6	Č4731	34 CrMo 4	poboljšan	270 HV-10	270 HV-10	530	260	1000
20	6	Č4732	42 CrMo 4	poboljšan	300 HV-10	300 HV-10	600	285	1080
21	6	Č5431	34CrNiMo6	poboljšan	310 HV-10	310 HV-10	630	305	1200
22	6	Č5432	30CrNiMo8	poboljšan	320 HV-10	320 HV-10	630	315	1300
23	7	Č1531	C45E	normalizovan	190 HV-10	560 HV-10	1030	270	1000
24	7	Č4731	34 CrMo 4	poboljšan	270 HV-10	590 HV-10	1070	430	1200
25	7	Č4732	42 CrMo 4	poboljšan	280 HV-10	610 HV-10	1170	360	1300
26	7	Č5431	34CrNiMo6	poboljšan	250 HV-10	590 HV-10	1270	380	1500
27	8	C4732	42 CrMo 4	gasnonitriran	180 HV-10	550 HV-10	1070	385	1000
28	9	Č4320	16MnCr5	gasnonitriran	280 HV-10	550 HV-10	1110	405	1050
29	10	C4737	31 CrMoV 9	gasnonitriran	320 HV-10	700 HV-10	1230	420	1170
30	10	C4737	14CrMoV6.9	gasnonitriran	360 HV-10	770 HV-10	1270	430	1250
31	11	Č 1530	1C45	normalizovan	220 HV-10	420 HV-10	710	310	680
32	11	Č 4320	16MnCr5	normalizovan	230 HV-10	560 HV-10	770	325	710
33	11	Č4730	42 CrMo 4	poboljšan	280 HV-10	610 HV-10	830	340	750
34	12	Č4130	34Cr4	poboljšan	450 HV-10	650 HV-10	1350	450	1400
35	13	Č1220	C15	cement. i kaljen	270HV-10	720HV-10	1460	220	880
36	13	Č4320	16MnCr5	cement. i kaljen	270HV-10	720HV-10	1470	430	1370
37	13	Č4321	20 MnCr 5	cement. i kaljen	280HV-K	720HV-10	1470	445	1470
38	13	Č4721	20 MoCr 4	cement. i kaljen	270HV-10	720HV-10	1470	385	1275
39	13	Č5420	15CrNi6	cement. i kaljen	310HV-10	730HV-10	1490	460	1570
40	13	Č 4520	17CrNiMo6	cement. i kaljen	400HV-10	740HV-10	1510	500	1670

Record: 1 of 44 No Filter Search

Sl. 2. Jedna od tabela iz baze podataka sa karakteristikama materijalima koji se koriste za izradu konusnih zupčanika

Naredni korak u našem primjeru iz prakse je prilagođavanje modelu orijentisanom ka podacima, koji je rezultirao prevođenjem tradiocionalnih tablica i dijagrama u bazu podataka *(slika 2.)* potrebnu za proračun geometrije i provjeru nosivosti konusnih zupčanika.

Obrada znanja - Poslednjih godina se računari sve više primjenjuju za obradu „znanja", ukoliko se ono može formalizovati. U inžinjerstvu se na primjer može pokazati kako se od datih normi mogu formirati pravila u obliku „Ako – Tada" (tj. kao veze ili relacije između stvari koje mogu biti „tačne" ili „netačne"). Ova pravila se tada zajedno sa podacima nekog problema obrađuju pomoću algoritma zaključivanja (inferencne mašine), koji su ranije razvijeni za određene klase problema i time „potvrđeni". Rješenja problema se zatim obrađuju pomoću „logičkog zaključivanja", tako da se odgovarajući koncept rješenja označava kao „logički model razmišljanja". I ovdje se pojavljuju algoritmi (na primer, u dijelovima pravila), ali ne oni, već **logičke reprezentacije** opisa problema, definišu koncept rješenja *(slika 3).*

Objektno-orijentisani model – Logičan nastavak u razvoju naše računarske aplikacije je prilagođenje modelu različitom od algoritamskiog. Radi o postavkama problema kod kojih se sa stvarima (objektima) opšte vrste „nešto radi". Ovde uvedeni model je označen kao objektno-orjentisani model [6].

Komunikacija čovjek - mašina (interaktivni grafičko okruženje) - Programi na korisničkom nivou nemaju izraženu svrhu da postignu „računske rezultate" već mnogo više operišu „objektima" u obliku „prozora", „ekranskih simbola", „prekidača", „klizača", „padjućih listi", itd., primjer za to su grafički objekti naše aplikacije nazvane – proracunKZ *(slika 5).* Pri primjeni programa je pogodno, operacije i podatke predstaviti i vidjeti kao **jedinstvo** i nasuprot klasičnom algoritamskom modelu ili modelu orijentisanom ka podacima spojiti ih u „**objekte**". Tako za objekte važi jezička jednačina: **Objekat = Operacije + Podaci.**

5. OBJEKTNO-ORJENTISANO PROGRAMIRANJE

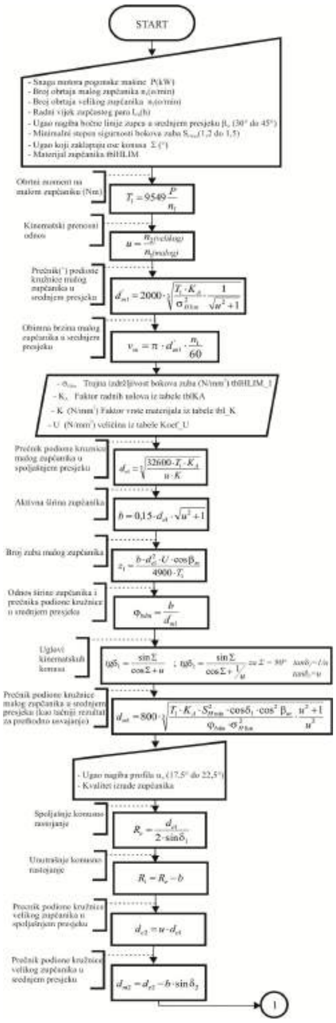
Objekti se sastoje od podataka i operacija, koje se izvode nad tim podacima, tj.: podaci jednog objekta su nerazdvojno povezani sa odgovarajućim operacijama. To vodi tome da su podaci postali „aktivni". Pri tome su objekti povezani sa drugim objektima pomoću **veza (asocijacije, relacije, linkovi).** Preko tih veza mogu se objekti kao elementi povezivati sa drugim objektima.

Primjer izračunavanja DI_BOK na osnovu odabranog materijala. U prvoj fazi su podaci o materijalima prebačeni u dvije tabele baze podataka. Prva tabela sadrži grupe materijala i ID koji je povezuje sa drugom tabelom u kojoj su konkretni podaci o materijalima. U drugoj fazi prilikom dizajniranja aplikacije na formu su postavljena dva kombo box-a (padajuće liste). Prilikom startovanja aplikacije u OnCreate event (događaj) je stavljena procedura za popunjavanje prve tabele (ID i naziv grupe materijala). Naziv grupe materijala je pridodat padajućoj listi, a ID grupe je ubačen u jedan niz tako da svaki položaj padajuće liste odgovara jednom ID-u iz niza npr. „Sivi liv" je u padajućoj listi na mjestu nula (0), a njegov ID ima vrijednost mat[0]. Prilikom odabira grupe materijala inicira se događaj ComboBox.OnChange (u objektnom programiranju, uvijek ide ova notacija objekt.osobina ili objekt.događaj). U taj događaj je ubačen dalji izbor materijala na osnovu izbora grupe. Pošto se desio događaj OnChange promijenio se ComboBox.ItemIndex i na osnovu njega određujemo koji je ID za sljedeći upit.

```
SQL.CommandText := 'SELECT JUS, DIN, DI_BOK FROM tblHLIM_1 WHERE HLIM = :id';
SQL.Parameters.ParamByName('id').Value := mat_ID[ComboBox1.ItemIndex];
ADODataSet1.Recordset := SQL.Execute;
```

Kao odgovor na ovaj SQL upit dobijamo nekoliko recorda koji zadovoljavaju uslov. Tačnije dobijamo podgrupe izabranog materijala. Podatke iz zahvata podataka ubacujemo u dvije nove padajuće liste (odvojeno za DIN i JUS) i niz hlim koji sadrži record DI_BOK.

Tako da se izborom bilo koje od tih listi npr. *dshlm := hlim[ComboBox3.ItemIndex];* dobija vrijednost za (dinamička izdržlivost boka zuba) DI_BOK za odabrani materijal.



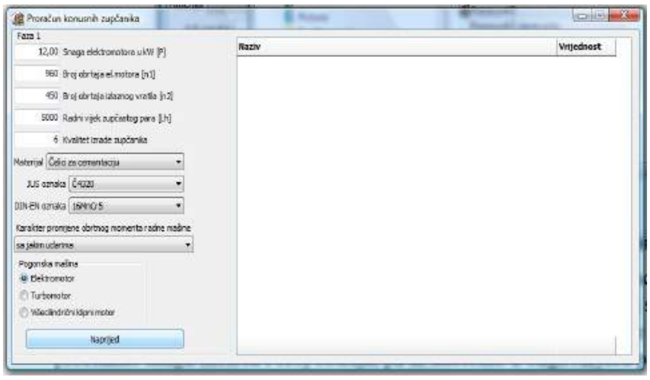
Sl.3. Dio logičke reprezentacije opisa ProracunKZ-a

Sl.4. Dio programskog koda proracunKZ

Sam objekat je tip podataka koji sadrži varijable (osobine), kao što zapis sadrži različite elemente u koje upisujemo podatke. Uz podatke, objekti sadrže procedure i funkcije koje rade s tim podacima. Procedure i funkcije koje su dio neke klase objekata nazivaju se metodama. U objektno-orjentisanom programiranju varijable i procedure su povezane, pa cijeli sistem funkcioniše na razumljiviji i jednostavniji način.

- objekti posjeduju osobine (varijable)
- objekti posjeduju procedure i funkcije (metode)
- osobinama i meodama objekata pristupa se kao što se pristupa elementima zapisa

(ImeObjekta.Osobine ili ImeObjekta.Metode).



Sl.5. Grafičko radno okruženje programa proracunKZ

Kao što je u uvodu navedeno, cilj je pokazati jednu od mogućnosti primjene računara u proračunu geometrije konusnih zupčanika. Kroz rad su obuhvaćena teoretska razmatranja i kao rezultat istih dobijen **program sa bazom potrebnih podataka** nazvan **ProracunKZ** (proračun konusnih zupčanika). Baza podataka je kreirana u **Microsoft Access-u 2007,** glavna forma programa je napravljna u **CodeGear™ RAD Studio 2007**, programski kod je pisan u **Borland Delphi Object Pascal-u** *(slika 4.),* upiti u **SQL**-u. Za izradu izvještaja naše aplikacije korišćen je **FastReport 3.4** „Add-Ins" programski paket nezavisnog proizvođača. Veoma je intuitivan za korišćenje, a u isto vrijeme ima jako mnogo opcija koje omogućavaju stvaranje željenih izvještaja, bilo ekranskih ili štampanih.

6. ZAKLJUČAK

Kroz kratak prikaz razvoja „računarske aplikacije iz inženjerske prakse", prikazan je evolutivni razvoj programerskih modela mišljenja i pisanja programskog koda, od linijskog, preko strukturiranog do objektno-orjentisanog. Primjer „proračuna Geometrije konusnih zupčanika, Faktora opterećenja, i provjere Nosivosti u odnosu na čvrstoću bokova i korjena zuba, može poslužiti kao univerzalni primjer proračuna i za druge mašinske elemente, a time dodati malu „kockicu u mozaiku" široke oblasti primijenjenog Computer Aided Engineering-a tj. Inženjerstva podržanog računarom [3].

ProracunKZ je standardna i (nadamo se) interaktivna Windows aplikacija. Baza podataka je inicijalno napunjena a dodavanje novih podataka je moguće jednostavnim dodavanjem u odgovarajuće tabele u bazi KZ.mbd, u kojoj (priznajemo) nisu realizovane baš sve prvobitne ideje.

Na primjer, prvo je bila ideja da se unese u bazu, tabela sa standardnim snagama elektromotora i tabela sa standardnim brojem obrtaja, ali pošto pogonska mašina ne mora biti samo elektromotor već može biti i klipni ili turbo motor čiji brojevi obrtaja i snage nisu standardizovani, odustali smo, razmišljajući i drugačije: odemo na lice mjesta i sa pločice pogonskog motora pročitamo snagu motora i broj obtraja, pa ih unesemo u odgovarajuća polja za unos.

I na posletku... potreban je probni rad s bazom i aplikacijom i provjera da li ona u potpunosti dobro i ispravno radi, kako bi otkriti potencijalne greške koje su se mogle potkrasti u svakoj od faza razvoja, a koje ćemo ispraviti u nekoj od budućih verzija ProracunKZ-a. Planiramo da ProracunKZ-a u svome finalnom obliku, bude jedna od nezavisnih cjelina modularnog CAD/CAE sistema za proračun i izradu tehničke dokumentacije mašinskih elemenata. Korisnici ovog CAD/CAE sistema bi mogle biti sve kompanije koje se bave proizvodnjom mašinskih elemenata, pri čemu bi se prema sopstvenim potrebama mogle opredjeliti da koriste sve ili samo neke od njegovih modula.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

INTEGRACIJA ROBOTA PRI MODELIRANJU I SIMULACIJI PROIZVODNOG PROCESA

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SAŽETAK

U ovom radu je predstavljen način kako modelirati i simulirati određeni proizvodni proces koristeći se gotovim kompaktnim kombinacijskim modelima koji predstavljaju jednu od stanica u proizvodnom procesu. Svaki od modela se upravlja pomoću sopstvenog kontrolera koji se programiraju pomoću računara. Koristeći modele stanica i slagajući ih prema potrebi procesa modeliramo proizvodni proces a potom simuliramo njegov rad prema ispisanim programima. U radu su navedene vrste i proizvođači modela i softvera. Također je prikazan primjer integracije simulacijskog robota u postojeći proizvodni proces.

Ključne riječi: integracija, robot, model, simulacija, proizvodni proces.

1. UVOD

Proizvodni proces služi da se u njemu vrši transformacija materijala, energije i informacija u gotov proizvod. Da bi smo dobili gotov proizvod, potrebno je da sirovina krene iz skladišta repromaterijala, prođe različite faze mjenjanja oblika, mehaničkih karakteristika, kvaliteta, vrijednosti u novcu, pakovanja itd. pa do dobijanja gotovog proizvoda u skladištu gotovih proizvoda. Želja je da ovaj proizvodni proces bude potpuno automatiziran u smislu potpunog isključivanja čovjeka kao izvršnog i upravljačkog faktora.

Razloga je mnogo ali neki od najčešće navođenih su isključivanja čovjeka iz sredine koja je loša po ljudsko zdravlje, kao i zamjena čovjeka na mjestima gdje su poslovi monotoni, pa sve do navođenja loših čovjekovih karakteristika koje utječu na kvalitet procesa i proizvoda. Sve je to dovodi do potpuno automatiziranih proizvodnih sistema kao što su fleksibilni proizvodni sistemi ili u posljednje vrijeme inteligentnih proizvodnih sistema. Za potpunu automatizaciju osim gore navedenih razloga potrebna je i tehnička podrška tj. automatska proizvodna oprema. To se uspjeva postići razvojem elektronike i računara u posljednjih 50 godina. Na ovaj način smo dobili i mehatroničke sisteme koja su nam potpuna podloga za dobijanje fleksibilnih, integriranih i automatiziranih proizvodnih procesa [3,4,5,6].

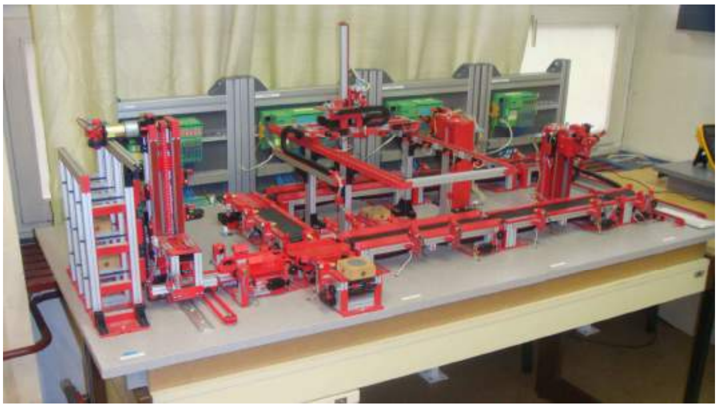
U procesu projektiranja novog proizvodnog procesa ili izmjene postojećeg veoma je dobro ponuditi nekoliko različitih modela proizvodnog procesa. To se danas postiže gotovim postojećim modelima pomoću kojih se slaže proizvodni sistem i simulira proizvodni proces.

2. MODELIRANJE I SIMULACIJA PROIZVODNOG PROCESA

Za modeliranje i simulaciju proizvodnog procesa korišteni su gotovi kombinacijski modeli njemačke kompanije Staudinger Gmbh. koji predstavljaju modele zasebnih obradnih stanica, skladišta, transportnih uređaja i slično [13]. Neke od primjera kao što su glodalica i portalni robot sa konvejerima su prikazani na slici 1.

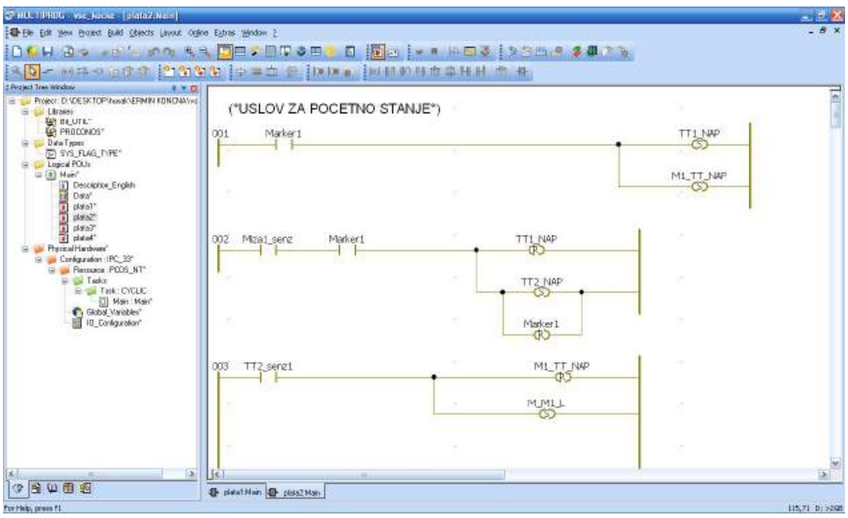
Slika 1. Kombinacijski modeli za integraciju proizvodnog procesa

Od ovih kombinacijski modela je modeliran proizvodni sistem prikazan na slici 2. Za ovaj proizvodni sistem možemo reći da je mehatronički sistem jer se sastoji od osnovnih komponenata koje čine senzori, aktuatori, kao i mikroprocesori [7,8,9,10,11,12]. Da bi dobili integrirani sistem nije dovoljno samo modele poredati jedan do drugog tj. napraviti hardversku integraciju već je potrebno sve module povezati u jedan automatski sistem na kojem ćemo moći simulirati određeni proces tj. potrebno je napraviti softverku integraciju.



Slika 2. Integrirani model proizvodnog sistema

Programiranje modela proizvodnog sistema se izvodi na principu programabilnih logičkih kontrolera. Za programiranje kontrolera je korišten ljestvičasti dijagram, što se može vidjeti na slici 3. Softver kojim je izvršeno programiranje je „MULTIPROG“.

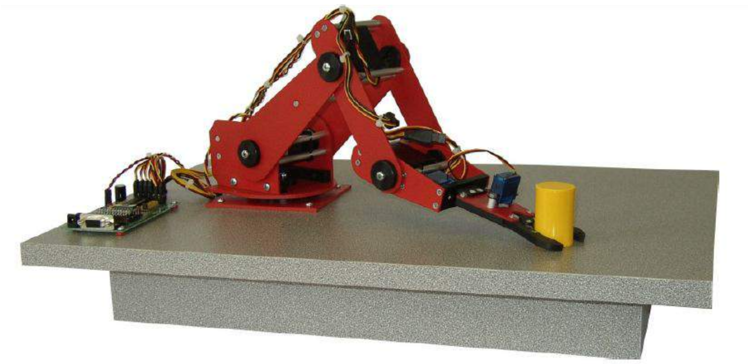


Slika 3. Softver za upravljanje sistemom za simulaciju

Koristeći se hardverskim komponentama kao na slici 1 i softverskim komponentama kao na slici 3 u mogućnosti smo da modeliramo i simuliramo proizvodne procese koji nas zanimaju.

3. PRIMJER INTEGRACIJE SIMULACIJSKOG ROBOTA U SISTEM

U ovom primjeru je predstavljen način modeliranja proizvodnog sistema pomoću integriranja simulacijskog petoosnog robota u postojeći automatski proizvodni sistem prikazan na slici 2. U sklopu rada je ispitana mogućnost integriranja robota kako hardverska tako i softverska na za to mogućim mjestima. Primjer simulacijskog petoosnog robota je prikazana na slici 4[1,2,13].



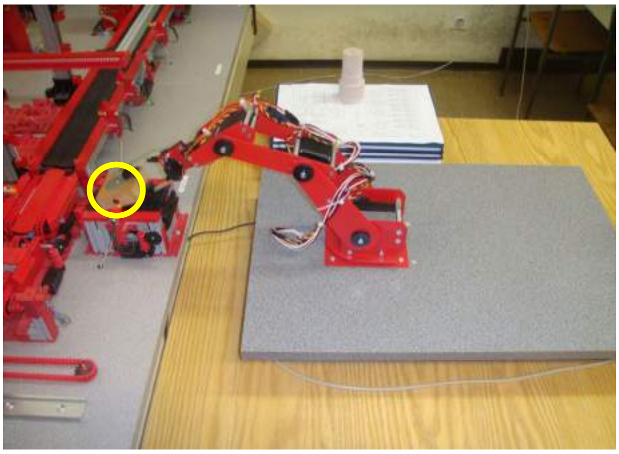
Slika 4. Petoosni robot za simulaciju[13]

Za jedan od primjera integracije simulacijskog robota uzeta je integracija robota sa sistemom preko konvejera na ulaznoj strani proizvodnog sistema.
Čitav proizvodni proces integriranog proizvodnog sistema počinje kada se komad postavi na ulazni transporter. Na ovaj način je i isprogramiran čitav proces. Signal koji se dobije na prvom senzoru pokreće obrtne stolove i transportere. U ovom slučaju smo integrirali robot upravo na mjesto ulaza u sistem. Funkcija robotske ruke na ovom mjestu je zamišljena kao uzimanje pripremaka sa palate i proslijeđivenje u obradni sistem. U slučaju automatskog rada bio bih nam potreban signal za početak izvođenja programa robota. U stvarnim pogonima na ovakvom mjestu bi bilo dobro postaviti kameru koja bi registrovala dolazak i prisustvo komada. Naročito bi to bilo bitno kada bi imali različite komade gdje bi robot morao da podesi end-effector prema datom komadu. U ovom slučaju taj signal je umjetno izazvan. Robotska ruka preuzima komad sa za to određenog mjesta što je prikazano i na slici 5. Simulacijski robot prenosi komad na ulazni konvejer proizvodnog sistema što vidimo na slici 6.

Slika 5. Preuzimanje komada i prenošenje na konvejer

Slika 6. Postavljanje komada na konvejer

Da bi sistem mogao da radi komad mora biti postavljen na način da mu metalni dio bude odmah uz senzor što je markirano i što vidimo na slici 7.



Slika 7. Pravilno pozicioniranje komada

Ovo je samo jedna od mogućnosti hardverske i softverske integracije simulacijskog robota u već postojeći proizvodni sistem, nakon čega dobijamo novi potpuno automatizirani proizvodni sistem sa integranim robotom.

4. ZAKLJUČAK

Ovakvi moduli su veoma pogodni za modeliranje i simulaciju proizvodnih procesa kao i simulaciju upravljanja i automatizacije istih procesa. Pronalazak mjesta kolizije je također jedna od prednosti krištenja ovakvih modela. Koristeći gotove modele možemo formirati različite proizvodne sisteme i simulirati proizvodne procese. Za u radu prikazani primjer u procesu modeliranja i simulacije dobijeni su dobri podaci o radnom prostoru robota kao i mjestu pozicioniranja i odabiranju pogodne trajektorije bez kolizije sa transportnim sistemom. Također je dobijen uvid koji su signali potrebni da bi se povezala ova dva sistema.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

PROGNOZE RAZVOJA AUTOMOBILA NA ELEKTROPOGON

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SAŽETAK
U radu se govori o prognozama razvoja automobila na elektropogon. Prognoze pokazuju da će se u idućih 15 godina jako razviti proizvodnja i upotreba automobila na električni pogon. U tih 15 godina riješit će se problemi koji danas opterećuju automobile na elektropogon. Cijena elektroautomobila će drastično pasti. U usporedbi sa klasičnim automobilom ukupni troškovi jednog elektro automobila za cijelo vrijeme njegovog životnog ciklusa biti će manji nego što će to biti troškovi klasičnog automobila. Povećana uporaba elektroautomobila izazvat će potrebu veće proizvodnje električne energije iz obnovljivih izvora energije. To će izazvati globalno smanjenje emisije stakleničkog plina CO_2 *kao direktne posljedice većeg korištenje elektropogona.*
Ključne riječi : automobil,elektropogon,prognoza,hibrid,okoliš,CO_2

1.UVOD

Svjedoci smo velikog interesa i zanimanja javnosti za sve oko automobila na elektropogon. Pošto je interes veliki tako se i proizvođači automobila utrkuju tko će dati bombastičniju izjavu, tko će najaviti ultimativni proboj na tržištu. Usprkos najavama velikih proizvođača o velikim probojima na tržištu trenutno stanje na tržištu je sasvim drugačije. Do 2009. godine na sveukupnom svjetskom tržištu prodano je manje od 10.000,00 automobila koje pokreću baterije. Jako reklamirana i prestižna vozila kao što su „Tesla Roadster" ili „TH!NK City" na tom tržištu prodana su za manje od 0,1 % kupaca. Tom broju se uvjetno može dodati broj od postojećih 2,5 milijuna hibridnih vozila. Na žalost ukoliko to usporedimo sa 850 milijuna postojećih klasičnih automobila sa unutarnjim sagorijevanjem, tek onda vidimo prave mjere priče o elektroautomobilu. Procjene za 2010. godinu govore kako će se manje od 2% novih prodanih vozila pogoniti električno ili će električni pogon dijelom biti zastupljen. Prema studiji koju je izradio Institut Oliver Wyman „Elektromobilität 2025" taj tržišni udio bi mogao tek za 15 godina iznositi oko 16 %. [1], [2]

Postoje više različitih stadija razvoja koji vode čisto električno pogonjenom automobilu. U prvom stadiju motor sa unutrašnjim sagorijevanjem biva potpomognut elektro motorom (Mild-Hybrid), u određenom periodu vremena u vožnji pogon biva zamijenjen električnim pogonom (Voll-Hybrid, Plug-in-Hybrid) i na samom kraju potpuno zamijenjen (elektro automobil, gorive ćelije) elektropogonom. [3]

Novi elektro automobil donosi i jako mnogo nepoznanica sa sobom: očekivanja kupaca, tržište, auto koncept, pogonske tehnologije, cijenu, zainteresiranost proizvođača, modele financiranja razvoja

Slika 1. Tesla Roadster

Slika 2. Protoscar

Slika 3. Toyota Prius

Slika 4. Chevrolet Volt

Slika 5. Fister Karma

Slika 6. Tango

Slika 7. Think! City

Slika 8. Smart Mercedes –Benz

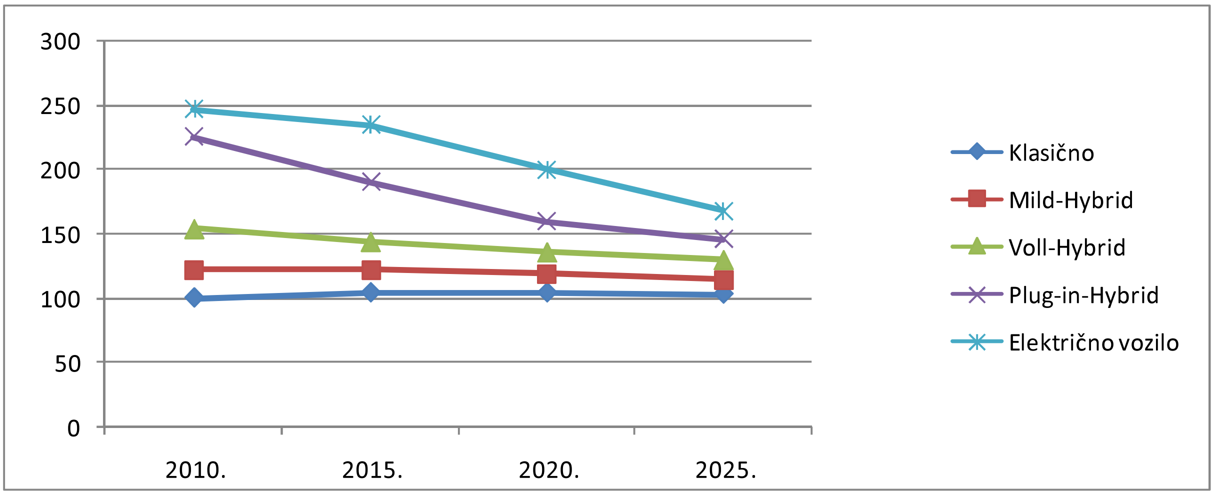
2. STUDIJA OLIVER WYMAN

Veliko međunarodno istraživanje raspoloženja kupaca automobila pokazalo je slijedeće. Kupac ne želi praviti kompromise na račun korisnosti, udobnosti u vožnji i sigurnosti svog automobila. Prije svega je ograničeni radijus kretanja elektro automobila glavni razlog protiv – samo 13 % ispitivanih akceptira radijus kretanja do 250 km. Tek kad tehnički bude izvodljiv odnosno dostigne se radijus od 400 km elektro automobili će napustiti svoj egzotični prostor i doći na ozbiljno i jako zainteresirano tržište. Modeliranje troškova proizvodnje pokazuje da su danas ti troškovi 150 % veći od troškova vozila sa unutrašnjim sagorijevanjem. Čak i u 2025. godini pretpostavlja se da će ti troškovi i dalje biti veći za oko 60 % !

Troškovi proizvodnje – usporedna tablica , za prosječno osobno vozilo, indeks 100 za klasično vozilo 2010. godine , Studija Instituta Oliver Wyman

Tablica 1. Troškovi proizvodnje usporedna tablica [1]

Vrsta vozila	Troškovi 2010.	Troškovi 2015.	Troškovi 2020.	Troškovi 2025.
Klasično	**100**	104	104	**103**
Mild-Hybrid	**122**	122	119	**115**
Voll-Hybrid	**154**	144	136	**130**
Plug-in-Hybrid	**225**	190	160	**146**
Električno vozilo	**247**	235	200	**168**



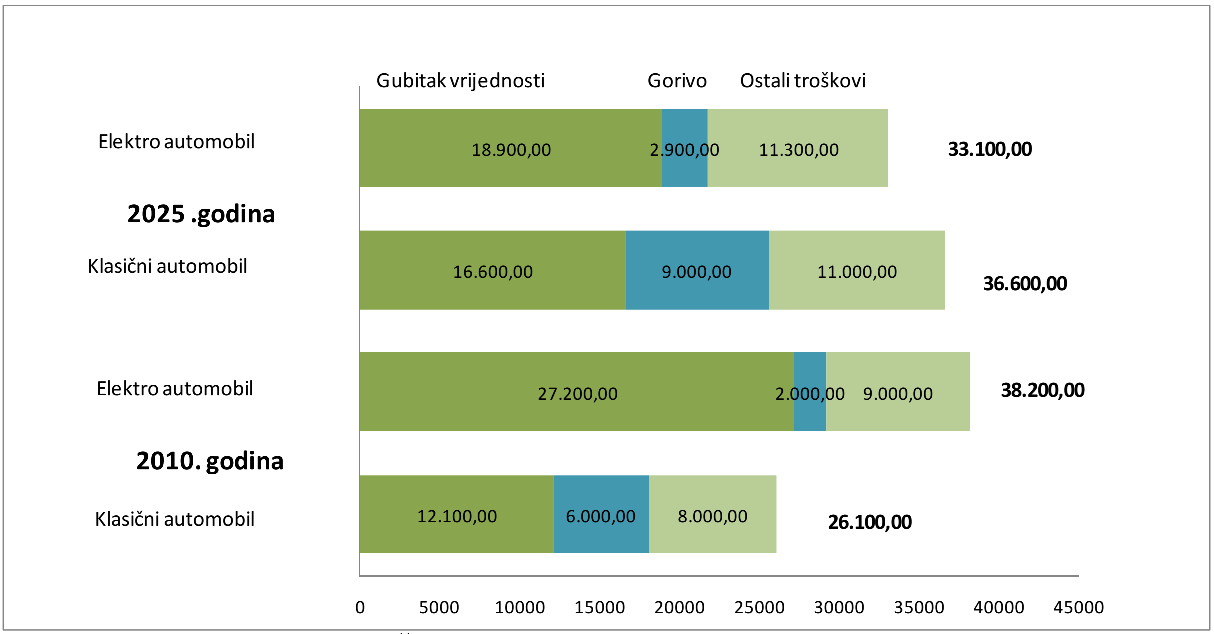
Grafikon 1. Troškovi proizvodnje usporedna tablica [1]

I pored jako velikog pada troškova proizvodnje ipak troškovi proizvodnje klasičnog automobila ostaju značajno manji od troškova proizvodnje elektro automobila i u prognozi za 2025. godinu U neki segmentima je elektro automobil povoljniji ali najveći udio u povećanoj cijeni čini pogonski akumulator, električni motor i dodatna elektronika. Prema već spomenutom ispitivanju samo 14 % kupaca je spremno više platiti za jedan elektro auto. U prosjeku će kupci za isti automobil koji je na električni pogon platiti nekakav dobrovoljni „porez“ od najviše 2.200,00 eura. Ukoliko automobil promatramo kroz cijeli njegov period korištenja (životni ciklus) a ne samo kroz nabavnu cijenu dolazimo do slijedećih podataka. Po sadašnjem stanju uz povoljne cijene struje jedan elektro automobil srednje klase za četiri godine prosječnog korištenja gledajući cijene goriva povoljniji je nego jedan prosječan automobil koji je pogonjen fosilnim gorivima. Na žalost u životni ciklus mora se uračunati gubitak vrijednosti takvog automobila na tržištu (zamjena pogonske baterije kao jako skupog dijela) pa i u tom pogledu račun pokazuje kako je danas, uzevši u obzir sve te faktore, održavanje elektroautomobila nakon četiri godine skuplje za čak 12.000,00 eura u usporedbi sa klasičnim automobilom. Po rezultatima studije to bi se vremenom trebalo drastično mijenjati i u ciljnoj 2025. godini ti troškovi bi bili ne veći nego za 3.500,00 eura manji na strani elektroautomobila!

Usporedni prikaz životnog ciklusa (troškova) električnog i klasičnog automobila (Studija Oliver Wyman) u eurima, za prosječno osobno vozilo, period korištenja od četiri godine, pretpostavljenih prevezenih 15000 km/godini

Tablica 2. Životni ciklusi klasičnog i elektroautomobila[1]

Udio cijene	Klasični automobil 2010. godina	Elektro automobil 2010. godina	Klasični automobil 2025. godina	Elektro automobil 2025. godina
Gubitak vrijednosti	12.100,00	27.200,00	16.600,00	18.900,00
Potrošnja goriva/struje	6.000,00	2.000,00	9.000,00	2.900,00
Ostali troškovi (fiksni troškovi, održavanje, popravke, čišćenje)	8.000,00	9.000,00	11.000,00	11.300,00
Ukupno troškovi	**26.100,00**	**38.200,00**	**36.600,00**	**33.100,00**



Grafikon 2. Životni ciklus klasičnog i elektro automobila [1]

Za krajnjeg kupca je danas posjedovanje i održavanje električnog automobila skoro 50 % skuplje nego troškovi jednog klasičnog automobila. Uzrok tomu je veliki gubitak vrijednosti novog vozila i pogonskog akumulatora. Tek za 15 godina taj odnos će se značajno promijeniti u korist električnog automobila čije će dugoročno posjedovanje i održavanje biti jeftinije u odnosu na klasični automobil za desetak procenata iako će nabavna cijena električnog automobila i dalje biti značajno veća od cijene klasičnog automobila.

Tržište elektro automobila će rasti ali lagano, mnogo laganije nego što bi prosječno informirani ljubitelj automobila očekivao. U svijetu se tek u 2025. godini predviđa prodaja potpuno električnih automobila u količini od 3,2 milijuna prodanih vozila. Do tada će se na cestama nalaziti oko 15 milijuna elektroauta što će činiti samo 3 % tada postojećih automobila. Mild i Voll-Hybrid automobili skupa će 2025. godine preuzeti oko 9 % ukupnog tržišta. Plug-in-Hybrid će po prognozama doseći 3,5% tržišta. Znači ukupan zbroj svih „alternativnih“ pogona neće preći 16 %. Dobre razvojne šanse prognoziraju se pratećoj industriji odnosno dobavljačima . Nastat će sasvim novo tržište komponenti elektro pogona, litijum-jonske baterije, električni pogoni, visokonaponska elektronika. Ovaj dio će privređivati oko 7 % ukupne vrijednosti cijele automobilske industrije. Osim toga biti će značajna suradnja sa proizvođačima električne energije koji će se morati prilagoditi novom značajnom tipu potrošača kakva su električna vozila.

Mnoge države se već sada aktivno uključuju u subvencioniranje razvoja električnih automobila: SR Njemačka subvencionira kupnju elektro automobila iznosom do 5.000,00 Eura, Velika Britanija je donijela odluku da od 2011 godine subvencionira kupnju novog električnog automobila iznosom do 6.000,00 eura po automobilu, SAD daje 7.500,00 dolara , Kina je odlučila da taj iznos bude 6.500,00 eura a Japan čak 11.000,00 eura! Za očekivati je i još neke porezne pogodnosti kako bi se povećale razvojne šanse električnih automobila. [4]

3.UTJECAJ NA OKOLIŠ

Usporedba emisije CO_2 jednog automobila na elektropogon i jednog klasičnog automobila sa unutarnjim sagorijevanjem je jako ovisna o načinu proizvodnje iskorištene struje. Odnosno zbog pravilne usporedbe jako je bitno gdje je proizvedena električna energija koju će električni auto koristiti: da li je to nuklearna centrala, termo centrala, hidrocentrala, solarna centrala ili vjetroelektrana.

Pošto je to za svaki pojedini slučaj u praksi nemoguće utvrditi, polazi se od svojevrsnog usrednjavanja zagađenja. Isporučitelj električne energije ima podatke o nastanku struje koju isporučuje i o pojedinačnom ispuštanju emisije CO_2 pri proizvodnji te struje. Iz tih podataka moguće je izračunati koliko je srednje ispuštanje CO_2/kWh proizvedene električne energije.

Pri vožnji električnim automobilom nema emisija CO_2 ali ima ih pri proizvodnji energije koju on koristi za pogon. Na primjer ukoliko se prema zvaničnim podacima uzme da je ispuštena količina CO_2 u Njemačkoj pri „mješavini“ proizvodnje iz raznih izvora oko 590 g/kWh tada se posredno zagađenje od elekropogona automobila „Smarta“ Fortwo eletric drive“ kreće oko 71 g/km.

Međutim ukoliko za osnovu uzmemo proizvodnju struje nastalu u termoelektrani gdje se spaljuje kameni ugalj slika je bitna drugačija. Pri proizvodnji struje od kamenog uglja vrijednost emisije CO_2 iznosi 890 g/kWh pa bi posredne emisije našeg Smarta u tom slučaju iznosile čak 107 g/km! [3]

Ipak čak i u tom nepovoljnom slučaju može se sa sigurnošću reći kako je emisija CO_2 uzrokovana korištenjem električnih automobila bitno manja od korištenja klasičnih automobila sa unutrašnjim sagorijevanjem jer se kod novih klasičnih automobila ta emisija kreće iznad 150 g/km.

Naravno pravo rješenje mora biti sveobuhvatno. Cilj je proizvoditi električnu energiju iz obnovljivih izvora energije i na samom izvoru smanjiti emisiju CO_2. U tom slučaju je bilanca na strani elektroautomobila neusporedivo bolja. Ukoliko odemo u drugu krajnost i uzmemo da automobil na elektropogon koristi struju iz obnovljivih izvora energije, tada bi se pri vožnji ovakvim automobilom proizvodilo bi samo 7 g/km CO_2 što je 95 % smanjenje u odnosu na konvencionalni automobil!

To je put kojim treba ići. Elektropogon nije sebi svrha. Cilj je preći na okolišno bolju soluciju uz dostignuti standard. Poboljšanjem svojstava elektro automobila i povećanjem njegovog tržišnog udjela vrši se povoljan utjecaj na okoliš iz više razloga. Potiče se proizvodnja električne energije iz obnovljivih izvora. Višestruko se smanjuje emisija stakleničkih plinova. Štede se neobnovljivi izvori energije odnosno nafta i njeni derivati i tako čovječanstvu ostavlja mogućnost njihovog duljeg korištenja u neke druge svrhe a ne samo kao pogonsko gorivo.

4. ZAKLJUČAK

Dok električni automobili postanu uobičajena pojava na prometnicama je još dug put. Ipak ovaj smjer razvoja automobilizma dugoročno gledajući ima budućnost ukoliko se relativno brzo razne državne subvencije usmjere u tehnički razvoj. Prema sadašnjim prognozama za petnaest godina broj automobila na elektropogon na svjetskim cestama činit će 16 % od ukupnog broja tada postojećih automobila. Zemlje koje su veliki proizvođači automobila već ulaže znatne napore u tom smjeru.

Najveći problem elektroautomobila predstavlja punjenje baterije – nedostatak mrežnih stanica za punjenje, kao i nužna stanka od nekoliko sati koja je potrebna da se baterija napuni. Prednosti ima podosta: ne ispuštaju štetne plinove, nije ih komplicirano održavati, ne mijenja se ulje, ne kupuje gorivo, tihi su, a neki se mogu i u potpunosti reciklirati. Tako razmišljanje kupiti ili ne automobil na elektropogon postaje jedno od normalnih pitanja koji si ljudi već postavljaju ili će postaviti u skoroj budućnosti.

Razvoj automobila na elektropogon poticat će i proizvodnju električne energije iz obnovljivih izvora energije. Sve to će globalno utjecati na smanjenje stakleničkog plina CO_2 što je vrlo pozitivan faktor koji svojim razvojem i raširenošću promoviraju automobili na elektropogon.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

NEKA ISKUSTVA U PROJEKTOVANJU I RADU MALIH HIDROELEKTRANA

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SAŽETAK
Bosna i Hercegovina raspolaže značajnim potencijalom za izgradnju energije iz obnovljivih izvora korištenjem malih i srednjih vodotoka na kojima se mogu graditi male hidroelektrane (MHE). Hidrološke podloge su veoma bitne kada je u pitanju određivanje osnovnih parametara agregata. Unutargodšnji raspored protoka je ključan za definisanje parametara agregata. Priključak na mrežu utiće na rad postrojenja a može biti limitirajući faktor u eksploataciji.
Ključne riječi: obnovljivi izvori, male hidroelektrane, hidrologija, priključak na mrežu

1. UVOD

Bosna i Hercegovina raspolaže sa hidropotencijalom od oko 6000 MW odnosno 21000 GWh, od čega je dosada iskorišteno 2000 MW odnosno 6000 GWh ili svega 30% u snazi a još manje u proizvodnji. Kada su u pitanju male hidroelektrane (novim zakonskim propisima iz 2010. je definisano da se pod malom hidroelektranom računa ona instalisane snago do 10 MW), kapacitet se procjenjuje na nešto više od 10% od ukupnog hidropotencijala, odnosno na oko 700 MW ili 2800 GWh. Ovi iznosi su jako mali kada se zna da je u nvećini zemalja zapadne Evrope iskorištenost hidropotencijala i preko 90% što vrijedi i za male hidroelektrane. Male hidroelektrane su u BiH u proteklih 60 godina bile zanemarene. Indikativan je podataka da je broj malih hidroelektrana u Austrougarskom periodu bio veči nego njihov broj u 2003. Godini. Tek su tokom 80-ih godina pokrenute neke aktivnosti na prikupljanju i obradi podataka o potencijalnim projektima malih hidroelektrana. Tada su nastale i prve studije koje su tretirale određena područja i određene vodotoke. Značajnije aktivnosti u ovaj oblasti pokrenute su nakon završetka ratnih dešavanja u BiH kada je Elektroprivreda BiH (inače javno preduzeće) u suradnji sa nekoliko kantona u Federaciji BiH pokrenula izradu studija hidroenergetskog korištenja srednjih i malih vodotoka. Prema podacima iz tih studija, samo na području četiri kantona, postojala je mogućnost izgradnje preko 140 MHE sa ukupnom instalisanom snagom od 170 MW i godšnjom proizvodnjom od 670 GWh. Ove studije su nešto kasnije bile osnova kantonima za raspis javnih poziva za dodjelu koncesija koji su uslijedili tokom 2005/2006 godine. Po osnovu tih javnih poziva u medjuvremenu je dodjeljeno preko 70 koncesija za MHE. U Republici Srpskoj je kao osnova za raspis javnog poziva za dodjelu koncesija bila studija hidroenergetskog korištenja pritoka rijeke Drine koja je urađena krajem 80-ih godina. Ova studija je prvobitno urađena sa namjerom definisanja mjera na pritokama rijeke Drine koje se ulijevaju u akumulaciju HE Višegrad u cilju sprečavanja nanosa u akumulaciju. Tokom 2006. godine Vlada RS je objavila javni poziv te dodjelila oko 100 koncesija za MHE. U međuvremenu, od 2003. kada su stvorene zakonske osnove za realizaciju ovih projekata u Federaciji BiH (u RS je to 2004. godina) donošenjem nekoliko zakona te odluke o metodologiji nivoa otkupnih cijena za RES projekate, do danas, u pogon je pušteno oko 25 malih hidroelektrana. U fazi izgradnje je nekih 10 MHE, dok je ostatak projekata u raznim fazama dobijanja dozvola („administrativna faza“). Mora se napomenuti da se određeni broj projekata odnosno koncesija, njih 10-ak, nalazi u fazi „čekanja“. To su projekti čija realizacija je upitna iz više razloga. U RS je situacija znatno drugačija. Iako je u 2006. godini dodjeljeno skoro 100 koncesija, dosada su u pogonu svega 4-5 male hidroelektrane. Ima nekoliko bitnih razloga zbog čega u pogonu nema više MHE, a jedan od najbitnijih je neusklađenost zakonskih propisa na nivou entiteta i lokalne zajednice odnosno općina. Stoga su mnogi koncesionari u fazi ishođenja raznih dozvola što traje i preko godinu i pol dana. I ovdje ima jedan broj koncesija koje su u fazi „čekanja“, odnosno realizacija ovih projekata je upitna.

2. PRVE MHE NA BAZI KONCESIJE I NA DBOT PRINCIPU

Intrade energija d.o.o. Sarajevo je pravni sljedbenik koncesije za četiri MHE na području općine Fojnica, koje je firma suosnivač Intrade d.o.o. Sarajevo stekla 2000. godine, tada u partnerstvu sa jednom austrijskom kompanijom. U projekat se tokom 2003., kada je Intrade energija i osnovana, uključila jedna slovenačka kompanija. Razlog odustajanja tadašnjeg austrijskog partnera je nepostojanje zakonske regaulative kada su RES projekti, konkretno projekti MHE u pitanju. Projekat se sastoji od ukupno četiri MHE, po dvije na rijekama Jezernica i Kozica. Rijeka Jezernica, kao što samo ime kaže, izvire iz jezera, tačnije poznatog Prokoškog jezera koje se nalazi na koti 1640 m.n.m., na obroncima planine Vranice, čiji okolni vrhovi dostižu visinu i preko 2000 m.n.m. na Njoj se nalaze dvije MHE: Jezernica i Mujakovići. Rijeka teče u pravcu grada Fojnice gdje se uljeva u istoimenu rijeku koja se kod grada Visokog ulijeva u rijeku Bosnu. Rijeka Kozica se nalazi s druge strane planinskog prevoja i na njoj se nalaze dvije MHE: Majdan i Botun. Rijeka teče u pravcu grada Busovače u čijoj se blizini ulijeva u rijeku Lašvu a ista se nakon 10 km ulijeva u rijeku Bosnu. Projekat se realizovao u nekoliko glavnih faza:

- pribavljanje potrebnih dozvola i saglasnosti,
- faza izrade projektne dokumentacije,
- tenderisanje i ugovaranje radova i isporuke opreme,
- pripremna faza realizacije projekta,
- izgradnja objekata i montaža opreme,
- puštanje elektrana u pogon uz praćenje rada u probnom periodu,
- pribavljanje potrebnih dozvola od strane regulatorne agencije u Federaciji BiH

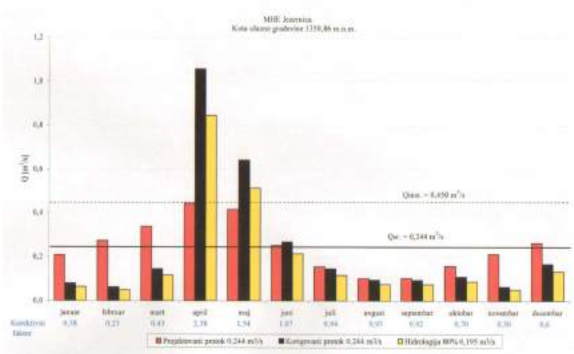
Projektna dokumentacija je rađena u nekoliko faza. Prvu fazu je predstavljala izrada (inoviranih) Idejnih rješenja. Ova dokumentacija se oslanjala i na postojeću dokumentaciju izrađenu tokom 80-ih godina. Pri tome su uzeti u obzir novi momenti koji su u međuvremenu dobili na večem značaju: ekološki uticaji i društvena prihvatljivost projekta. Idejna rješenja su poslužila za podnošenje zahtjeva i dobijanje Urbanističkih saglasnosti. Sljedeća faza je bila izrada Glavnih projekata za što je angažovana sarajevska kompanija Energoinvest dok je osoblje Intrade energija pružilo konsultantske usluge. Po izradi iste izvršena je revizija, a što je u skladu sa propisima koji tretiraju ovu oblast. Revidovani Glavni projekti su služili za izradu tenderske dokumentacije, izbor izvođača radova i isporučioca opreme ali i za pribavljanje Dozvola za građenje. Tokom faze izrade projektne dokumentacije te odabira isporučioca opreme došlo je do značajne evolucije u projektu. To se prije svega očitovalo u činjenici da se u fazi izrade Idejnih rješenja odustalo od jedne MHE jer je investitor (pravilno) procijenio da bi njena eventualna izgradnja potakla određene dileme i javne nesuglasice. Naime, dokumentacijom iz 80-ih godina planirana je izgradnja jedne MHE na mjestu gdje iz Prokoškog jezera ističe rijeka Jezernica. Investitor je odlučio da odustane od te lokacije jer Prokoško jezero predstavlja prirodnu ljepotu i vrijednost koja zaslužuje da zadrži svoju ambijentalnost. Druga značajna i još radikalnija promjena se dogodila na rijeci Kozici na kojoj je dokumentacijom iz 80-ih predviđena izgradnja jedne akumulacione MHE sa kotom akumulacije iznad 1100 m.n.m. koja je trebala imati višenamjensku funkciju: izvor pitke vode za vodosnabdijevanje Busovačke doline, sprečavanje poplavnih valova i proizvodnja električne energije. Specifičnost projekta je bila i u činjenici da je predviđena izgradnja tlačnog cjevovoda od skoro 10 km. Inoviranim Idejnim rješenjem, a u dogovoru sa lokalnom zajednicom, izvršeno je preprojektovanje koje je za posljedicu imalo odabir lokacija za dvije MHE [(1) M.Mihajlović]. Sve ovo je za posljedicu imalo izmjenu parametara MHE koji su nakon projektovanja i odabira isporučioca opreme izgledali kao u *Tabeli 1.*

Tabela 1: Osnovni parametri MHE

	Kota vodozahvatne građevine - KGV [m.n.m.]	Kota lokacije strojare - KDV [m.n.m.]	Dužina tlačnog cjevovoda [m]	Prečnik TC [mm]	Bruto pad [m]	Instalisana snaga turbine i agregata [kW]	Moguća godišnja proizvodnja [GWh]
MHE Jezernica, rijeka Jezernica	1350,00	952,00	2910	Ø500/450/400	398	1376/1294	5,6
Mujakovići, rijeka Jezernica	950,00	705,00	2570	Ø700/600	245	1633/1535	7,5
MHE Majdan, rijeka Kozica	1059,00	734,00	2820	Ø700/600	325	2802/2635	10,6
MHE Botun, rijeka Kozica	669,50	564,50	1340	Ø800/600	105	1100/1034	4,9

3. HIDROLOGIJA

Za fazu projektovanja je bitno je još istaći da se u proračune parametara postrojenja, prije svega instalisane snage agregata i iz toga proistekle moguće godišnje proizvodnje, ušlo sa hidrološkim podacima usvojenim iz dokumentacije iz 80-ih uz vršenje simultanih mjerenja na profilima vodozahvatnih građevina za svaku MHE pojedinačno. Podaci iz studije iz 80-ih su usvojeni na bazi određenih hidroloških osmatranja i mjerenja. Međutim, pokazalo se da taj nivo mjerenja ali i metodologija proračuna hidrologije (komparacijom podataka sa najbliže vodomjerne stanice i metodom analogije veličina oticaja po km^2 slivnog područja) nisu zadovoljavajući. Vodomjerne stanice su uglavnom dosta udaljene od lokacija MHE i nalaze se na kotama dosta nižim od kota večine MHE smještenih na planinskim vodotocima. U eksploataciji postrojenja tokom zadnjih skoro pet godina uočeno je da postoji značajna razlika prije svega u tzv. „unutargodišnjem rasporedu“ protoka između projektne dokumentacije i stvarnog stanja. Naročito je to izraženo kod dvije MHE čije vodozahvatne građevine se nalaze na nadmorskim visinama znatno iznad 1000 m. Na *dijagramu 1* se može vidjeti komparacija stanja na MHE Jezernica čija se vodozahvatna građevina nalazi na 1345 m.n.m.



Dijagram 1

Iz dijagrama je vidljivo da se unutargodišnji raspored protoka na ovoj MHE drastično razlikuje on onoga iz projektne dokumentacije, naročito u ključnim mjesecima april-maj. Vidljivo je da tokom ova tri mjeseca proteče više od polovine ukupno raspoloživog protoka na nivou jedne godine. Da je ovaj podatak bio poznat prije izrade projektne dokumentacije vjerovatno bi došlo do korekcije parametara agregata. Instalisana snaga bi bila još i veća, odnosno omjer Qinst./Qsr. bi bio veči od omjera postignutog isporukom opreme a koji iznosi 1,8. Može se smatrati srećom da je isporučilac opreme isporučio „bogatiji“ agregat od onog traženog u tenderu, prema kojem je taj omjer iznosio svega 1,4. [(2) Allen R. Inversin]. Ovo je za posljedicu imalo prije svega neostvarivanje projektovanih vrijednosti godišnje proizvodnje električne energije. Može se konstatovati da razlika između projektovane i dosada ostvarene proizvodnje iznosi oko 4,5 GWh ili minus od 20% na godišnjem nivou. Ova činjenica nije uticala na ostvarivanje instalisanih snaga. Ostvareni su parametri elektrana kao u *Tabeli 2.* Ovakva razlika unutargodišnjeg rasporeda na dvije MHE čiji vodozahvati su na znatno nižim kotama (950,00 i 669,00 m.n.m.) ne postoji.Dakle, iskutvo je pokazalo da se mora uobziriti visinu kote ulazne građevine, jer se pokazalo da je za kote preko 1000 m.n.m., a za tipične planinske vodotoke kojih je veliki broj u BiH, potrebno zbog vremenskih uslova, o dnosno niskih temperatura u periodu novembar-mart, izvršiti detaljniju hidrološku analizu uz uvažavanje pomenutih činjenica

Tabela 2: Ostvareni parametri MHE

	Instalisana snaga turbine i agregata - ugovorena [kW]	Ostvarena snaga na turbini [kW]	Ostvarena snaga na agregatu [kW]	Razlika [%]
MHE Jezernica	1376/1294	1488	1400	8,1
Mujakovići	1633/1535	1648	1550	1
MHE Majdan	2802/2635	2711	2550	-3
MHE Botun	1100/1034	978	920	-12

4. NEKA DRUGA ISKUSTVA

Na neostvarivanje instalisanih snaga na MHE Majdan i Botun uticali su sljedeči faktori:

- poddimenzionisana gruba rešetka na zahvatnom dijelu ulazne građevine na MHE Majdan,
- smanjen bruto pad postrojenja za oko 5 metara na MHE Botun.

U međuvremenu je izvršena sanacija zahvatnog dijela ulazne građevine na MHE Majdan tako da se u periodu velikih voda na proljeće 2009. očekuje potvrda veličine instalacije na ovoj elektrani. Do ove razlike od 5 metara u bruto padu na MHE Botun došlo je zbog činjenice da je u samom početku realizacije projekta lokacija strojare morala biti premještena uzvodnije zbog neriješenih imovinsko-pravnih odnosa. Ovj objekat je imao još nekoliko problema od kojih navodimo sljedeče:

- pijozometrijska linija bila viša od linije pada terena što je uzrokovalo pojavu uvlačenja zraka u cjevovod - zračni djep,
- loše odabran rotor turbine – nemogućnost „gutanja“ projektovane količine vode,
- parametri turbine definisani uz pretpostavku stalnog pada od 110 m, ne uzimajući gubitke u obzir

5. OPREMA ELEKTRANA

Za glavnog isporučioca opreme je izabrana kompanija Turboinštitut iz Slovenije. Isporučilac generatora je Končar iz Zagreba, transformatori su Elin Ljubljana, SN postrojenje je Siemens dok je NN postrojenje vlastite potrošnje bosanskohercegovačke kompanije Energovest SUE. Isporučena su ukupno četiri agregata parametara i karakteristika kao u *Tabeli 3*.

Tabela 3: Parametri agregata i opreme u MHE

	Vrsta turbine	Generator	SN postrojenje	NN postrojenje	Transformator	Rad
MHE Jezernica	Pelton, horizontalna, jednomlazna	Sinhroni, 1500 kVA, 0,4 kV, Cosφ 0,8	3 ćelije: -dalekovodna, -mjerna, -trafo ćelija	Razvod 24 V DC, Razvod 110 V DC	Blokovski, uljni, 1500 kVA, 10(20)/0,4 kV	Paralano sa mrežom + ostvrski
Mujakovići	Pelton, horizontalna, dvomlazna	Sinhroni, 1800 kVA, 0,4 kV, Cosφ 0,8	3 ćelije: -dalekovodna, -mjerna, -trafo ćelija	Razvod 24 V DC, Razvod 110 V DC	Blokovski, uljni, 1800 kVA, 10(20)/0,4 kV	Paralano sa mrežom + ostvrski
MHE Majdan	Pelton, horizontalna, dvomlazna	Sinhroni, 3000 kVA, 6,3 kV, Cosφ 0,8	3 ćelije: -dalekovodna, -mjerna, -trafo ćelija	Razvod 24 V DC, Razvod 110 V DC	Blokovski, uljni, 3000 kVA, 10(20)/6,3 kV *Kućni trafo 100 kVA*	Paralano sa mrežom + ostvrski
MHE Botun	Francis, horizontalna	Sinhroni, 1500 kVA, 0,4 kV, Cosφ 0,8	3 ćelije: -dalekovodna, -mjerna, -trafo ćelija	Razvod 24 V DC, Razvod 110 V DC	Blokovski, uljni, 1500 kVA, 10(20)/0,4 kV	Paralano sa mrežom + ostvrski

Ormar razvoda 110V DC je ubačen naknadno jer se tada smatralo da je isti potreban u slučaju ispada razvoda 24V DC te radi unifikacije pomoćnog napona na postrojenjima 10(20)kV i sigurnosti u pogonu. Ovaj set za istosmjerno napajanje sastoji se od ispravljača 220 V izmjenično/110 V istpsmjerno, izlaza 10 A, treba biti “maintenance free” sa baterijom 110 V DC kapaciteta cca 50 Ah, razvoda sa automatima na odvodima i pretvaračem 110V DC/24VDC, snage od cca 100 W. Danas se razvod 110V DC na malim hidroelektranama više ne upotrebljava budući je sva potrebna oprema smještena u ormar 24V DC. [(3) Tong Jiandong i grupa autora]. Regulaciono-upravljačke sheme uvezivanja opreme u elektrani su usklađene sa zahtjevom mogućnosti i otočnog rada postrojenja. Iako ne postoji zakonska obaveza, investitor se odlučio na ovaj korak iz razloga iskustava iz nedavne prošlosti BiH.
Jedna takva shema je data na *Slici 1*.

6. PRIKLJUČAK NA MREŽU

Za potrebe priključka na elektrodistributivnu mrežu izrađen je projekat uklapanja elektrana u EE sistem. Projektom je predeviđeno i u praksi urađeno:

- Izgradnja priključnih 20(10) kV dalekovoda za sve četiri MHE do TS 35/10/0,4 kV u Fojnici,
- Ugradnja novog transformatora 20/10 kV, prividne snage 4000 kVA u postoječoj TS u Fojnici,
- Ugradnja dvije RS sa po 4000 kVA, po jedna na slivu,
- Instalacija dalekovodnog 20(10) kV kabla do Prokoškog jezera

Na ovaj način je područje općine Fojnica, kao jedno od prvih u BiH, prešlo na strateški distributivni napon od 20 kV. Osim toga, umjesto nekadašnjih 60% sada pokrivenost mrežom područja Fojnice iznosi preko 90%. Stvoreni su uslovi otvaranja značajnijih proizvodnih kapaciteta što ranije nije bio slučaj. Naime, područje Fojnice se električnom energijom snabdijevalo preko starog i u ratu oštečenog 35 kV dalekovoda iz pravca Kiseljaka odnosno Visokog. Ovo je jedno od rijetkih područja u kojem nema 110 kV dalekovodne mreže. Iako je investicionim planom iz 2002. odobrena investicija povezivanja grada Visoko sa područjem Fojnice novim 110 kV dalekovodom, taj projekat do danas nije realizovan. Na štetu investitora u MHE ali i područja općine Fojnica. I pored toga, realizacijom projekta izgradnje 4 MHE i instalacijom preko 100 km 20(10) daelovodne mreže, stvorene su pretpostavke za dinamičniji razvoj ovoga kraja.

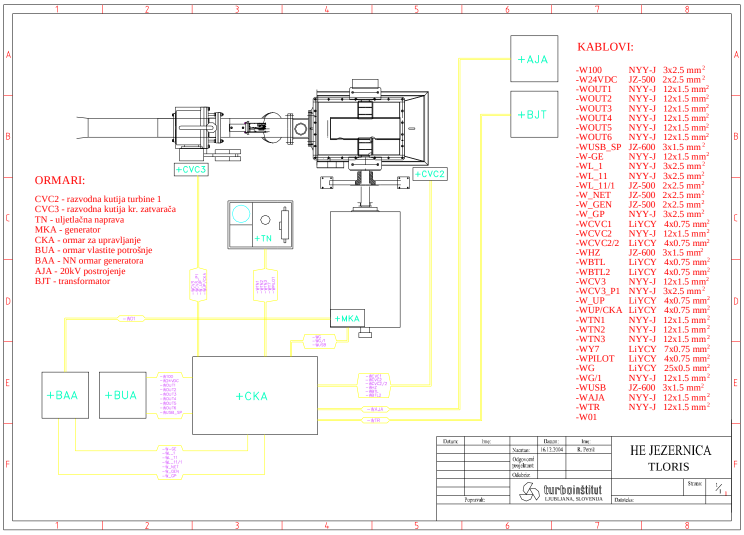
7. UTICAJI IZGRADNJE MHE I NA EE MREŽU

Dobrim tehničkim rješenjem MHE, znatnom pogonskom spremnošću, uticaji MHE na distributivnu mrežu su pozitivni. Navodima neke:

- Povećava se pogonska sigurnost distributivne mreže jer se napaja iz dva, tri ili više nezavisnih izvora,
- Poboljšavaju se naponske prilike u mreži i smanjuju gubici aktivne energije u mreži, jer su naponi veći a prenešene struje manje,
- Poboljšavaju se uslovi rada potrošača jer rade sa naponima i strujama bližim nominalnim,
- Poboljšavaju se tokovi aktivne i reaktivne struje i smanjuju gubici električne energije u mreži. Nepotrebno kolanje energije je svedeno na najmanju moguću mjeru, naročito reaktivne, jer se ona proizvodi tamo gdje se i troši,
- U toku gradnje MHE, u većini slučajeva se ulažu znatna sredstva za proširenje i poboljšanje lokalne distributivne mreže.

Mora se priznati da je u praksi bilo slučajeva kada je uticaj MHE bio negativan. To se prije svega odnosi na prekomjerno trošenje reaktivne energije kod napajanja vlasite potrošnje preko blok transformatora i na pogoršanje naponskih prilika u elektrodistributivnoj mreži. Međutim, glavni razlog ovih problema je činjenica da se na postoječim transformatorskim stanicama, prije svih onim gdje se napon transformiše sa VN (prenosnih) na SN (distributivni) dalekovoda, ne vrši regulacija naponskih prilika u skladu sa stanjem na terenu već je glavni zadatak bio „zaštiti svoju distributivnu mrežu“.

Dakle, prenosni omjer i tim TS su bili pogrešno podešeni tako da je dolazilo do nepotrebnog kolanja reaktivne energije u mreži, a što je za posljedicu imalo lošije naponske prilike. Čim je izvršeno prepodešenje prenosnih omjera u TS, naponske prilike u mreži su postale normalne, gubici su svedeni u normalu a MHE nisu više „predstavljale problem“ [(4) Celso Penche].



Slika 1: Regulaciono-upravljačka shema MHE

8. ZAKLJUČAK

Prilikom projektovanja MHE potrebno je izvršiti detaljnu analizu hidroloških parametara, a ukoliko ne postoje potrebno je izvršiti mjerenja. Za ulazne građevine koje se nalaze na kotama većim od 1000 m.n.m. potrebno je uraditi dodatne analize, prije svega unutargodišnjeg rasporeda voda tj. protoka. U praksi se pokazalo da je unutargodišnji raspored voda za ovakve MHE netipičan, odnosno ne može se „povezati“ sa hidrološkim podacima sa referentnih vodomejrnih stanica koje se uglavnom nalaze na znatno manjim kotama. Evidentan je podbačaj u ostvarenoj proizvodnji električne energije u odnosu na projektovane vrijednosti. Razlog je loš izračun hidroloških parametara a najviše neuzimanje u obzir korektivnih faktora s obzirom na nadmorsku visinu kote vodozahvatne gradjevine. Mjere koje se mogu poduzeti u cilju ublažavanja:

- Što je veća nadmorska visina kote vodozahvatne gradjevine ići sa večim Qinst. u odnosu na Qsr. (preko 2 ako je visina veča od 1300 m.n.m., 1,5-2 za visine oko 1000 m.n.m., 1,2-1,5 za visine manje od 800 m.n.m.)
- najefikasnija mjera je formiranje (sezonske) akumulacije na gornjem dijelu vodotoka čime se dobiva povečanje proizvodnje u odnosu na Tirolski zahvat i
  do 30%, stim da se energija može proizvoditi u skladu sa potrebama EE sistema, izravnanje voda i ekološki efekti koji se odnose na visinu tzv. vodoprivrednog minimuma i mogućnost vodosnabdijevanja nizvodnih naselja prirodnim putem itd.)

Priključak na mrežu je veoma bitna stvar budući da se večina MHE nalaze na „repu“ elektrodistributivne mreže što iziskuje značajna finansijska sredstva za priključak MHE na istu. MHE u principu imaju pozitivan uticaj na elektrodistributivnu mrežu pod uslovom da se na transformatorskim stanicama izvrši pravilno podešenje prenosnih omjera odnosno pravilno podešenje zaštita.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

POSSIBILITY OF REDUCING EMISSIONS OF POLLUTANTS IN URBAN AREAS

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ABSTRACT
During the last decades the world has been facing the constant increase in number of vehicles which considerably contributes to the greater emissions of pollutants, especially in urban areas.
Considering the total number of vehicles with more than 330,000 registered vehicles in 2009, where 25 % is in the Pristine, the review of the most important parameters of the park vehicle in Kosova has been presented in the paper. Taking in the consideration permanent traffic jams in urban areas and the fact that gasoline operated vehicles are responsible for the most emission of CO and diesel operated vehicles for the NO emission, lead us to the conclusion that special attention is to be paid to the emissions of pollutants and definition of measures for their reduction. The most efficient way of reducing the emissions of pollutants is the use of alternative instead of conventional fuels and hybrid vehicles.
Keywords: Ecology, transport, urban area, alternative fuels, hybrid vehicles**.**

1. INTRODUCTION
The first connection between motor vehicles and environmental pollution in urban areas is decided at 50 years of last century when researchers have concluded that transport was the main cause for the filling the air with smoke on Los Angeles, California, USA. This observation has helped the fact that the development of the industry after Second World War, the number of motor vehicles has increased significantly.
The second factor, which is more important, is fuel consumption which made connection between motor vehicles and environment pollution and is main source of energy for driving of motor vehicles. With increases of motor vehicles in road, the amount of fuel consumed and the number of passes kilometres emitted amount of pollutants which are: CO, C_XH_Y, NO_x, CO_2 and particles. Although the first steps of control and reducing emissions of pollutants mentioned above are listed at 70 years of the last century, however, important steps are taken in the last decade of last century when plan called "*small emission*" [1].
On the other side, Prishtina city in the last 25 years is defined as one of the most polluted cities in Kosova with known pollutants fog. The situation has changed after the last war in Kosovo where except the Kosova Power Plants they don't have the industry that will take part in environmental pollution in the Prishtina region.
Recently, pollution can be defined as motor vehicles, the city's heating system and Kosovo Power Plants. Bypassing Power Plants and heating system, following are presented results which define environmental statements in the Prishtina region for year 2009, and the possibility of reducing pollution in urban environments.

2. ENVIRONMENTAL REVIEW IN THE PRISHTINA REGION

To review the definition of successful urban ecological environment as the Prishtina region, have to known enough relevant data to provide a more realistic picture of the real situation, such as park of vehicle structure, the amount of fuel consumption, the number of kilometres passes, the average speed of movement, climatic conditions, etc.

The total number of registered vehicles in Kosovo after the war, there was a significant increase which can be justified with ruin of park of vehicles during the war and during easement import vehicles immediately after the war. In 2007 and 2008 is stabilized total number of registered vehicles, reaching a value about 300,000 vehicles in 2009, statistics presented in Table 1. [3].

Table 1. Number of registered vehicles in Kosova

Year	Passenger vehicle	Total
2007	207.675	256.989
2008	248.355	310.681
2009	301.199	379.273

Based on data taken from [3] can be observed that the largest number of vehicles is shown in more developed regions of Kosova, for example, in the region of Prishtina, Prizren, Gjakovë, etc.

Information on the total number of vehicles registered in the Prishtina region, [3] are taken from the Vehicle Registration Centre of the Republic of Kosova and are given in Table 2.

Table 2. Number of vehicles on the Prishtina region

Year	2006	2007	2008	2009
Number of vehicle	72.766	86.102	102.813	124.781

Based on the data of Table 2, there is a steady increase during the specified period. Given the large number of vehicles belonging to international organizations concentrated in Prishtine region, with very great certainty can be concluded that the number of vehicles circulating in the region of Prishtine is over 125,000, which represents over 25 % of the total number registered vehicles in Kosova. For further analysis of the structure of the park vehicle serving the data for age structure for 2009 taken from [3]. Structure of park of vehicle is presented in Table 3.

Table 3. The structure park of vehicle in the Prishtina region in 2009

Kind of vehicles	Passenger cars	Track	Bus	Motorcycles	Others	Total
Number of vehicles	102.745	17.278	1.046	1.953	1.759	124.781

If the compared data in Table 1 and 3, observe that nearly 90% of the total park of vehicles in Kosova consists of passenger cars. Using the same sources, can be determine structure of the age of the park vehicle in the Prishtina region for 2009, presented in Figure 1, which is seen by 83,622 vehicles that are older than 15 years.

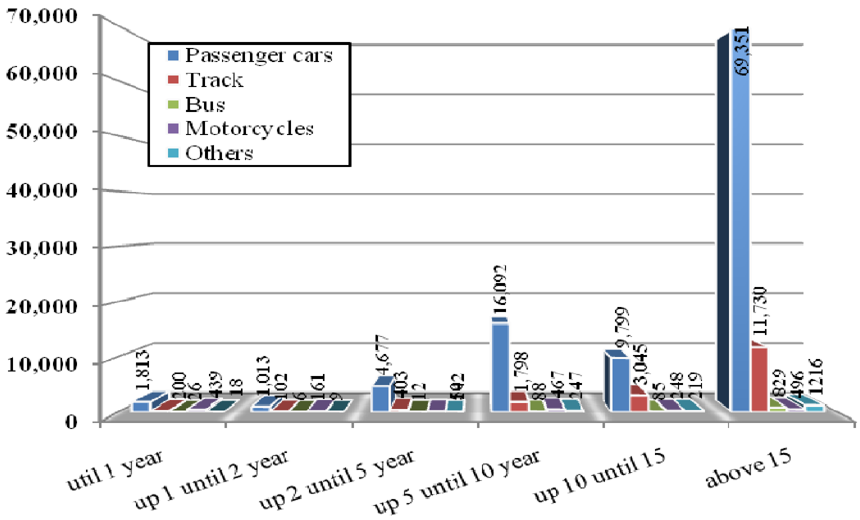

Figure 1. The age structure of the vehicle park in the Prishtina region in 2009.

Analysis of the situation in 2009 and appropriation of certain assumptions about the actual age of the park of the vehicles, can be determine the average age of the park of vehicles in the Prishtina region , (which is presented in Table 4).

Table 4. Average age of the park vehicles in the Prishtina region for 2009 year

Kind of vehicles	Passenger cars	Track	Buses	Motorcycles	Total
Ages (years)	16,79	18,47	20,68	9,51	17,00

Based in detailed analysis of the park of vehicle present above, and referenced relevant data for determining the success of environmental review in the Prishtina region, has made calculation of characteristic emissions of pollutant from motor vehicles using the computer program Copert IV.
The program mentioned is downloaded from [4], and successfully used throughout the European Union region. To estimates emission of pollutant was necessary knowledge of the fuel consumed for that purpose. It made the balance of the estimated amount of fuel consumed, and based on data taken from [5] for Republic of Kosova, and results for fuel calculations is obtained estimate the amount emission of pollutants. Comparative indicators of the amount of spent fuel are shown in Table 5.

Table 5. Consumption fuel during 2009 year

	Unleaded Petrol (t)	Leaded Petrol (t)	Diesel (t)
2002 year	32.221	0	71.210,5
Copert IV	31.476,23		68.773,79
Error %	-2.3		-3.4

Since the calculation error is less than ± 10 %, based on the recommendations of the author's calculation program [4] performed the calculation can be considered valid and may be initiated with the introduction of environmental review in the Prishtina region for 2009. Calculation results in ratio to the characteristic emission of pollutants from motor vehicles are given in Table 6.

Table 6. Emission of pollutants in 2009 year

Emission of pollutants, *ton*	Passenger cars	Light truck	Heavy track	Buses	Motorcycles	Total
CO_2	186.699	32.215	74.124	32.193	770	326.001
CO	3.127	177	274	83	91	3.752
NMVOC	653	28	139	18	22	860
NO_x	936	154	664	313	1	2.068
Particulates	100	17	40	17	0	174

Basis of the results presented, it is seen that the greatest responsibility for the emission of CO and NMVOC come from passengers cars. On the other site, motor vehicles for transport (track and buses) have produced significant emission NO_x and particles, considering that their participation in the estimated number of motor vehicles is not large.
However, the number of passenger cars equipped with diesel engine are important, it can be concluded that the passenger cars are the main culprits for the emission of NO_x and particles. The emission of CO_2 is the consequence of the overall of fuel consumption and can't directly be affected. It may be noted that passenger cars are responsible for the emission of CO_2. Diesel engines required driving track and buses, with relative little participation number of motor vehicles and the most part of kilometres passes contribute to the creation of significant CO_2 emissions.
Analyzing the results obtained, it can be concluded that passenger cars are responsible for producing the emission of pollutant in the region of Prishtina. But the specifics of the Prishtina region in space of the five municipalities circulates 90 % of the total park of vehicles, equal care should be paid to reducing the emission of pollutants from passenger cars as well as transportation vehicle and buses for urban and inter urban traffic.

Of course that may be made logical question for the validity of the environmental statement submitted to the region of Prishtina and their connection with ecological statements of other European capitals cities. For the first question should be asked to respond to the collection of more reliable data from various factors, which will significantly improve the ecological validity of the statement, while answer for the second question can be found by comparing ecological statements of European cities similar or less similar.

By analyzing the obtained ratios, can be conclude that environmental statements in the Prishtina region are is level of environmental review from 2003 year of the Western European countries [1].

3. POSSIBILITY OF REDUCING EMISSIONS POLLUTION

Given the indicators presented in Table 7, we can say that the developed countries of Europe, OECD members [1], planned reduction of pollutant emission.

Although the planned reduction of pollutant emission are assumed by using of new technologies which applied in modern motor vehicles (with electronic injection and hybrid vehicle), one of the most important reasons for this environmental review on the Prishtina region, the park of vehicles is older and renewal its poor.

Besides renewing the park of vehicles, following activities in reduction on the pollutant emission should be oriented with the using more quality conventional fuel and alternative fuels. It is certain that CNG (*Compressed Natural Gas*) today represents the most important alternative fuel which enables the realization of much smaller emission of pollutants, particularly of NO_x and particles. Application of CNG in the first case will be use in vehicles with less perfect equipment for bringing the fuel and without installation catalyst of the output gas.

Given that CNG has found wide application, as the urban public transport vehicles as well as passenger cars in Western Europe, but also in some of our closest countries and can be expected that this type of alternative fuels will be used in the Prishtina region in a near future.

4. CONCLUSION

The Prishtina region, due to the specific position is one of the most polluted cities, where the main culprits for creating the emission of pollutants are motor vehicles, central heating system and Kosova Power Plants.

In this context, it is analyzed and defined ecological overview of the most important pollutants as a result of the using of motor vehicles.

It is shown that the passenger cars are primary responsible for most emission of all pollutants, as well as transport vehicles and urban traffic buses produce enough emissions of NO_x and particulate given their very small participation in total number of registered vehicles.

Reducing emissions of these pollutants can be accomplished with the renewal of the park of vehicles, by using more quality conventional fuels and using alternative fuel, but also with some other economic measures and alternative kind of transport that is shown in this paper.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

PROMOTION OF RENEWABLE ENERGY CONSUMPTION IN EUROPEAN UNION

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ABSTRACT
Renewable energy is on the quest. Nonrenewable resources are getting scarce and expensive. In order to promote new energy resources, which could contribute to development, innovation and bring competitive advantage on the energy markets in the future, population has to become sensible and responsive to this issue. The European Commission committed itself to raise the awareness of EU citizens in the direction of sustainable future. In this paper some promotional activities, campaigns and educational cases are highlighted from standing points of different stakeholders and discussed to draw a framework for developing promotional strategies for renewable energy and sustainable consumption of energy.
Keywords: promotion, sustainable consumption, renewable energy, EU, development, market

1. INTRODUCTION
Without doubt, Europe's citizens and companies need a secure supply of energy at affordable prices in order to maintain our standards of living. At the same time, the negative effects of energy use, particularly fossil fuels, on the environment must be reduced. That is why EU policy focuses on creating a competitive internal energy market offering quality service at low prices, on developing renewable energy sources, on reducing dependence on imported fuels, and on doing more with a lower consumption of energy [1]. We could say that electricity generation is one of the leading causes of air pollution in the EU. Main part of electricity comes from non-renewable power plants. Producing energy from these sources takes a severe toll on our environment, polluting our air, land and water. Renewable energy sources can be used to produce electricity with less environmental impacts. It is possible to make electricity from renewable energy sources without producing CO_2, the leading cause of global climate change. The new Directive on renewable energy improves the legal framework for promoting renewable electricity, requires national action plans that establish pathways for the development of renewable energy sources including bioenergy, creates cooperation mechanisms to help achieve the targets cost effectively and establishes the sustainability criteria for biofuels [2].

The main purpose of this paper is to identify goals and interests of renewable energy promoters, marketers, and utilities with those of purchasers, policymakers, and the communities that might benefit upon clean energy. There exists a clear commitment of EU to implement the strategy of increasing the share of renewable energy and to replace classical resources of energy, witch are not contributing to the planned sustainable development. Of course this agenda is not straightforward and without powerful opponents, so we are going to assess both arguments – pro and contras, trying to dig deeper under surface. We would like to overview and analyze the market development of renewable energy in the EU.

We are presenting several cases of individuals and companies that help build the market for green power. In order to increase the awareness and sensibility of consumers, there have been invented original and innovative marketing campaigns by green power suppliers; some effective programmes focused on education related to green power have been released; also the green power purchasers have been putting in place outstanding promotional campaigns. Several projects, centered on the most recent developments in the photovoltaic, small hydropower, wind, biomass, geothermal energy, and solar thermal energy sectors, and a geographical approach have been presented during the last decade. The geographical approach focuses on actions in the new member states of the EU, in European islands, and actions outside the EU.

2. DEVELOPMENT IN THE EU'S SECTOR FOR RENEWABLE ENERGY

EU countries are highly and increasingly dependent on imports of fossil fuels (oil and gas) for their transport and electricity generation. In fact, in the EU, we rely on energy imports for about half of our energy consumption. Moreover, fossil fuels account for 79% of the EU's gross inland energy consumption. The problem is that fossil fuel resources are finite; furthermore, supplies are vulnerable to price fluctuations or logistical or political difficulties. It is therefore important to reduce our dependence on fossil fuel imports and to diversify our supply of energy. Renewable energies help us do this because it means using more 'home-grown' energy – energy based on Europe's own natural resources. It helps to diversify the energy mix and the sources of energy that we rely on [3].

Table 1. Renewable energy in final energy consumption (2020 target)

	EU Member State	2006 Figure	2020 Target	% To cover:
1	United Kingdom	1,5 %	15 %	**13,5 %**
2	Ireland	2,9 %	16 %	**13,1 %**
3	Denmark	17,2 %	30 %	**12,8 %**
4	France	10,5 %	23 %	**12,5 %**
5	Netherlands	2,7 %	14 %	**11,3 %**
6	Spain	8,7 %	20 %	**11,3 %**
7	Greece	7,1 %	18 %	**10,9 %**
	EU	9,2 %	20 %	**10,8 %**
8	Italy	6,3 %	17 %	**10,7 %**
9	Latvia	31,4 %	42 %	**10,6 %**
10	Belgium	2,6 %	13 %	**10,4 %**
11	Cyprus	2,7 %	13 %	**10,3 %**
12	Germany	7,8 %	18 %	**10,2 %**
13	Luxembourg	1,0 %	11 %	**10,0 %**
14	Malta	0,0 %	10 %	**10,0 %**
15	Portugal	21,5 %	31 %	**9,5 %**
16	Slovenia	15,5 %	25 %	**9,5 %**
17	Finland	28,9 %	38 %	**9,1 %**
18	Austria	25,1 %	34 %	**8,9 %**
19	Lithuania	14,6 %	23 %	**8,4 %**
20	Estonia	16,6 %	25 %	**8,4 %**
21	Hungary	5,1 %	13 %	**7,9 %**
22	Sweden	41,3 %	49 %	**7,7 %**
23	Poland	7,5 %	15 %	**7,5 %**
24	Slovakia	6,8 %	14 %	**7,2 %**
25	Bulgaria	8,9 %	16 %	**7,1 %**
26	Romania	17,0 %	24 %	**7,0 %**
27	Czech republic	6,5 %	13 %	**6,5 %**

Source: Collected and Compiled by Europe's Energy Portal [4]

For twenty years now, the EU has been engaged in an ambitious plan to become world leader in renewable energy. The EU is working to reduce the effects of climate change and establish a common energy policy. By 2020 renewable energy should account for 20% of the EU's final energy consumption (9.2 % in 2006).

The mere availability of renewable energy resources, incentives, technology, capital, expertise and government policy does not suffice if there is insufficient end-user awareness. Germany has less sunshine than France, and less wind resource than the UK. But its application of renewable energies is so much more because of the general awareness of the German population [3]. To expand the market share, public awareness-raising and demand-side stimulation can be used; these are viewed as powerful tools in countries such as the Netherlands. The national campaign, radio and TV programmes, national publicity, national information centres, studies on the value of the consumer market and so on have positive impacts on market development. In China, nationwide communication focused on the supply side and less on the demand side. The government and industry will work together on communication with the consumers on awareness of SHW technology and the environment [4].

Renewable energies have huge potential to boost Europe’s industrial competitiveness, too. They are expected to be economically competitive with conventional energy sources in the medium- to long-term, so we should gain if we take the lead now. Boosting investment in renewable energies should help create businesses and jobs, and promote innovation in the EU economy. Exporting renewable energy technologies to other countries will also bring business opportunities, further boosting the EU economy. The EU is a world leader in renewable energy and the sector is already important economically. Renewable energy in the EU has a turnover of € 30 billion, providing 350 000 jobs [5].

3. PROMOTION OF RENEWABLE ENERGY IN EU

The EU has numerous schemes to promote wider involvement. The European Commission’s ManagEnergy [7] initiative supports work on energy efficiency and renewable energies at local and regional level through training workshops and online events. The Commission’s Sustainable Energy Europe campaign [8] raises public awareness about sustainable energy and helps you play your part in changing the energy landscape. Key topics to be addressed with third countries could include the dissemination of new technologies, development and implementation of energy management plans, choice of energy mix to minimize pollution, climate change and health effects of energy. The EU should continue to facilitate international negotiations to develop a global framework for addressing climate change. Renewable energy and energy efficiency have to be an integral part of any EU external energy policy.

3.1. ManagEnergy

ManagEnergy is a technical support initiative of the Intelligent Energy - Europe (IEE) programme of the European Commission which aims to support actors from the public sector and their advisers working on energy efficiency and renewable energies at the local and regional level. The ManagEnergy initiative includes [7]:

- The ManagEnergy website (www.managenergy.net), which offers databases on case studies and good practices as well as a directory of energy agencies;
- Information on relevant European policy and legislation;
- Electronic newsletters;
- Capacity building workshops;
- Other networking facilities, such as online events, an Annual Conference and awards.

Energy management in public buildings and educational campaign in schools in the city of Maribor

Energy Agency of Podravje (EnergaP) is oriented towards the field of reducing energy consumption in public buildings and to raise awareness of the importance of energy saving among pupils, teachers and other users of the buildings in Maribor (which is the second biggest city in Slovenia). In a partnership with the Municipality of Maribor, which is also the main source of funding, EnergaP has installed the Central Energy Management System (CEMS) in 70 public buildings. CEMS is a software tool, which uses general data from the buildings such as climate characteristics, energy use and consumption (energy bookkeeping). It can take into acount saving measures, price of energy, possible savings and CO_2 emissions. The system offers around 2-3 % potential energy saving because of the good monitoring availability and 8% cost saving within the first year of installation because of mistakes that are found (i.e. on the bill and in the metering system). Besides new technologies and advanced systems, user behaviour is today one of the most important ways to achieve energy savings and to reduce GHG emissions. That's why the second part of EnergaP's project is oriented towards an educational campaign focusing on pupils and teachers in primary schools. The two parts are connected in a way that pupils and teachers can see and use the real data of their school and monitor its imapct on energy use. With better understanding of energy issues and the potential of energy saving, the pupils can also influence their parents' behaviour. Furthermore, due to the results of the educational campaigns in schools, teachers and pupils (as well as their parents) will become more responsible energy consumers. Until now EnergaP organized more than 40 workshops for pupils between 6 and 15 years old. In the beginning of the project EnergaP spent a lot of time explaining to people in different municipal sectors and public buildings about the importance of sustainable energy use and about the benefits of the CEMS. Users viewed the system as additional work that consumed their time. But after using the system for some time they also found the positive aspect and benefits of CEMS [9].

Resinbuil

Resinbuil is a project financed by the IEE programme (Intelligent Energy - Europe). It was approved in December 2005 and its total duration is 26 months from January 2006. The consortium is formed by eight partners from four European regions (Pomurje - Slovenia, Spain, Italy and Romania). The project is focused on the encouragement of the use of Renewable Energy in the building sector by means of a three-pronged strategy centred on new and concrete market, promotion and training actions. The expected result in the short term is a significant boost in the instalment of small scale RES in the residential sector in a close cooperation with the installers and the local authorities. The promotion of RES in buildings has started by means of the creation of the Resinbuil Web site, first and second semester bulletins, conferences and congress appearances, publication of info booklets about RES in buildings in the four participating regions - fulfilling in this way the planned part of the third - strategic objective. It is worth pointing out the necessity of communication among partners. In Resinbuil Consortium the communication has been fluent and that is one of the main reasons of the success of the project. In all the participant regions, the project has had an excellent reception from local agents, they have participated in all the tasks in which they have been invited and partners agree to use the experience of these key actors along the duration of the project. The main preliminary lessons learnt, emerging from the Resinbuil Project, are [10]:

- Increasing interest in new generations of architects and engineers. These groups have accepted very well the project, participating actively in all the actions executed.
- The construction sector (promoter and constructors) is reticent to install RES in buildings, arguing that it would increase the cost of dwellings. Partners have notice a lack of interest in this group.
- General public is the best tool to promote RE in buildings. This is the reason why the majority of the actions performed by the Consortium have been aimed to citizens in general.

3.2. The Sustainable Energy Europe Campaign

The Sustainable Energy Europe Campaign is a European Commission initiative in the framework of the Intelligent Energy - Europe programme, which aims to raise public awareness and promote sustainable energy production and use among individuals and organisations, private companies and public authorities, professional and energy agencies, industry associations and NGOs across Europe. The Sustainable Energy Europe Campaign wants to support you as a European actor committed to sustainable energy. You are part of this communication effort, and there are various ways to participate in this Campaign. The specific objectives of the Sustainable Energy Europe Campaign are to [8]:

- raise the awareness of decision-makers at local, regional, national and European level;
- spread best-practice;
- ensure a strong level of public awareness, understanding and support;

- stimulate the necessary trends towards an increase in private investment in sustainable energy technologies.

Within the Campaign, achievable benchmarks are also provided, in order to measure the progress of sustainable energy actions and serve as goals for decision-makers and planners. Within the EU, there is a wide range of organisations working to promote sustainable energy. These include, not only local and regional energy agencies, but also industry actively marketing their products in the sector of renewable energy or energy efficient technologies. The Campaign will develop a network to support small and medium size enterprises, which represent the lion’s share of the renewables and energy efficiency industrial market, helping them to cooperate with each other and to learn from experiences across Europe. The Sustainable Energy Europe Campaign will support local and regional promoters – energy agencies, NGOs, consumer associations – and provide a network for sharing good practice and information about relevant dissemination activities.

The Award Competition- Rewarding the best
Europe is a leading light in implementing sustainable energy initiatives, and as ingenious methods are successfully implemented across the Union, the European Commission wishes to reward the best examples of sustainable energy schemes, and promote their achievements to a wider audience. Sustainable Energy Partners are eligible to participate in the prestigious Annual Competition. The competition is held to reward Partnerships that have made an outstanding contribution to the development and promotion of the Campaign through their programmes and projects. Evaluated by an independent jury, the foremost examples of successful sustainable energy projects will be selected and awarded at a highly visible public Award Ceremony held in prominent locations across Europe.

Persuading the wider public
The easy choice is so often to stick with the status quo, but the Campaign aims to convince the public at large that making a commitment to sustainable energy is an investment in the future of Europe. To ensure this close involvement of European citizens in energy decisions, the Campaign is therefore developing a range of strong media actions and decentralized events throughout Europe.

Media Actions
Via the Campaign Media Desk, press and television journalists will be regularly alerted to the latest information on sustainable energy issues and success stories of the Campaign. The Media Desk will also provide journalists with networking opportunities and access to interviews with main energy actors during key Campaign events. Strengthening links with media representatives will ensure that public awareness is raised and that local and regional actions are brought to the widest possible audience.

4. CONCLUSIONS

Apart from those occasions when, perhaps for financial reasons, there is no choice but to become involved, there are circumstances in which “new” consumers are willing to invest time and attention in making a purchase [11]: to save time; to gain personal advantage; and to increase their enjoyment. Renewable resources are biotic populations which can reproduce [12]. So we have to involve personally EU citizens in a social dialogue and make their effort worth the troubles. Research, demonstration and market replication initiatives are needed to bring clean and renewable energy sources closer to markets. The value of good practice and successful examples is of vital importance in pursuing the goals of replacing the non-renewable energy sources with renewable ones. To increase the emphasis on education it should be placed more effort upon the local energy actors, as they reach the local publics with more ease. Of course efficiency campaigns are not enough; governments have to harness financial instruments and mechanisms to further stimulate investments into renewable sources.

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1st International Scientific Conference on Engineering
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MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

PROS AND CONS FOR INVESTMENTS IN PHOTOVOLTAIC ENERGY

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Slovenia

ABSTRACT
Due to the long-term return of investment of the photovoltaic power plants, energy yield and long-term performance are very important for the profitability of investment. Without subsidies and government warranty of feed-in tariff, this kind of renewable energy source is not competitive on the energy market. However, we have some good examples of power plants that are built on the photovoltaic technology. We are assessing current state of renewables market in EU and Slovenia.
Keywords: energy market, renewable energy systems, photovoltaic energy, EU, subsidies, price

1. INTRODUCTION
In view of rising global concern pertaining to fossil fuel as well as the presence of global warming whose effects can already be felt, the worldwide political arena has put the use of renewable energy sources (RES) on its agenda and is now promoting the development and installation of wind and solar energy systems. In EU the political decisions to this end have already been made.

Due to the long-term highly profitable return on investment of the photovoltaic (PV) power plants, energy yield and long-term performance are far more important for the profitability of power plants than the initial cost of the investment. However, Kalan [1] argues that the investment into biomass oven exceeds economically photovoltaic investment for 6 times; and investment in heat pump 4 to 6 times. Of course it makes no sense to compare directly the outcome of solar energy transformation into electrical energy (appr. 17 %) and transformation into heat (40 – 50 %).

Of all renewables, solar thermal energy is considered to be practically unlimited in the long-term, and is a very abundant resource in the developing world. Concentrated solar thermal power plants produce most of the world's energy derived from direct radiation. The prospect for these technologies and solar upwind chimneys are good.

We studied the economic view of photovoltaic investment decision, having in mind the political incentives that might shorten the return on investment significantly and also the sustainable view of green energy. Interest is growing and already results in concrete projects that are getting realized all over the globe. Materials improvement, political back up, increasing awareness of non-renewable resources shortage and environmental commitment of involved companies and citizens are some of important factors that have to be taken under consideration when discussing opportunities and threats.

2. FIELD OVERVIEW
Alternative sources of energy, among them photovoltaic is taking an important place, are becoming essential source of electric energy. EU provided intensive programmes of support to increase the use of renewable sources of energy. Slovenia as a member of EU has to follow this development, that's why government planned to build a substantial number of solar plants until 2015. Of course financers

have to assess the return on investment and feasibility plans, before deciding to invest the capital in such venture.

Table 1: Photovoltaic capacity installed in the European Union in 2008 & 2007 - Capacity in MWp (Megawatt Peak) on-grid plus off-grid

Ranking:	**Country:**	**Amount:**	**Bar Graph:**
1	Spain	2671 (2007: 591)	
2	Germany	1505 (2007: 1103)	
3	Italy	197,3 (2007: 70,2)	
4	Czech Rep.	50,3 (2007: 3,1)	
5	Portugal	50,3 (2007: 14,5)	
6	Belgium	49,6 (2007: 17,2)	
7	France	44,5 (2007: 12,8)	
8	Greece	9,3 (2007: 2,5)	
9	United Kingdom	3,5 (2007: 3,8)	
10	Austria	2,5 (2007: 2,1)	
11	Sweden	1,7 (2007: 1,4)	
12	Netherlands	1,6 (2007: 1,6)	
13	Bulgaria	1,3 (2007: 0,1)	
14	Slovenia	1,1 (2007: 0,6)	
15	Poland	1 (2007: 0,2)	
16	Cyprus	0,8 (2007: 0,3)	
17	Finland	0,5 (2007: 0,5)	
18	Luxembourg	0,5 (2007: 0,2)	
19	Romania	0,2 (2007: 0,1)	
20	Malta	0,1 (2007: 0,1)	
21	Denmark	0,1 (2007: 0,1)	
22	Hungary	0,1 (2007: 0,1)	
23	Slovakia	0,1 (2007: 0,1)	
24	Lithuania	0,1 (2007: 0,1)	
25	Estonia	0,1 (2007: 0,1)	
26	Ireland	0 (2007: 0)	
27	Latvia	0 (2007: 0)	
	Total EU	4592,3 (2007: 1825,6)	

Source: Collected and Compiled by Europe's Energy Portal [2]

Development of photovoltaic has boosted in the last few years, but the praxis differs from country to country. Largest investments were done in Spain because of favourable regulatory environment, stimulations with subsidized price and additional subventions. And while other European countries (even less sun exposed Germany) have already got relevant experiences with building and financing solar systems, in Slovenia we are still at the beginning [3].

2.1. Threats for banks

As Bole [3] explains, banks meet new, non-tested technologies and original assessing of these projects. They are quite different from classical approach of banks to estimate projects. Majority of these investments have namely a structure of projects financing and they are performed outside balance-shits of interested investors or sponsors. Key questions which encounter banks are: type and verification level of used technology; micro-location – geographical position, sunny day per year and the condition of real estate; price and feed-in tariff, important for the risk of demand; investor's financial strengths and condition, experience from the field.

2.2. Financial Sustainability

Photovoltaic programs should be operated as businesses. They should generate revenues sufficient to recover capital investment, service debt, pay for administrative and support services, cover payment defaults and, in the case of for-profit operations, provide satisfactory returns for investors [4]. Market support mechanisms are required to stimulate the deployment of most renewable energy technologies becoming already competitive with existing energy technology options for off-grid areas.

Historically the promotion of renewable energy technologies (RET) in isolated areas has involved international donors or government subsidising the initial capacity investment. Instead, the renewable electricity generation support scheme, the feed-in tariff (FiT) combined with financial schemes, has been a successful mechanism to increase the deployment of renewables in the country's electricity grid [5].

2.3. Partnership between State and Industry

Photovoltaics are a global business today, and all the big companies are engaged worldwide. On the other hand, governments want companies to be involved in their national programs. This is successful in some countries but difficult in others. Besides today's real market development programs in Japan, Germany and a few other countries, the R&D budgets offered from the beginning some special market in the field of demonstration and test installations.

It should be pointed out that the market of demonstration systems is extremely important for the industry, not only because of its size. The main advantage is that it is the only possibility to test new products, to demonstrate the reliability of PV, and to be a showcase for future customers [6].

3. SLOVENIAN MANUFACTURER OF PV POWER PLANTS

BISOL is a worldwide customer oriented company with rich international experience in manufacturing the core elements of solar power plants - premium quality crystalline silicon photovoltaic modules. BISOL accelerates technological innovations by industry led research and development of photovoltaic technology offering outstanding long-term performance. BISOL provides solutions that demonstrate cost effectiveness, added value, and go beyond the business-as-usual scenario.

Setting the highest quality standards is BISOL's main objective. Headquartered in Slovenia, BISOL positions itself predominantly in diverse international markets, where it supports its activities with representative offices in Belgium, France and Italy. The strategy of BISOL is sustainable growth of the company and production cost reduction as a main photovoltaic industry driver. BISOL produces high quality mono- and multicrystalline silicon photovoltaic modules designed for both commercial and residential applications suitable for grid connected and stand-alone systems.

For the reason of highly advanced product design and production properties, BISOL photovoltaic modules exhibit the highest energy yield recorded in low as well as in high irradiation areas. High kWh/kWp performance originates from [7]:

- Very high shunt resistance for improved performance at low irradiation and very low series resistance for improved performance at high irradiation,
- Pre-sorting according to P(MMP) and I(MPP) leveraging out module mismatch losses,
- Lowest NOCT of just 44°C (due to negative γ of solar cells every additional °C reduces energy yield by 0.43 %),
- EVA foil with negligible Yellowing Index (due to degradation proceses EVA foil gradually turns from transparent to yellow colour reducing the amount of incident light),
- High EVA gel content contributes to low NOCT and outstanding long-term performance,
- Lowest module capacitance *C* for highly repeatable *I-V* curve and lowest mismatch losses,

- Whole spectrum highly transparent glass,
- TÜV approved lowest 20 years equivalent degradation of just 0.5 % out of allowed 5.0 %.

In Slovenia we have a manufacturer that produces high quality mono- and multicrystalline silicon photovoltaic modules designed for both commercial and residential applications suitable for grid connected and stand-alone systems. BISOL was one of the first companies worldwide to successfully implement three bus-bar and back-contact solar cells into photovoltaic modules.

They exist since 2006, in year 2009 they generated 27 millions Euro, in 2010 they expect to earn 50 millions. In April 2010 they stipulated a contract for 7 millions worth electric plant with 2.5 MWp in Check Republic. German's journal Photon research said, their systems have the best energy yield, recorded in low as well as in high irradiation areas, when assessing 31 systems from all over the world.

BISOL gives 10 year product warranty, 12 years warranty on 90 % output and 25 years warranty on 80 % output. In July 2010 Slovenian PV modules manufacturer BISOL solemnly opened the biggest rooftop solar power plant in Slovenia together with the investor Keter Invest. The biggest rooftop PV system in Slovenia with a power of 998 kW was installed with BISOL PV modules in Maribor. Estimated yearly energy production is 1200 MWh. Its main feature is special aerodynamic construction which was developed by BISOL itself.

Construction, on which the modules are attached, is placed on the roof without penetrations in it or any additional fitting. Its aerodynamic design enables extreme stability even in a strongest wind. Photovoltaic modules manufactured by BISOL are result of intensive research and development efforts done by highly skilled personnel who possess comprehensive professional know-how. Premium quality PV modules are engineered in-house and manufactured within a state-of-the-art automated production environment delivering the highest power output and energy yield. Investor Keter Invest is actively involved in renewable energy project. They are very much aware of the energy industry gaining an increasing importance in the economy and represents at the same time on of the main development axis. BISOL was chosen due to the highest quality PV modules.

Due to the long-term highly profitable return on investment of the photovoltaic power plants, energy yield and long-term performance are far more important for the profitability of the power plants than the initial cost of the investment. Their reference built power plants can be found from Spain, Germany, Italy, Slovakia, Slovenia, France and Belgium, up to 1 MWp. Together with Seaway they developed an innovative hybrid boat and built many systems for individual houses and public institutions.

4. PV INVESTMENT IN SLOVENIA

Government of Slovenia has just approved the national action plan for renewable energy sources that had to be sent to the European Commission until June 30th. Experts from the Institute of Milan Vidmar are questioning plan's practical usefulness for Slovenia's actual fulfillment of given obligations, if we are assessing real circumstances in Slovene energetic. Plan is oriented toward planned goal of 25 percent share of renewable energy in the final consumption until 2020, but there is no economic assessment and precise presentation of wanted development.

Biggest problems could arise in the area of financing the investments and placing the objects in space. Renewable sources are financed from the contribution for assurance of RES electrical energy subsidies. Based on scenario of building RES up to day, this subsidy would more than double until 2020. In 2010 we will collect 70 mio €, in 2020 there would be the need for 150 mio €. For an average household this means 1.5 € per month, in the year 2020 it would represent about 4 €.

With the price of 75 € per MWh all other RES systems besides huge hydro plants are noncompetitive, so they have to be subsidized. Subsidies for most of RES are between 100 and 200 € per MWh, PV is strongly stepping out with over 400 € per MWh. And PV systems are the most invested in the last time; in 2009 there were built 174 electricity producing systems, 156 were PV plants [8].

5. CONCLUSIONS

Indisputable fact is that an investment in a PV plant is not economical at this state of technology. There are some benefits offered from governments, together with guaranteed price of produced PV electricity and for the production of electricity in remote areas. But the sun represents unlimited source of energy and the share of this source will be further increasing with improved technologies and sinking costs of investment.

Feasibility studies for similar projects clearly show that investments are not feasible or economically rentable without the support of the government, with guaranteed feed-in tariff (mostly because of high investment costs). With the increase of solar solutions and equipment providers costs are sinking, but it is still far away until the break through point, where the investment would be economically acceptable without the help of the government.

We have to keep in mind that we are dealing with long term investments, bringing small yields on longer time period of 30 years [Bole]. From the view of financing the investment is sensible only if we can secure long term financing, at least for the time of 15 years. Financial crisis, lack of long term sources and risk management in banks will not stimulate investors to bite in this green apple.

As Holm [9] says, governments have a longer planning horizon than individuals and commercial interests. Their policies are – or should be – built on long-term future visions. Their own investments in buildings and other acquisitions should consequently reflect this perspective, based on least life cycle cost calculations, including the full externality costs.

The evolution of new energy technologies and systems cannot follow the compartmentalised model that has worked so well in the past, because of the time constraints imposed by oil depletion and climate change. All parts of the new energy economy are strongly interlinked, and researchers in the field must be aware of the entire enterprise to maximize their own contribution.

As Girona [5] stated, although capital costs of renewable energy projects are much higher than a conventional genset, the fact to have low operation and maintenance costs together with the support of the RPT financial scheme, helps to offset the large capital costs associated with RET. The determination of an optimal set-up of the business model among various conditions plays an important role in the implementation of the RPT financial mechanism.

In order to identify under which renewable electricity purchase values make the renewable energy mini-grid most financially viable, a cost-benefit analysis is carried out calculating the net present value (NPV) and Internal Rate of Return (IRR) for each of the renewable electricity purchase values (€RPT from 0.1 €/kWh to 0.6€/kWh), using the cost and revenue streams over a 20-year period. The cost-benefit analysis determines the minimum renewable electricity purchase values that make the project financially viable (an NPV above zero). However, higher renewable electricity purchase values are generally more viable, delivering the best value for money over the period.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

ANALIZA STRUJANJA U KASKADNOM PROSTORU USMJERIVAČKIH LOPATICA VODNIH TURBINE FRANCIS

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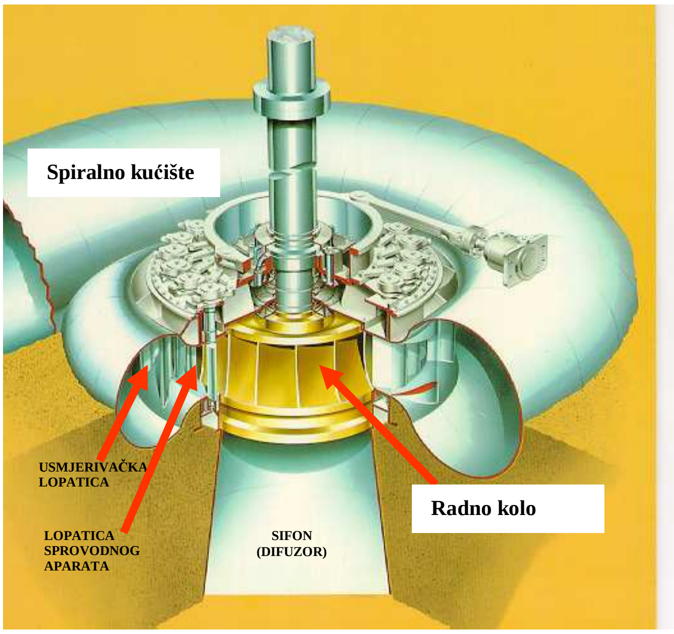
SAŽETAK
Rad predstavlja doprinos razumjevanju dvodimenzionalnog strujanja u kompleksnim geomterijskim oblicima kao što je kaskadni prostor vodnih turbina i doprinos budućem razvoju alata i metoda baziranih na numeričkim metodama u procesima modernizacije hidroelektrana kao obnovljivih izvora energije. Bez obzira što su moderne hidroelektrane napravljene sa velikim koeficijentom iskorištenja, industrijski interes ovog istraživanja leži u činjenici da se u procesima modifikacije i rehabilitacije postojećih hidroelektrana može ostvariti znatan ekonomski profit.
Ključne riječi: Numerička dinamika fluida, CFD, metod konačnih volumena, vodne turbine, Francis turbina, usmjerivačke lopatice, lopatice sprovodnog aparata, brzina, polje brzina

1. UVOD

Instalisana snaga i proizvodnja pojedine hidroelektrane zavisi od neto pada, protoka i koeficijenta iskorištenja ili efikasnosti. Neto pad je fiksna i teško promjenjiva varijabla, protok se u procesima rekonstrukcije može povećavati, ali to često nije opravdano. Koeficijent iskorištenja ostaje kao varijabla koja se kod rekonstrukcija raznim tehničkim rješenjima može povećavati do određene granice.

2. ANALIZA STRUJANJA U FRANCISOVOJ TURBINI

Francisova turbina koje je tretirana u ovom radu je turbina radijalno-aksijalnog tipa. Voda iz tlačne cijevi dolazi u spiralno kućište turbine (Slika 1), koje služi da vodi nametne obodnu komponentu brzine i da ravnomjerno rasporedi količinu vode po čitavom obimu. Voda iz spiralnog kućišta dolazi na usmjerivačke lopatice koje su fiksirane na spiralu i imaju ulogu da pravilno usmjere vodu na lopatice sprovodnog aparata te na radno kolo turbine. Lopatice sprovodnog aparata su regulacione lopatice koje regulišu protok kroz turbinu i snagu turbine. Na radnom kolu se vrši pretvorba energije vode u kinetičku energiju, odnosno obrtni moment, koji se dalje prenosi preko osovine na generator. Poslije prolaska kroz međulopatične kanale radnog kola voda odlazi u difuzor i dalje u odvodne kanale. Uloga difuzora je da pri datoj izlaznoj brzini iz radnog kola smanji pritisak te time smanji gubitke na izlazu iz radnog kola.

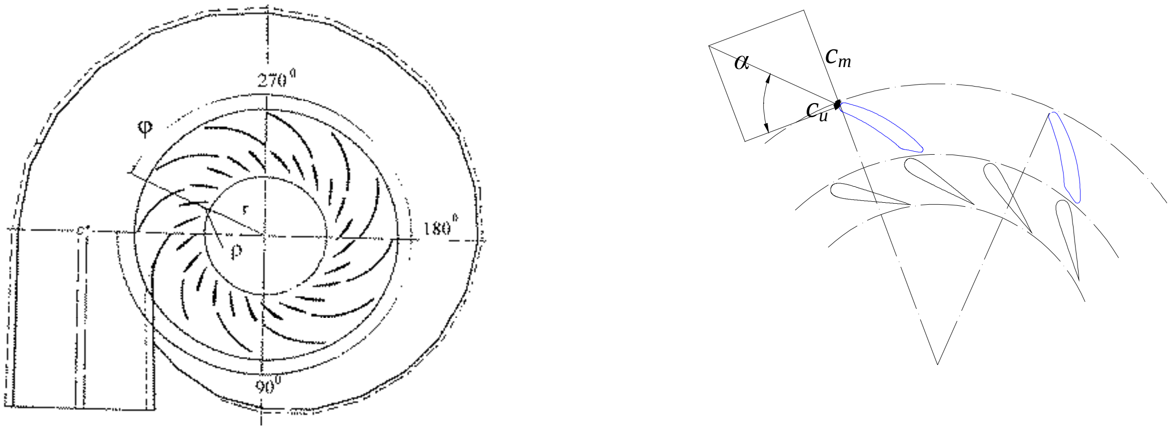


Slika 1. Presjek kroz Francisovu turbinu

2.1 Strujanje u kaskadnom sistemu

Brzina strujanja na nekom radijusu spirale r može se rastaviti na obodnu komponentu c_u i meridionalnu komponentu c_m. Brzina na ulaznom dijelu usmjerivačkih lopatica takođe se može rastaviti na pomenute dvije komponente. Ulazni ugao vode na usmjerivačke lopatice je:

$$\alpha_i = a\tan\left(\frac{c_m}{c_u}\right) \qquad \ldots(1)$$

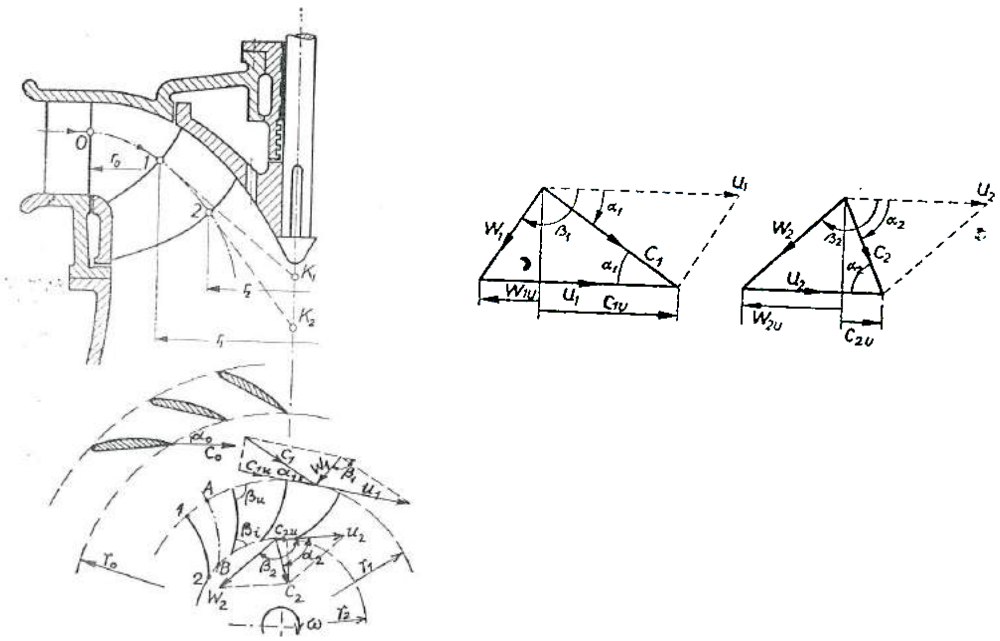


Slika 2. Kaskadni sistem(lijevo) i komponente brzine na ulaznoj strani usmjerivačkih lopatica(desno)

Poslije prolaska kroz prostor usmjerivačkih lopatica fluid dolazi u zonu lopatica sprovodnog aparata Fluid izlazi iz prostora lopatica sprovodnog aparata apsolutnom brzinom c_0, usmjeren lopaticama pod uglom α_0 prema tangenti na obod. Elemenat fluida prošavši kroz međulopatični prostor ulazi u radno kolo apsolutnom brzinom koja neposredno pred ulazom u radno kolo ima vrijednost c_1, a usmjerena je prema obodnoj brzini pod uglom α_1. Pretpostavlja se da fluid prolazi bez trenja prostor između izlaza sa lopatica sprovodnog aparata i ulaza na lopatice radnog kola turbine i zbog toga fluid zadržava nepromijenjen obrtni moment. To znači da je $r \cdot u$ konstantno, a odnos između komponenti rc_{ou} i rc_{1u} postaje:

$$c_{1u} = c_{0u}\,\frac{r_0}{r_1} \qquad ...(2)$$

gdje je r_0 radius izlazne ivice lopatica sprovodnog aparata, r_1 radius ulaza radnog kola.
Radijalna komponenta brzine na ulazu u radno kolo koja odgovara radiusu r_1 je $u_1 = r_1\omega$. Ovim su definisane apsolutna brzina c_1 i radijalna brzina u_1. Relativnu brzinu w_1 određujemo konstrukcijom pomoću paralelograma brzina. Na taj način definisan je tzv. ulazni trougao brzina. Na izlazu iz rotora elemenat fluida ima relativnu brzinu w_2, a budući da elemenat fluida usljed rotacije kola ima još i radijalnu komponentu u_2, njegova apsolutna brzina na izlazu c_2, rezultanta je brzina w_2 i u_2. Time je definisan izlazni trougao brzina.



Slika 3. Trouglovi brzina na ulazu i zlazu iz radnog kola (lijevo) i putanje i brzine tačaka fluida u kaskadnom sistemu (desno)

Da bi se upotpunio ovaj dio teorije oko strujanja u pojedinim dijelovima turbine, potrebno je dati osnovnu jednačinu turbomašina, poznatu kao Eulerova jednačina:

$$\eta_h \cdot H_n = \frac{1}{g}(u_1 c_{1u} - u_2 c_{2u}) \qquad ..(3)$$

gdje su H_n neto pad i η_h hidraulički stepen djelovanja
Protok je definisan izrazom:

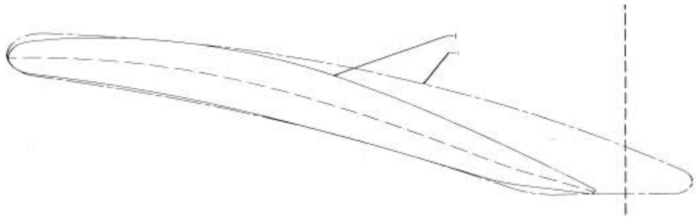
$$Q = f\,(b_0, \alpha_0, \beta_2) \qquad ...(4)$$

Promjena protoka pri konstantnom padu i broju obrtaja može biti izvršena promjenom nekog od sljedećih parametara: (i) visina lopatica sprovodnog aparata b_0, (ii) ugao toka vode na izlazu iz sprovodnog aparata α_0 i (iii) ugao toka vode na izlazu iz radnog kola β_2.
Za regulaciju protoka potrebno je variranje parametra A_0 . Ova regulacija uzrokuje promjene u pravcu vektora apsolutne brzine te se i trougao brzina se mijenja. Varijacije ugaone brzine i protoka,uključuju i promjene po pravcu i intenzitetu vektora relativne brzine w_1 . Relativna brzina w_2 varira u zavisnosti od protoka. Razlika $(u_1c_{1u} - u_2c_{2u})$ a time i snaga turbine zavisi od ovih promjena. Najefikasniji slučaj

sa stanovišta snage dobio bi se kada bi se relativna brzina w_1 podudarala sa uglom lopatice β_1 na ulazu u radno kolo, a time bi brzina c_{2u} bila približno jednaka nuli. Prema tome hidraulički zakon svih reakcionih turbina je zasnovan na broju okretaja *n*, protoku *Q* i neto padu H_n.

3. OPIS ANALIZIRANOG SLUČAJA

U radu je analizirano strujanja u kaskadnom prostoru turbine broj 4 Hidroelektrane Jablanica i to prije i poslije preoblikovanja usmjerivačkih lopatica i zamjene lopatica sprovodnog aparata. Kao eksperimentalni podati korišteni su egzaktni podatci dobiveni mjerenjima na agregatu broj 4 HE Jablanica prije i poslije preoblikovanja lopatica. Prilikom rekonstrukcije agregata broj 4 HE Jablanica dobivena je veća snaga agregata. Veća snaga agregata dobijena je na račun većeg koeficijenta iskorištenja radnog kola i većeg protoka vode kroz turbinu. U toku projekta rekonstrukcije konstrukcija nekih dijelova turbine je promjenjena u konačnosti dok su drugi dijelovi preoblikovani (npr. usmjerivačke lopatice).

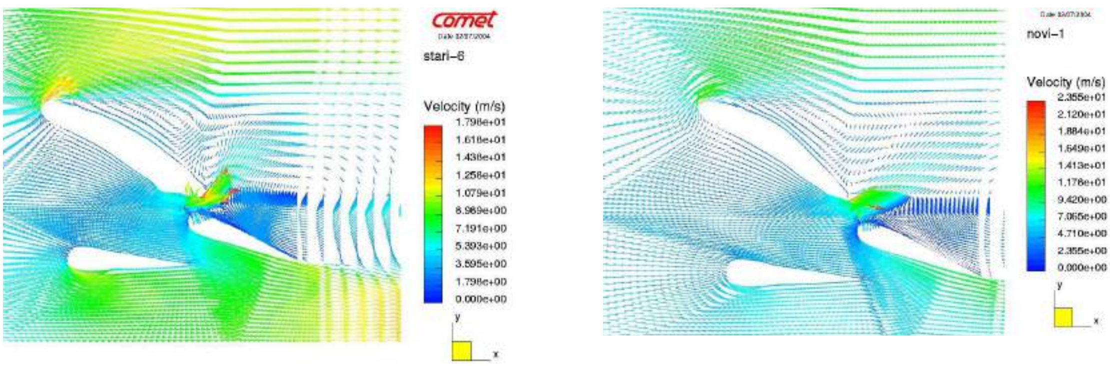


Slika 4. Profil usmjerivačkih lopatica: stari profil (isprekidana linija); novi profil (puna linija)

4. NUMERIČKA ANALIZA STRUJANJA

Za analizu i simulaciju strujanja korišten je metod konačnih volumena i programski paket COMET (Continuum Mechanic Engineering Tool) razvijen na ICCM (Institute for Computational Continuum Mechanic), Hamburg, Germany. COMET je pisan u standardnom C i FORTRAN 77 programskom jeziku Izvršena je analiza strujanja u kasakadnom prostoru usmjerivačka lopatica–lopatice sprovodnog aparata Francis turbine broj 4 Hidroelektrane Jablanica za više različitih realnih slučajeva. U radu su prezentirana dva i to:

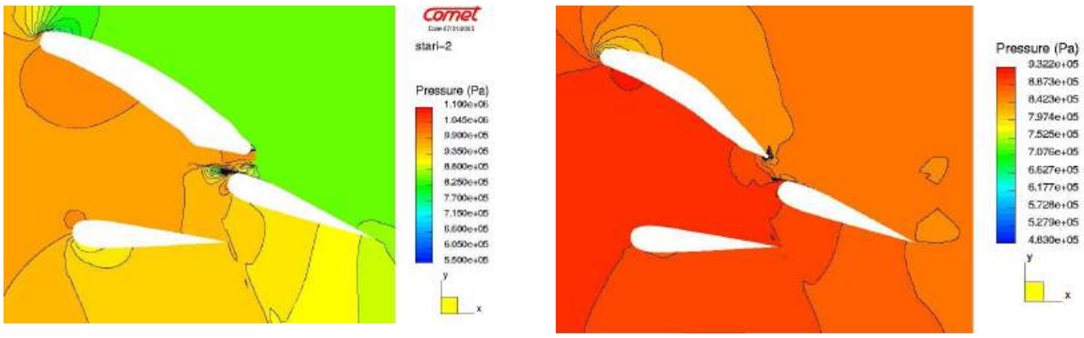
(1) za stari i novi profil usmjerivačke lopatice, neto pad 99 m i protok od 20,7 m^3/s,
(2) za stari i novi profil usmjerivačke lopatice, neto pad 99 m i protok od 34,5 m^3/s,



Slika5. Polje brzina za stari profil (lijevo) i polje brzina za novi profil (desno)-Slučaj (1)

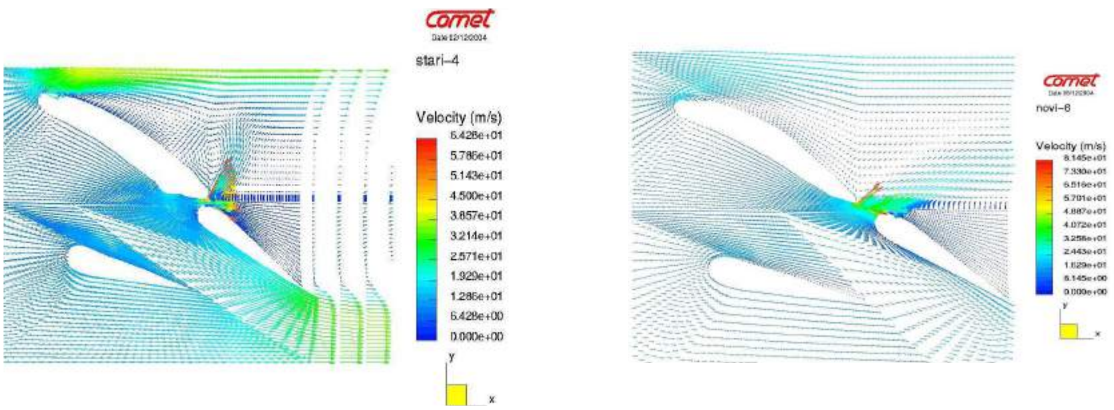
Prvi slučaj koji je analiziran kao kaskadni sistem sa jednom usmjerivačkom i dvije lopatice sprovodnog aparata je otvor sprovodnog aparata od 121 mm, neto pad 99 m i protok 20,7 m^3/s.
Slika 5 prikazuju polja brzina za stari novi profil. Na izlaznoj ivici usmjerivačke lopatice (stari profil) uočava se formiranje zone vrtloga sa povećanim vrijednostima brzina. Takva zona postoji i kod usmjerivačke lopatice novog profila ali znatno manjeg intenziteta. Zona vrtloženja može se vidjeti i na ulaznoj ivici starog profila, dok kod novog profila ne postoji. Takođe na „usisnoj" strani stare usmjerivačke lopatice vrtlozi su većeg intenziteta od vrtloga na novoj usmjerivačkoj lopatici.

Na izlaznoj ivici lopatica sprovodnog aparata može se uočiti značajna razlika polja brzina kao i polja pritisaka. Polje kod novog profila usmjerivačke lopatice je više jednolično bez vrtloga na samoj izlaznoj ivici lopatice sprovodnog aparata. Polje brzina kod starog profila usmjerivačke lopatice je više nestacionarno sa pojavom većeg broja vrtloga. Vrtlog se pojavljuje čak i na izlaznoj ivici lopatice sprovodnog aparata što ima direktan uticaj na profil brzina na ulazu u radno kolo a time i na hidraulički stepen djelovanja.



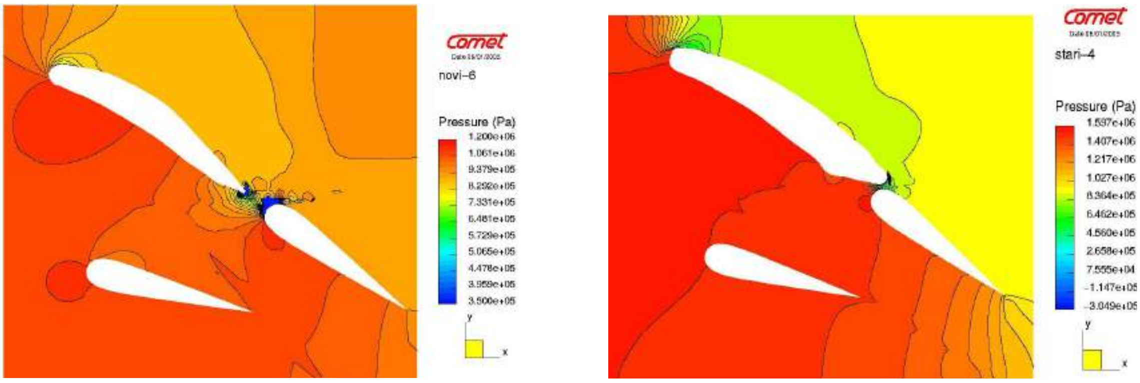
Slika 6. Polje pritisaka za stari profil (lijevo) i polje pritisaka za novi profil (desno)- Slučaj (1)

Slika 6 prikazuju polja pritisaka za stari i novi profil. Analizirajući ove rezultate kao i same razlike između polja uočavamo da kod starog profila usmjerivačke lopatice postoji više različitih izobara, tj. egzistira više različitih nivoa pritisaka. Ove razlike su naročito izraženu u prostoru oko lopatica sprovodnog aparata. U slučaju kod novog profila usmjerivačke lopatice polje pritisaka je znatno konstantnije, pogotovo na izlaznim ivicama lopatica sprovodnog aparata.



Slika 7. Polje brzina za stara profil (lijevo) i polje brzina za novi profil (desno)- Slučaj (2)

Sljedeći slučaj koji je analiziran kao kaskadni sistem sa jednom usmjerivačkom i dvije lopatice sprovodnog aparata je otvor sprovodnog aparata 202 mm, neto pad 99 m i protok 34,5 m^3/s.
Na slici 7 prikazana su polja brzina. Posmatrajući samo usmjerivačke lopatice uočava se formiranje zone sa povećanim vrijednostima brzina na izlaznoj ivici lopatice (stari profil). Takva zona postoji i kod usmjerivačke lopatice novog profila, gdje je po pravcu ,,skretanje" manje. Na ,,usisnoj" strani stare usmjerivačke lopatice vrtlozi su većeg intenziteta od vrtloga na novoj usmjerivačkoj lopatici. Na izlaznim ivicama lopatica sprovodnog aparata kod starog profila usmjerivačke lopatice primjećuje se veće skretanje toka dok kod novog profila usmjerivačke lopatice tok više slijedi pravac lopatice sprovodnog aparata. Polje brzina na izlaznim ivicama lopatica sprovodnog aparata je znatno jednoličnije sa usmjerivačkom lopaticom novog profila u odnosu na drugi slučaj.



Slika 8. Polje pritisaka za stari profil (lijevo) i polje pritisaka za novi profil (desno)- Slučaj (2)

Na slici 8 prikazana su polja pritisaka. Sa slika se može vidjeti da je unutrašnja strana usmjerivačke lopatice starog profila znatno više opterećena od one novog profila. Istovremeno je pritisak na vanjskoj strani lopatice starog profila niži u odnosu na pritisak na vanjskoj strani usmjerivačke lopatice novog profila. Ovaj slučaj uzrokuje veće skretanje toka na izlaznoj ivici usmjerivačke lopatice starog profila, što se vidi iz polja brzina.Na izlaznim ivicama usmjerivačkih lopatica, u slučaju sa novim profilom usmjerivačke lopatice polje pritisaka je dosta izjednačeno, dok u slučaju sa starim profilom usmjerivačke lopatice postoji više zona sa različitim vrijednostima pritisaka. Pri istom protoku i sa istom geometrijom lopatica sprovodnog aparata a za različite geometrije usmjerivačke lopatice dobivaju se povoljnije uslovi ulaza fluida u radno kolo sa novim profilom usmjerivačke lopatice.

5. ZAKLJUČAK

U okviru ovog rada izvršena je analiza problema opstrujavanja fluida oko profila usmjerivačkih lopatica i lopatica sprovodnog aparata. Posmatran je dvodimenzionalni slučaj. Rad predstavlja doprinos razumjevanju dvodimenzioanlnog strujanja u kompleksnim geometrijskim oblicima kao što je kaskadni prostor vodnih turbina i doprinos budućem razvoju alata i metoda baziranih na numeričkim metodama u procesima modernizacije hidroelektrana kao obnovljivih izvora energije. Numeričkim simulacijama dobijeno je mnoštvo podataka koje ne možemo dobiti standardnim eksperimentalnim ispitivanjima, a koje imaju veliku važnost za razumijevanje strujanja u kaskadnom prostoru vodnih turbina. Kao rezultat analize dobivena su polja brzina i polja pritiska za sve ispitivane slučajeve. Iz pregleda rezultata može se vidjeti da geometrija profila usmjerivačkih lopatica ima jak uticaj na polje brzina oko lopatica sprovodnog aparata, a samim tim i na profil brzina na ulasku u radno kolo. Može se zaključiti da se rekonstrukcijom tj. preoblikovanjem usmjerivačkih lopatica znatno smanjuje intenzitet vrtloženja a time su smanjeni i hidraulični gubitci turbine.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

MOGUĆNOSTI KLASTERSKE PROIZVODNJE OPREME ZA OBNOVLJIVE IZVORE ENERGIJE

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ABSTRACT
Radom su prikazani rezultati kapaciteta energije vjetra i energije sunčevog zračenja na području BiH. Kroz projekat FP-6 finansiran od EU u periodu 2006-2010. prikupljeni su rezultati isztraživanja Federalnog hidrometrološkog zavoda za povratni period od 50 godina, te rezultati istraživanja Centra za obnovljive izvore energije Mostar za period 2000 - 2010.
Rezultati istraživanja su obrađeni na METEO Institutu u Švicarskoj i DEWI Institutu u Njemačkoj i prezentirani javnosti kroz Atlas vjetrova u BiH i Atlas sunčevohog zračenja u BiH.
Donošenjem pravne regulative, maj 2010., za obnovljive izvore energije u FBiH otklonjena je prepreka investicionim procesima i transferu kapitala i tehnologija u sektoru obnovljivih izvora energije. Radom su prikazane mogućnosti uključivanja domaće industrije u realizaciji projekata u sferi korištenja energije vjetra i energije sunčevog zračenja.
Putem privredne komore FBiH Federalnog ministarstva razvoja, malog i srednjeg poduzetništva pokrenut je proces stvaranja baze podataka o karakteristikama institucija i privrednih subjekata u oblasti razvoja i proizvodnje opreme u ovom sektoru.
Ključne riječi: energija vjetra, energija sunčevog zgračenja, razvoj, klasterska proizvodnja

1.UVOD

Istraživanja karakteristika vjetra i sunčevog zračenja kroz meterološku službu u BiH realiziraju se već 125 godina. Metode im oprema za istraživanje bile su primjerene tehničkim mogućnostima u vremenima istraživanja. Buran razvoj i implementacija opreme u EU u oblasti obnovljivih izvora energije, pokrenuo je 2000. godine istraživanja karakteristika vjetra i sunčevog zračenja u BiH. Kroz konzorcij koga su sačinjavali Federalni meterološki zavod BiH (FHMZ) i Univerzitet Džemal Bijedić, na principima i tehničkoj regulativi EU za kompleksne terene, 2000 godine počela su istraživanja karakteristika vjetra za korištenje u energetske svrhe. Uvođenjem partnera iz Austrije 2003 (Vjetroenergetika - Windkraft) i Slovenije 2005. (Energy 3) stvorena je solidna tehnička struktura za pokrivanje 12 interesantnih mikrolokacija. Izraženi interes za energiju vjetra realizirala je i EPHZ-HB već od 2004. sa istraživačkim kapacitetom na 13 mikrolokacija.
Kroz projekat FP-6 koji je ostvario Konzorcij sa DEWI Institutom, te METEO Institutom educirano je 35 istraživača iz BiH i regije Balkana, o metodama istraživanja karakteristika vjetra i projektovanja farmi vjetroelektrana na kompleksnim terenima. Kroz isti projekat FHMZ je arhivske baze podataka od 1956. do 2008., definisane grafički u svim stacionarnim meterološkim stanicama, modelirao u 10 - minutnu vremensku formu u digitalnoj verziji.

Rezultati istraživanja na mobilnim meteo stanicama u Hercegovini (25 jedinica) i stabilnim meteroloških stanicama u BiH, obrađene su u Švicarskoj te je dobijena karta vjetrova u BiH u prostornoj rezoluciji 3x3 km. Nakon prezentiranja rezultata istraživanja akademskoj i privrednoj javnosti BiH u periodu poslije 2008. godine veliki interes o istraživanju izrazile su mnoge male kompanije pa i javna preduzeća EP BiH i EPRS. Trenutno je područje BiH pokriveno sa 48 mjernih stanica čime se u budućnosti u periodu od 3 do 5 godina stvaraju uslovi za izradu Atlasa vjetrova po kriterijima RISO Instituta iz Danske, te uključivanje u BiH u Atlas vjetrova EU (rezolucije 1x1 km).
Kroz incijativu Centra za obnovljive izvore energije od 2005 u Mostaru proizlašlog iz Konzorcija, Ministarstvo za energiju, rudarstvo i industriju FBiH je u maju 2010. donijelo Uredbu o korištenju obnovljivih izvora energije, što već sada otvara mogućnost implementacije istraživačkih tradova. Novi Zakon o električnoj energiju u F BiH i RS sa podzakonskim aktima kiji se očekuju do početka 2011. godine mora biti potpuno usklađen sa normama u EU, konačno će pravno i tehnički u potpunosti regulisati ovu oblast. Istraživanja energije sunčevog zračenja oslonjeno je na baze podataka FHMZ I MZRS, te djelimično na mjerne stanice Centra za obnovljive uzvore energije Mostar.

2. REZULTATI ISTRAŽIVANJA I MOGUĆA IMPLEMENTACIJA

Tehnički kriteriji istraživanja vjetropotencijala i projektovanja farmi vjetroelektrana (VE), za kompleksne terene koje prihvataju razvojne banke u EU već su ispunjeni za slijedeće lokacije (Tabela 1).

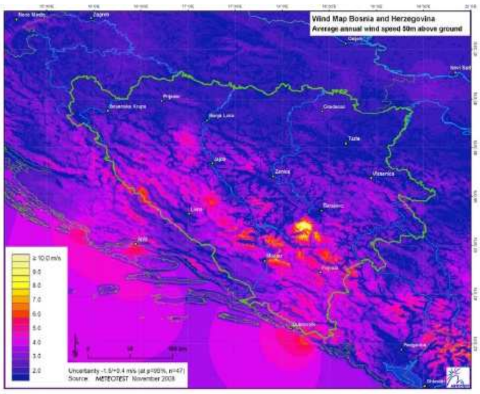
Tabela 1. Farme vjetroelektrana [3]

Lokacija	NosiocI aktivnosti	Instalisana snaga (MW)	Energetska efikasnost (%)	Vrijeme implementacije
Merdžan glava	Energy 3	6	26	2011/12
Poljica	Energy 3	24	29	2011/12
Mali grad	Vjetroenegetika EP BiH	30	29	2014
Sveta gora	Vjetroenegetika EP BiH	16	28	2014
Mesihovina	EP HZ-HB	44	29	2011/12
Jastrebinka – Velika Vlajna	EP HZ - HB	32	30	2014
Debelo Brdo	EP HZ - HB	68	32	2013
Trusina	Vjetroenergetika EOL DRUGI	86	28	2013
Borova Glava	EP HZ-HB	52	30	2014
Pločno	Energy 3	34	32	2013
Bahtijevica	Impro - Impex	36	29	2016
UKUPNO		428		

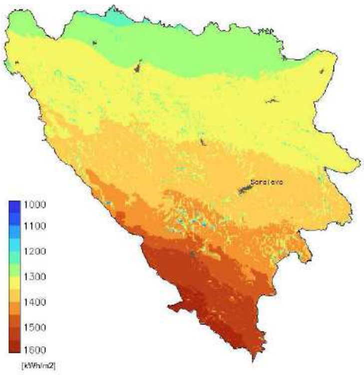
Preliminarni rezultati istraživanja u BiH koji će zadovoljiti kriterije EU, okončat će se do 2013., uz grubu procjenu mogućnosti instalisanja 1200 MW sa koeficijentom energetskog iskorištenja od 26 –32 %, sa mogućnošću priključka u energetski sistem od 35,110, 220 kV.
Pored ovih sistema u sistemu malih vjetroelektrana na naponskom nivou 0,4 i 10 kV moguće je instalisati 60 do 100 MW. U ovisnosti od potreba lokalnih zajednica u ruralnim područjima BiH, prostornih i energetskih mogućnosti sistem malih VE činile bi VE snage 5do 250 Kv. Kapaciteti energije sunčevog zračenja u svokja oba oblika, termalni i fotonaponski, veoma su interesantni zbog stimulativnih tarifnh pravila za male investitore.

U narednom periodu se očekuju veliki investicioni zahvati na objektima javnih ustanova, hotelskih kompleksa, stambene gradnje i privrednih objekata sa instalisanim kapacitetima u fotonaponskoj verziji od 5 do 155 kW. Novi sistemi fotonaponskih panela sa $\eta \approx 25$ % i pad tržišnih cijena sa 5 na 3

Eura po watu već sada stimulišu instalisanja ove opreme u području Hercegovine, Dalmacije i Crne Gore (područja 1600 – 1800 kWh/god sunčevog zračenja.



Slika 1. Karta vjetrova BiH



Slika 2. Atlas sunčevog zračenja BiH

3.USLOVI ZA PRIHVAT NOVIH TEHNOLOGIJA U INDUSTRIJSKI KOMPLEKS BIH

Područje BiH je u energetskom smislu veoma bogato neiskorištenim resursima za proizvodnju električne i toplotne energije. Procijenjeni resursi obnovljivih izvora po [1] i [2] su navedene u tabeli 2.:

Tabela 2.

Tip opreme	Kapacitet [MW]	Proizvodnja [GWh]
Vjetroelektrane	1300	2925
Male hidroelektrane	1000	1430
Biološka masa	7.10^6 m^3, $3{,}9.10^3$ t uljarica	33518 PJ
Energija sunčevog zračenja u fotovoltik tehnologiji	1000 000 m^2	225

Velika zasićenost prostora u EU sa opremom vjetroelektrana uz izrazito značajnu proizvodnju opreme od 59,7 % svjetske proizvodnje u 2008. godini već 2012. godini širit će plasman proizvoda prema zemljama Balkana, Turske, Baltičkog mora, Magreba i Kine. Procesi istraživanja karakteristika vjetra u bIh, Hrvatskoj, Rumuniji i Turskoj su znatno razvijeni, pa će ta područja biti veoma interesantna za buduće investicije. Da bi se domaća industrija mogla uključiti u ove procese neophodne su brze i kvalitetne aktivnosti države i njenih institucija u svim oblastima i to:

- Izrada strategije razvoja energetike i njene sinhronizacije po entitetima do 20011
- Izrada novih zakona o energetici, shodno EU direktivama u entitetima do 2011.
- Izrada tehničkih propisa i standarda po EU normama do 2011.
- Konačno definisanje realnih investicionh radova u energetici i transportu iste do 2011(plin i električna energija)
- Izrada projekata infrastrukture u energetici, saobraćaju, razvoju industrije, obrazovanju do 2012.
- Restitucija i privatizacija proizvodnih sistema koji mogu zbog svojih kapaciteta biti interesantni za proizvodnju opreme u oblasti obnovljivih izvora energije do 2013. Revizija privatizacijskih procesa kod neuspješnih firmi.
- Otpočeti realizirati aktivnosti u društvu i privredi zacrtane Studijama razvoja i industrije u F BiH (usvojena 2010.) i Studijama razvoja malog i srednjeg poduzetništva (usvojena 2010.), te indentičnim normativima u RS do 2011.
- Realizirati zakonske podloge za intenzivniju saradnju privrednika iz BiH sa privrednicima iz zemalja Balkana i EU do 2012.
- Formirati agenciju pri Vijeću ministara, sa jakom kadrovskom strukturom i u Briselu, za promociju BiH projekata iz pristupnih fondova EU do 2011.

- «Giljotinom» propisa na kantonalnim i općinskim nivoima skratiti procedure uvođenja investitora u privredne aktivnosti do 2011.
- Antikorupcionim aktivnostima korupciju u administraciji i javnim institucijama svesti na prihvatljiv nivo do 2012.
- Izvršiti reformu poreznog sistema u cilju rasterećivanja privrdno – proizvodnih aktivnosti na približan nivo u zemljama okruženja do 2012/13.
- Ojačati fondove razvojnih banaka u FBiH i RS a kriterije raspodjele uskladiti sa razvojnim programima entiteta i države do konca 2011.

4. ZAKLJUČCI

Na bazi eksperimentalnih istraživanja u oblasti energije sunca, vjetra, malih hidrotokova i otpadne biomase, svih istraživačko-razvojnih organizacija u BiH za period do 2010. može se zaključiti slijedeće:

- prirodne mogućnosti BiH za korištenje obnovljivih izvora energije su značajne, pa će investicioni ciklus u iste biti intenzivan u periodu 2012-2025. Realizacijom ovih investicija BiH će ispuniti uslove Quoto sporazuma i EU kriterije o korištenju obnovljivih izvora energije i energetskoj efikasnosti.
- Istraživanja u energiju vjetra po savremenim principima od 2000. godine, sunčevog zračenja i karakteristika vjetra od 1956. godine, te malih vodotokova od 1970. godine su osnove za izgradnju ovih energetskih objekata
- Pravna regulativa, kroz Uredbu Vlade Federacije od maja 2010. godine otvara procese intezivnijih investicija u sektoru obnovljivih izvora energije
- Tehnička regulativa i standardi za obnovljive izvore energije moraju se prilagoditi normativima u EU, te biti obavezna u fazama istraživanja i projektovanja sistema proizvodnje i upravljanja energetskim tokovima
- Država i entiteti moraju stvoriti uslove za brže oživljavanje metalne, građevinske i elektro industrije shodno entitetskim planovima
- Entiteti i kantoni moraju stvoriti uslove za jačanje materijalne baze obrazovnih i razvojnih institucija u oblastima tehničkih nauka
- Kroz klasterske sisteme za svaki sektor obnovljivih izvora energije privredne komore i adekvatna ministarstva, te entitetske institucije i agencije moraju se uvezati privredna i akademska zajednica na državnom i regionalnom nivou.

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1st International Scientific Conference on Engineering
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MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

HIDROENERGETSKI SISTEMI U OTVORENIM TRŽIŠNIM USLOVIMA

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SAŽETAK

Nove okolnosti u elektroenergestkom sistemu koje karakterizira otvaranje i deregulaciju tržišta električne energije te povećanje udjela proizvodnje iz nereguliranih obnovljivih izvora energije kao što su vjetroelektrane povećat će se potreba za unapređenjem rada hidroelektrana i za optimizacijom proizvodnje hidroenergetskih sistema koja na dereguliranom tržištu podrazumjeva maksmizaciju profita. Ovi trendovi će bitno uticati na rad hidroelektrana, na nadogradnje i rekonstrukcije postojećih hidroelektrana i za dizajniranje novih hidroelektrana.

Cilj ovog rada je da se ukaže na to kako hidroenergetski sistem može biti korišten da bi zadovoljio zahtjeve koji će proisteći iz otvaranja tržišta i povećanja udjela nereguliranih izvora energije i projceni koje aspekte i pojave je potrebno dodatno istražiti kako u postojećim hidroelektranama tako i u slučaju izgradnje novih hidroenergetskih objekata.

Ključne riječi: hidroenergetski sistem, otvaranje tržišta, optmizacija

1. UVOD

Električna energija je poseban proizvod. Neka bitna svojstva električne energije su:

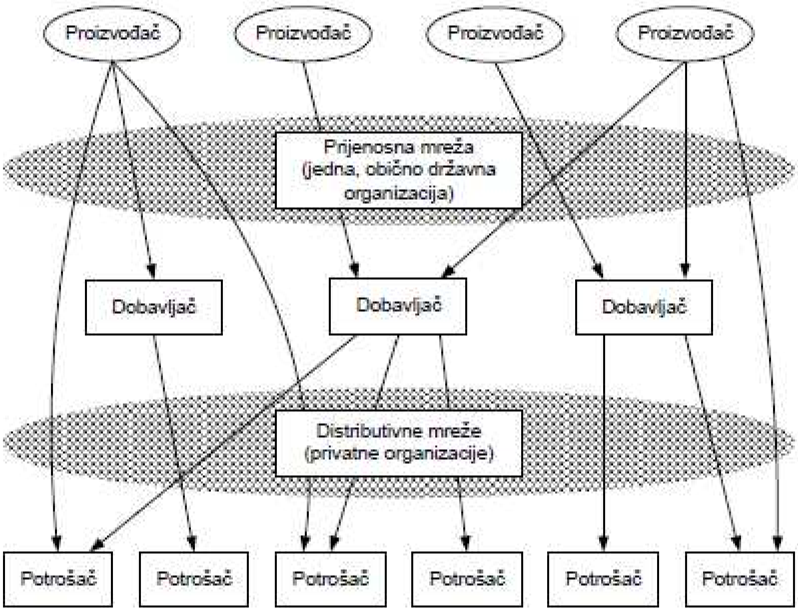
- *Neprekidan tok*. Električna energija proizvodi se i troši u kontinuitetu.
- *Istodobna proizvodnja i potrošnja*. Električna energija troši se u onom trenutku kad je proizvedena.
- *Nemogućnost uskladištenja*. Električna energija ne može se skladištiti u znatnijim količinama na ekonomičan način.
- *Promjenljivost potrošnje*. Potrošnja električne energije ili potražnja je promjenljiva s karakterističnim oblikom za dan/noć, preko sedmice ili tokom godine.
- *Bez poznatog porjekla*. Ne postoji fizički način po kojem bi se jedinica električne energije (kWh) isporučena potrošaču mogla slijediti do proizvođača koji je proizveo tu jedinicu.
- *Bitna za društvenu zajednicu*. Električna energija predstavlja apsolutnu nužnost u modernom društvu. Svako kućanstvo i svako preduzeće povezani su na električnu mrežu.
- *Mogućnost raspada*. Zahvaljujući tehničkim svojstvima elektroenergetskog sistema (EES) slučajni prekidi u opskrbi ne pogađaju samo individualne potrošače. U slučaju raspada EES-a mogu biti zahvaćena i velika područja.

2. RESTRUKTUIRANJE ELEKTROENERGETSKOG SEKTORA

Elektroenergetski sektor je dugo vremena bio prirodni vertikalno integrisani monopol u državnom vlasništvu. U većini zemalja u svijetu elektroenergetski sektor je bio pod kontrolom jedne vertikalno

integrisane kompanije i strogo regulisan od strane državnih agencija, koje su kroz energetski sektor provodile svoju socijalnu politiku.
Monopol, kao model organizacije tržišta električne energije se pokazao neefikasan u smislu osiguranja realne cijene električne energije. Zbog tog nedostatka, kao i zbog tehnološkog napretka u proizvodnji i prenosu električne energije nametnula se potreba za reformom elektroenergetskog sektora, odnosno liberalizacijom tržišta električne energije.
Konačni cilj reformskog procesa je uvođenje konkurencije na tržište električne energije, odnosno davanje mogućnosti krajnjem kupcu da bira dobavljača/distributera od kojeg će kupovati električnu energiju.
Reformski proces je vrlo kompleksan. Iskustva vezana za dosadašnje korake učinjene u procesu reformi energetskih sektora zemalja u svijetu su omogućila da se uspostavi konsenzus u vezi nekih generičkih mjera za postizanje fukcionalne i tržišno orijetnisane industrije.
Liberalizacija generalno zahtijeva provođenje nekoliko međusobno povezanih koraka. Ti koraci su:

1. restrukturiranje sektora,
2. uvođenje konkurencije na veletržištu i na maloprodajnom tržištu
3. regulacija prenosnih i distributivnih mreža
4. uspostavljanje nezavisnog regulatora sistema
5. privatizacija



Slika 1. Elektroenergetski sistem na otvorenom tržištu

Pioniri u europskom restrukturiranju bili su Engleska i Wales u kojima se privatizacija i deregulacija pojavljuju u zakonu - Electricity Act iz 1989. Slijedi Norveška s Energy Actom iz 1990. te druge skandinavske zemlje i Finska koje se priključuju tokom 1990-ih. Španjolska (1998) i Nizozemska (1999) također su otvorile potpunu konkurentnost tržišta. Njemačka je uvela puni pristup mreži ali su neki elementi izostali da bi se njemačko tržište moglo smatrati potpuno tržno konkurentnim. Proces restrukturiranja u EU dijelom je rezultat tih ranih nacionalnih inicijativa, a dijelom je rezultat inicijativa EU. Direktiva 96/92/EC, decembar 1996., korigirana s Direktivom 2003/54/EC iz juna 2003., teži ka potpuno otvorenom tržištu.

3. POVEĆANO UČEŠĆE NEREGULIRANIH OBNOVLJIVIH IZVORA ENERGIJE

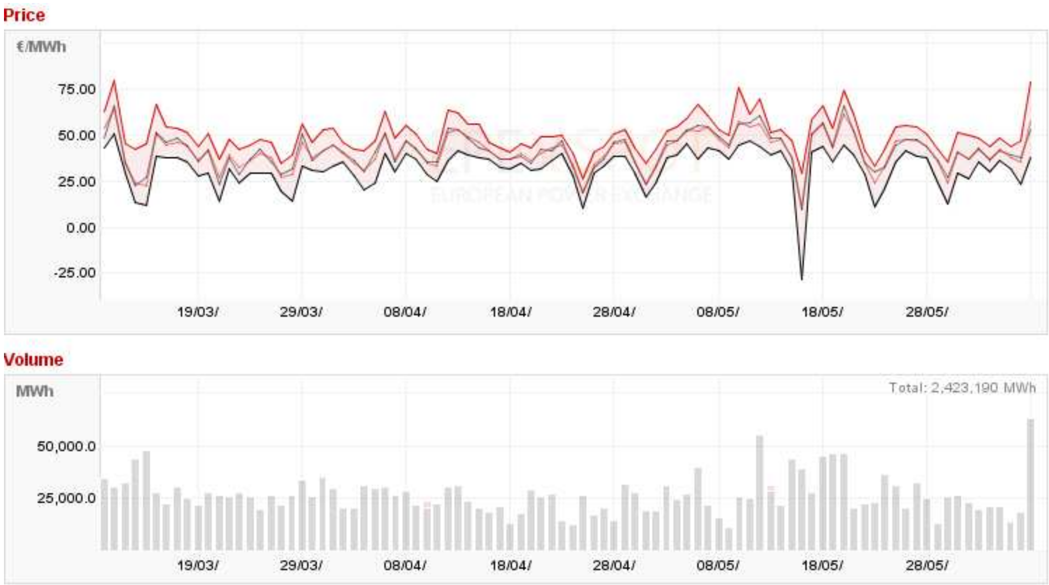
Postojeći hidroenergetski sistemi uglavnom su razvijani za opskrbu baznog opterećenja. Uz izgradnju i puštanje u pogon nereguliranih obnovljivih izvora energije kao što su onshore/offshore vjetroelektrane, očekuje se da će hidroelektrane proizvoditi puno više energije za vršna opterećenja i uravnoteženje. Korištenje hidroelektrane za podmirivanje vršnih opterećenja i uravnoteženje podrazumjeva brze promjene snage, protoka i razine akumulacije što znači nove izazove za rad hidroenergetskih sistema koje mogu imati negativne učinke na turbine, hidrauličke strukture, brane i tunele te na rijeke i akumulacije. Ispunjavanje dodatnih zahtjeva za korištenje hidroenergije za vršno opeterećenje i uravnoteženje može se ispuniti i) promjenom i unapređenjem režima rada postojećih hidroenergetskih sistema, ii) nadogradnjom i modernizacijom postojećih sistema i iii) razvojem novih hidroelektrana i pumpnih hidroelektrana.

4. OTVORENO TRŽIŠTE I HIDROENERGIJA

4.1. Optimalno planiranje rada hidroenergetskih sistema

Optimalno planiranja proizvodnje električne energije može biti definisano kao „iskorištavanje dostupnih resursa za proizvodnju električne energije da bi se zadovoljli zahtjevi za potražnjom električne energije na takav načain da se dobiju optimalni rezultati i zadovolje sva relevantna ograničenja". Na otvorenom tržištu optimalan rezultat dolazi iz maksimizacije profita dok se ograničenja uobičajeno sastoje od ograničenja proizvodnih sistema, ograničenja prenosnih sistema i okolinskih ograničenja.

Voda dotiče u rijeke i akumulacije bez ikakvih troškova i potpuno besplatno i varijabilni troškovi proizvodnje elektrečne energije iz hidroelektrana su relativno niski. Sa druge strane, količina vode koja utiče je ograničena i npredvidiva i prema tome ima neku vrijednost. Proizvodnja 1 kWh više u datom trenutku znači proizvodnju 1 kWh manje u nekom trenutku u budućnosti kada cijene električne energije mogu biti veće. Marginalni trošak vode zavisi od volumena akumulacije, ukupne instalisane snage proizvodnog sistema, očekivanja za potražnjom električne energije u narednom periodu, očekivanja dotoka vode u akumulacije i cijena električne energije na tržištu.



Slika 2. Cijena električne energije i obim trgovanja na EEX berzi u Leipzigu za drugi kvartal 2009. godine

4.2. Hidrologija i prognoza dotoka

Sa već pomenutim povećanjem zahtjeva za proizvodnjom električne energije iz nereguliranih obnovljih izvora energije, korištenje hidroelektrana za vršna opterećenja ili uravnoteženje snage zahtjevaće unapređenje alata za prognozu dotoka u akumulacije kako za dugoročno tako i za kratkoročno optimalno planiranje, uključujući i upravljanje poplavama. Naglasak će biti stavljen na razvijanje metoda za simulaciju dotoka sa vrlo kratkim vremenskim korakom i prikupljanje i ažuriranje hidroloških podataka sa mjernih stanica.

4.3. Regulacija snage i frekvencije

Varijacije snage i povećana dominantnost neregulirane energije predstavljat će izazov za postojeće regulatore turbina i sisteme upravljanja hidroagregata. Stabilnost postojećih turbinskih regulatora je robusna i energija iz vjetroelektrana neće pozitivno doprinositi njihovoj stabilnosti. Hidroelektrane će biti izložene bržim i frekventnim promjena izlazne snage što će rezultirati pojavama pražnjenja pritiska u tlačnim cjevovodim i dovodnim sistemima. Aspekti koje će se u budućnosti morati uzeti u obzir su i) evaluacija i ocjena postojećih kriterija za dimenzionisanje turbinskih regulatora sa aspekta stabilnosti ii) definisanje novih kriterija za dizajniranje turbinskih regulatora kod promjenjenog režima rada hidoelektrana iii) razvoj novih turbinskih regulatora i sistema upravljanja koji će zadovoljiti nove kriterije

4.4. Revezibilne hidroeletrane

Reverzibilne hidroelektrane su pogodne za regulaciju opterećenja kao i za podršku elektroenergetskom sistemu u smislu regulacije napona i frekvencije. Promjenama na tržištu električne energije sa značajnim razlikama cijene električne energije u periodu dana ili noći, reverzibilne hidroelektrane su postalne aktivnije bilo da rade u pumpnom ili turbinskom režimu rada. Današnje reverzibilne hidroelektrane nisu dizajnirane da odgovore izazovu brze promjne režima rada pumpa-turbina da bi zadovoljili sve zahtjeve sistema. Pitanja na koje je u budućnosti potrebno dati odgovore su i) evaluirati i ocjeniti zahtjeve za promjene režima rada reverzibilnih hidroeletrana ii) ocjeniti dinamike sistema za postojeće reverzibilne hidroelektrane iii) razvijati sisteme i koncepte za efikasniju promjenu režima rada pumpa-turbina.

4.5. Dovodni tuneli i pripadajuće hidrauličke strukture, obale rijeka i akumulacije

Tranzijentni prelazni režimi rada hidroelektrana izazvani učestalim promjenama snage mogu izazvati destabilizaciju dovodnih tunela što se manifestuje tzv. transportom piješčane mase i oštećenjima turbina i turbinske opreme ili pak prouzročiti eksplozije zarobljenih zračnih jastuka koje mogu da izazovu havarije. Takođe, promjene pritiska mogu destabilizirati kamene obloge i prouzrokovati odvajanje i transport kamenih naslaga. Vodozahvati na hidroelektrana su slabo ili gotovo nikako nadzirani i praćeni i ne postoji dovoljno podataka o gubitcima vode i gubitcima usljed trenja.

Brze promjene snage snage imaju za posljedicu i brze promjene nivoa vode koje mogu destabilizirati obale na rijekama i akumulacijama i uzrokovati pojave klizišta. Takođe, kao posljedica varijacije vode u jezeru očekuju se inteziviranje transporta naslaga. Generalno povećanje protoka kroz rijeke zbog klimatskih promjena dodatno može intenzivirati ove probleme.

Zbog gore navedenog potrebno je i) razvijati scenarije za hidrauličke fluktuacije ii) razvijati eksperimentalne metode za ispitivanja i testiranja na terenu iii) analizirati efekte fluktuirajućeg opterećenja na dovodne tunele i pripadajuće strukture te na obale rijeka i jezera iv) razvijati alate za previđanje kratkoročnih i dugoročnih efekata v) razvijati preporuke i mjere za izbjegavanje negativnih posljedica.

5. ZAKLJUČAK

Deregulacija donosi nove kriterijume uspješnog poslovanja u elektroprivredi. Prije deregulacije opimalno poslovanje je bilo takvo koje obezbeđuje minimalne gubitke i troškove poslovanja, ali sada optimalno poslovanje je postalo ono koje donosi maksimalan profit. Takvo okruženje uključuje nove ekonomske strategije i uvođenje tržišnih principa u snabdjevanje i proizvodnju električne energije. Takođe, povećano učešće nereguliranih izvora električne energije na otvorenom tržištu će definisati nove zahtjeve za održavanje postojećih i razvoj novih hidroenergetskih sistema. Ispunjavanje dodatnih zahtjeva u otvorenim tržišnim uslovima može se ispuniti i) promjenom i unapređenjem režima rada postojećih hidroenergetskih sistema, ii) nadogradnjom i modernizacijom postojećih sistema i iii) razvojem novih hidroelektrana i pumpnih hidroelektrana.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

MOGUĆNOST PLANSKOG ISKORIŠTENJA BIOMASE U TUZLANSKOM KANTONU

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ABSTRACT
Poznato je da je biomasa je generički izraz kojim su opisani svi oblici organske materije, uključujući drvo, poljoprivredne kulture i otpad, životinjske ekskremente i ljudski otpad, koja se može koristiti kao gorivo.Najčešće se koristi direktno kao izvor energije za grijanje ili zagrijavanje tople vode, ali se može koristiti i za proizvodnju električne energije i topline. Biomasa je obnovljivi izvor energije, koji bez obzira kako je uzgojen, planski ili divlje, predstavlja značajan izvor energije. Godišnja svjetska produkcija biomase cca. 70 milijardi tona (oko 8 puta veća od svjetke potrošnje primarne energije), cca. 1800 milijardi tona postojeće biomase, te činjenica da biomasa predstavlja "CO_2 neutralnu energiju" ukazuju na potrebu značajnijeg iskorištenja ovog energetskog resursa.
U radu će biti prikazana analiza mogućnosti planskog iskorištenja biomase u Tuzlanskom kantonu, uz istovremeni poticaj razvoja poljoprivrede i stočarstva na trenutno neobrađenom zemljištu. Analizirat će se mogućnost proizvodnje toplotne energije, el.energije ili kombinovane proizvodnje toplotne i električne energije u kotlovskim postrojenjima namijenjenim za tu svrhu, te korist koju bi od toga imale lokalne zajednice i krajnji potrošači. Na osnovu dobijene cijene tako proizvedene el. energije izvršit će se uporedba sa cijenom el. energije dobijene iz konvencionalnih izvora energije, uz napomenu da u radu neće biti razmatrana zakonska regulativa po pitanju distribucije na ovaj način dobijene toplotne i el.energije.
Keywords: biomasa, obnovljivi izvori energije, toplotna i električna energija.

1. UVOD
Obaveza BiH je da slijedi smijernice EU u oblasti energije kako primjene konvencionalnih izvora, tako i obnovljivih izvora energije, ne samo zbog težnje da se pristupi EU nego i zbog svih pozitivnih posljedica koje u tom smislu proističu iz takve politike. Korištenje obnovljivih izvora energije važno je zbog smanjenja ovisnosti o energiji iz uvoza, mogućnosti zapošljavanja domaće radne snage kao i očuvanja životne sredine. Osnovni izvori energije u BiH su ugalj i hidroenergija. Takođe, BiH ima znatne potencijale za iskorištenje biomase kao obnovljivog izvora energije, zbog toga što raspolaže sa određenim količinama obradivog zemljišta koje je sada većim dijelom neobrađeno. Svjetski kapaciteti obnovljivih izvora energije danas učestvuju sa cca. 25 % ukupne svjetske proizvodnje električne energije.

2. PREGLED ENERGETSKE SITUACIJE U BOSNI I HERCEGOVINI
U Bosni i Hercegovini se ukupna količina proizvedene el.energije dobija iz: hidroelektrana-32,8 %, termoelektrana-65,8 %, i industrijskih energana-1,4 %. U finalnoj potrošnji el.energije domaćinstva učestvovuju sa cca. 43,4 %, industrija 38 %, a ostali potrošači uključujući građevinarstvo, saobraćaj i

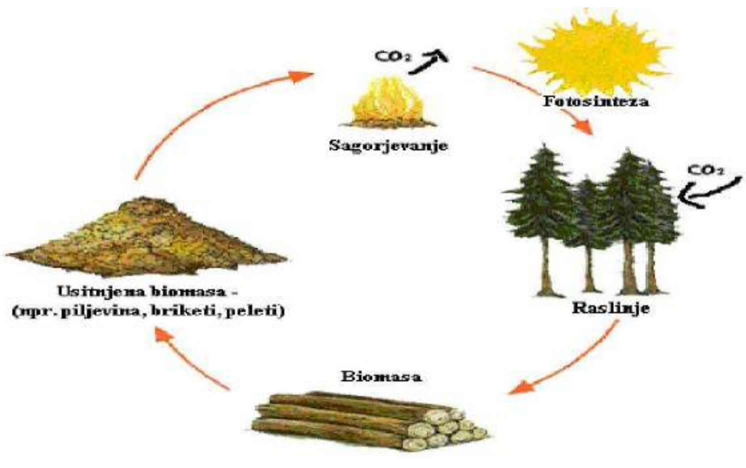
poljoprivredu s 18,6 %. Ukupna godišnja proizvodnja toplotne energije je cca.3.787 TJ, od čega je 48,8 % proizvedeno u toplanama, u termoelektranama je proizvedeno 29 %, dok je u industrijskim energanama proizvedeno 22,2 %. U konačnoj potrošnji toplotne energije najveće učešće imaju domaćinstva sa 72 %, a ostali sektori sa 28 %. Do sada je iskorišteno manje od 40% hidro-potencijala u FBiH, ali se u budućnosti predviđa izgradnja novih proizvodnih kapaciteta instalirane snage 442,5 MW odnosno godišnje proizvodnje 1281,68 GWh. Prema dosadašnjim istraživanjima mogucnosti korištenja vjetropotencijala u proizvodnji el.energije utvrdeni su znacajni potencijali koji, prema rezultatima studija daju godišnju proizvodnju od preko 1621 GWh elektricne energije.
Međutim, dva osnovna obnovljiva izvora energije u Bosni i Hercegovini su energija vode za proizvodnju električne energije i biomasa za proizvodnju toplotne energije, pri čemu korištenje biomase podrazumijeva tradicionalno iskorištavanje drveta kao čvrstog goriva u domaćinstvima i lokalnim kotlovnicamo bez ikakve kontrole i granica.BiH ima zavidne potencijale biomase čemu ide u prilog i činjenica da je oko 50% teritorije BiH pokriveno šumama pri čemu ne treba zanemariti i biomasu nastalu u poljoprivredi. Na nivou BiH, prema najnovijim podacima, imamo oko 400 000 hektara oranica koje se ne obrađuju. Npr. U 2003.god. neiskorišteni potencijali rezidualnog drveta i drvnog otpada iznosili su približno oko 1 milion m3/a što bi moglo osigurati toplotnu energiju za 130000 domaćinstava ili 300000 građana.

3. KORIŠTENJE BIOMASE U PROIZVODNJI TOPLOTNE I ELEKTRIČNE ENERGIJE

3.1. Osnovne karakteristike biomase

Biomasa se odnosi na živuću ili donedavno živuću materiju biljnog ili životinjskog porijekla, koja se može koristiti kao gorivo ili za industrijsku proizvodnju. Biomasa je najstariji izvor energije koji je čovjek koristio. Biomasa je obnovljivi izvor energije, koji kao biljna masa bez obzira kako je uzgojen, planski ili izrasla divlje, predstavlja značajan obnovljivi izvor energije. Vrste biomase su:

- šumska biomasa (ostaci i otpad iz drvne industrije, nastali redovitim gospodarenjem šumama, prostorno i ogrjevno drvo);
- biomasa iz drvne industrije (ostaci i otpad pri piljenju, brušenju, blanjanju);
- poljoprivredna biomasa (ostaci godišnjih kultura: slama, kukuruzovina, oklasak, stabljike, ljuske, koštice);
- energetski nasadi (biljke bogate uljem ili šećerom, s velikom količinom suhe tvari-ugljik C, kao što su trska, eukaliptus, zelene alge, toplole, vrbe itd.);
- biomasa sa farmi životinja (proizvodnja bioplina iz izmeta životinja);
- biogoriva (etanol, methanol, biodizel);
- gradski otpad (zeleni dio kućnog otpada, biomasa iz parkova itd.)



Slika 3.1 Kružni tok CO_2 pri proizvodnji i korištenju biomase

Glavna prednost u korištenju biomase kao izvora energije su obilni potencijali te neusporedivo manja emisija štetnih plinova i otpadnih tvari. Računa se da je opterećenje atmosfere s CO_2 pri korištenju

biomase kao goriva zanemarivo, budući da je količina emitiranog CO_2 prilikom izgaranja jednaka količini apsorbiranog CO_2 tijekom rasta biljke- ukoliko su sječa i prirast drvne mase u održivom odnosu.
Važni fizički parametri, koji kod procjene biogoriva igraju bitnu ulogu, jesu forma i veličina čestica, sadržaj vode, gustoća energije, te i mnogi drugi parametri koji variraju unutar širokog opsega vrijednosti. Oni utiču prije svega na izbor i dimenzionisanje tehnologije za pripremu i konverziju, kao i na eventualno neophodnu tehnologiju obrade otpadnih tokova. Što se tiče ogrjevne moći biomase tu je osnovna karakteristika nehomogenost kao posljedica različitih udjela vlage i pepela. U tabeli 3.1 dat je prikaz ogrjevne moći različitih vrsta biomase uz usporedbu sa ogrjevnom moći fosilnih goriva, dok je u tabeli 3.2 dat opis tržišta i cijena bio-goriva.

Tabela 3.1 Ogrevna moć pojedinih tipova biomase

Vrsta biomase	Ogrevna moć (MJ/kg)	Vrsta fosilnog goriva	Ogrevna moć
Drvo	8,2-18,7	Nafta	Cca. 42 MJ/l
Biljni ostaci	5,8-16,7	Prirodni plin	34-38 MJ/Nm3
Biodizel	37,2	Lignit	Do 12,6 MJ/kg
Etanol	26,8	Mrki ugalj	12,7-23,9 MJ/kg
Bioplin	26	Kameni ugalj	24-37,7 MJ/kg

Tabela 3.2 Opis tržišta i cijena bio-goriva

GORIVO	PONUĐAČI	TRŽIŠNI OPIS	FAKTOR FORMIRANJA CIJENE	SREDNJA CIJENA, €/GJ
Kora	Pilane	Stabilna ponuda, monopol papirne industrije	Teško lož ulje	1,22-2,43
Industrijska sječena građa	Pilane, drvoprerađivačka Industrija	Stabilna ponuda	Cijena celuloze	2,43-3,25
Šumska dobra	Šumarstvo	Visok potencijal, netransparentno tržište	Industrijska cijena drveta	4,46-7,10
Slama	Poljoprivreda	Stabilna ponuda	Cijena proizvodnje, đubriva	1,62-5,07
Peleti	Pilane, drvoprerađivačka industrija	Tržište u nastajanju, primarno za konačne korisnike, politika visokih cijena	Ekstra lako loživo ulje	6,09-9,13
Energetske vrste	Poljoprivreda	Samo za napredne svrhe	Cijena proizvodnje	5,07-9,13

3.2. Tehnologije za spaljivanje biomase

Do danas je razvijen veliki broj različitih tehnologija spaljivanja čvrstih bio-goriva, od kojih je većina tehnički zrela i komercijalno raspoloživa. U spomenute tehnologije se ubrajaju:

- **Zajedničko spaljivanje sa fosilnim gorivima** – u modernim, velim termoelektranama na ugalj predstavlja efikasan i isplativ način iskorištenja energije biomase uz umjerena dodatna finansijska ulaganja. Stepen iskorištenja je do 10 % niži nego u klasičnim TE, ali u postrojenjima velike snage je i dalje veći (35%-45%) nego u postrojenjima specijalizovanim za spaljivanje biomase.
- **Sagorijevanje biomase u klasičnim i CHP (kombinovana proizvodnja električne i toplotne energije) postrojenjima -**. Ova postrojenja su do 10 puta manja od postrojenja za zajedničko spaljivanje (od 1 do100 MW). Stepen iskorištenja ovih postrojenja je oko 30% zavisno od veličine postrojenja.
- **Gasifikacija**– Pretvorba biomase u bioplin može biti ili putem termo-hemijskog procesa (tkzv. pirolize) ili iz spore anaerobne fermentacije kojom se iskoristi samo dio (50%-60%) stočnog otpada ali se dobijaju đubriva kao nusproizvod. Bioplin može sagorijevati u postrojenjima snage 10 kW do 10 MW uz stepen iskorištenja od 30%-35%; zatim u plinskim turbinama sa većim

stepenom iskorištenja ili u visoko-efikasnim kombinovanim ciklusima. U budućnosti se očekuje komercijalizacija plinskih turbina sa integrisanom gasifikacijom biomase (BIG/GT) dok je prvi takav kombinovani ciklus (IGCC) već u upotrebi. Ostale tehnologije ukjlučuju Stirlingov motor, organski Rankinov ciklus (ORC) i postrojenja sa gorivnim ćelijama (IGFC).

- **Anaerobna feremenentacija na deponijama otpada-** najčešće je korištena u malim, ruralnim sredinama.
- **Bio-refinerije i hidrogen** – Teoretski se na ovaj način može dobiti bioplin korišternjem stočnog otpada i upotrebom sinergijskih proizvodnih metoda.

U tabeli 3.3 dati su osnovni podaci o proizvodnji el.energije iz biomase za prethodno navedene tipove postrojenja.

Tabela 3.3 Prikaz osnovnih karakteristika postrojenja na biomasu

Vrsta tehnologije	**Stepen iskorištenja (%)**	**Instalisana snaga (MW)**	**Troškovi izgradnje (KM/kW)**	**Cijena el.energije (KM/kWh)**
Zajedničko sagorijevanje	35-40	10-50	1600-2000	0,075
Specijalizovani parni ciklus	30-35	5-25	4500-7500	0,16
IGCC ciklus	30-40	10-30	2750-8200	0,16-0,2
Gasifikacija i CHP	25-30	0,2-1	4500-6000	0,16
Stirlingov motor-CHP	11-20	< 0,1	7500-10000	0,2

4. ANALIZA MOGUĆEG ISKORIŠTENJA BIOMASE U TUZLANSKOM KANTONU

Prema podacima Ministarstva poljoprivrede, Tuzlanski kanton raspolaže sa više od 100 000 ha poljoprivrednog zemljišta, koje nije potpuno iskorišteno. Tuzlanski kanton, iz godine u godinu, ima sve lošiji odnos raspoloživih obradivih i poljoprivrednih površina po stanovniku sa tendencijom daljeg narušavanja i uništavanja kvaliteta zemljišta. Prema ovim podacima, oko 33 % obrađenih površina su pod žitom, povrtno bilje je zastupljeno sa oko 16,78 %, udio krmnog bilja je značajan oko 20 %, što govori o raspoloživim kapacitetima za iskorištenje biomase (izuzev šumske). Tuzlanski kanton svojim energetskim potencijalima daleko nadmašuje potrebe ovog kantona i može osigurati kvalitetno i sigurno snabdijevanje potrošača elektičnom energijom. Međutim, na području Tuzlanskog kantona korištenje obnovljivih izvora energije nije značajno zastupljeno. S obzirom na njihovu obnovljivost i značajno smanjen negativan uticaj na okolinu, potrebno je istražiti i mogućnost korištenja ovih izvora. Jedan od osnovnih faktora u donošenju odluke o investiranju u postrojenja za korištenje obnovljivih izvora energije jesu upravo troškovi proizvodnje po kWh el.energije. Kao što se može vidjeti u Tabeli 4.1 troškovi proizvodnje el. energije iz biomase ne odstupaju bitno od troškova proizvodnje iz lignita i mrkog uglja. To može biti dodatni poticaj za ulaganje u ovaj sektor.

Tabela 4.1 Troškovi proizvodnje el.energije u novoizgrađenim elektranama u 2010.god

Izvor energije	**Troškovi proizvodnje el.energije pf/kWh**	**Izvor energije**	**Troškovi proizvodnje el.energije pf/kWh**
Nuklearna energija	20 – 25	Vjetroelektrane	7-30
Lignit i mrki ugalj	17-20	Hidroenergija	7-25
Kameni ugalj	20-22	Solarna energija	56-80
Prirodni plin	20-24	**Biomasa**	**15-23**

Analizom podataka o godišnjim prinosima ratarskih kultura kao i stočnog fonda na području Tuzlanskog kantona, moguće je izračunati koja bi se količina energije mogla proizvesti iz raspoložive biomase tj. stočnog otpada. U tabelama 4.2 i 4.3 su prikazane minimalna i maksimalna količina el.energije koja bi se mogla dobiti na ovaj način. Razlika između ove dvije vrijednosti pojavljuje se usljed različitih iznosa u odnosu prinos/otpad.

Tabela 4.2 Godišnja raspoloživa energija iz ratarskih kultura u Tuzlanskom kantonu

Vrsta rataske kulture	**Prinos (t/god)**	**Biomasa (ostaci) (t/god)**	**Energija (GWh/god)**
Pšenica	14.484	12.890	-
Raž	1.000	890	-
Ječam	1.631	1.451	-
Zob	2.238	1.991	-
Kukuruz	94.240	83.873	-
Stočna repa	2.102	1.870	-
Ukupno ratarskih i drugih poljoprivrednih kultura	245.111	218.148	**Min. 351** **Max. 1.011**

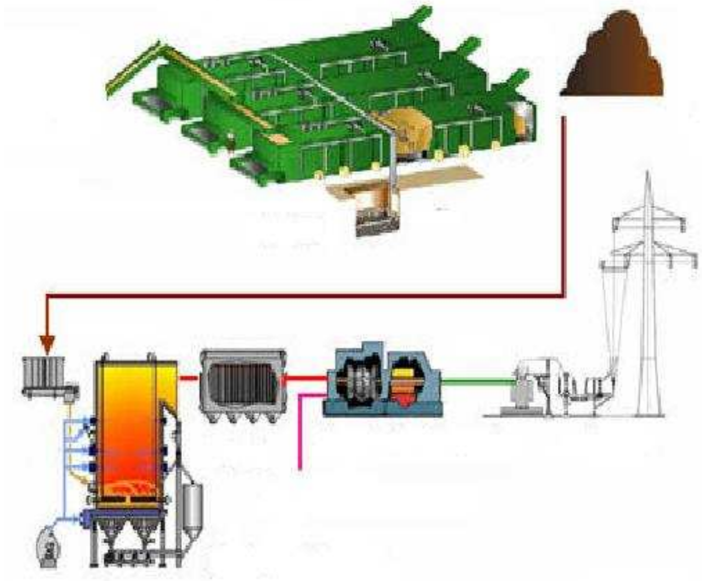
Tabela 4.3 Godišnja raspoloživa energija iz stočnog otpada u Tuzlanskom kantonu

Vrsta stoke	**Broj grla u TK**	**Bioplin (m3/dan)**	**Energija po grlu (kWh/god)**	**Energija (GWh/god)**
Goveda	63.471	3,2	6.800	431
Ovce	63.020	0,59	1.100	40
Svinje	7.250	0,92	1.940	14
Perad	3.068.000	0,07	36	11
Ukupno	-	-	-	**496**

Poznato je da je sa ukupno instalisanom snagom od 715 MW, prosječna godišnja proizvodnja energije u Termoelektrani Tuzla je oko 3100 GWh (bez blokova 32 MW), uz godišnju potrošnju uglja oko 3,3 miliona tona uglja. Analizom podataka u tabelama 4.2. i 4.3 može se zaključiti da se radi o značajnoj energiji koja bi se mogla iskoristiti iz postojećih ratarskih kultura i bioplina dobijenog iz stočnog otpada.

Što se tiče vrste postrojenja koja bi se mogla koristiti za spaljivanje biomase i bioplina, s obzirom na to da su u Tuzlanskom kantonu uglavnom poljoprivredna dobra manjih kapaciteta, preporuka je da se ovako dobijena el.energija koristi za podmirivanje sopstvenih potreba, a ne priključivanje na postojeći elektro-energetski sistem. S tim u vezi, također je preporuka da se gdje god je potrebno i moguće ostvarivo vrši instalisanje postrojenja za kombinovanu proizvodnju električne i toplotne energije (CHP), u kojima se postiže najefikasnije iskorištenje energije biomase. Ovakva postrojenja se isplati graditi tamo gdje postoji stalni potrošač toplotne energije.

Na slici 4.1 dat je šematski prikaz jednog takvog postrojenja. Zbog troškova transporta za biomasu su pogodna postrojenja manje snage, ali imaju niži stepen djelovanja (npr. za TE na biomasu snage 5 MW η= 15 do 20%, za plinske turbine veći stepen djelovanja η= 45 do 50%). Zbog različitosti navedenih procesa za preradu biomase i stočnog otpada, troškovi ovako dobijene energije variraju. Zajedničko spaljivanje u postojećim termoenergetskim postrojenjima na ugalj zahtijeva početna ulaganja od 70-350 KM/kW instalisane snage, dok cijena proizvedene el.energije može biti konkurentna ako je raspoloživa biomasa (iz ratarskog ili stočnog fonda) dostupna po niskim cijenama bez potrebe za troškovima transporta. Za biomasu se srednja cijena el.energije dobijena iz CHP postrojenja (koja imaju najnižu cijenu od svih spomenutih postrojenja za preradu biomase) kreće u intervalu 60-120 KM/MWh.



Slika 4.1 Shematski prikaz CHP postrojenja

5. ZAKLJUČAK

Kratkoročno posmatrajući, zajedničko spaljivanje biomase sa fosilnim gorivima i dalje je najefikasniji način korištenja energije biomase, zajedno sa malim postrojenjima koja nisu priključena na elektrodistributivnu mrežu. Međutim, posmatrajući u srednjoročnom periodu BIG/GT postrojenja i biorafinerije takođe mogu biti veoma isplative. Procjene Međunarodne agencije za energiju su da bi se udio biomase u ukupnoj proizvodnji el.energije u svijetu mogao povećati sa trenutnih 1,3% na nekih 3%-5% do 2050.god. u zavisnosti od različitih pretpostavki. Ovo predstavlja malo povećanje u poređenju sa ukupnim procijenjenim rezervama biomase (10%-20% od ukupne primarne energije do 2050.god.). Treba uzeti u obzir činjenicu da se biomasa takođe koristi za dobijanje toplotne energije kao i gorivo za transport. Osnovne prepreke za masovnije korištenje biomase su i dalje troškovi, stepen iskorištenja u pretvorbi energije, troškovi transporta, raspoloživost biomase, nedostatak logističke podrške, rizici povezani sa intenzivnim poljoprivrednim aktivnostima (gnojivo, hemikalije, biodiverzitet).

Imperativ svake zemlje treba da bude smanjenje korištenja fosilnih goriva te iskorištenje vlastitih obnovljivih energetskih resursa. Prema tome, ovoj problematici treba posvetiti posebnu pažnju i raditi na razvoju konkretnih rješenja koja će uključiti sve nivoe vlasti, od lokalnih do državnih.

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UPOTREBA TOPLOTNIH PUMPI I TREND NJIHOVOG RAZVOJA

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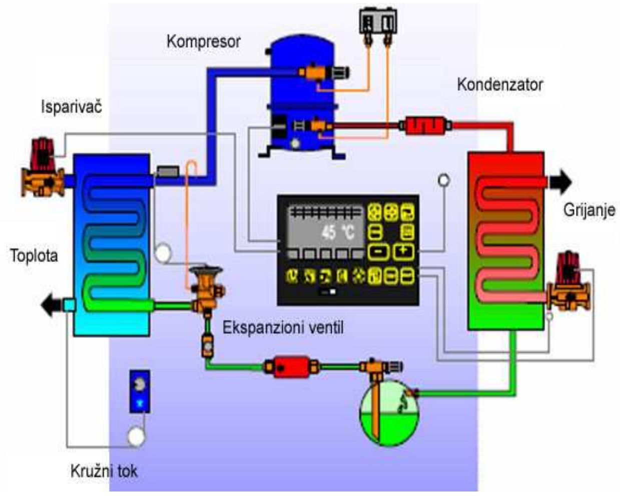
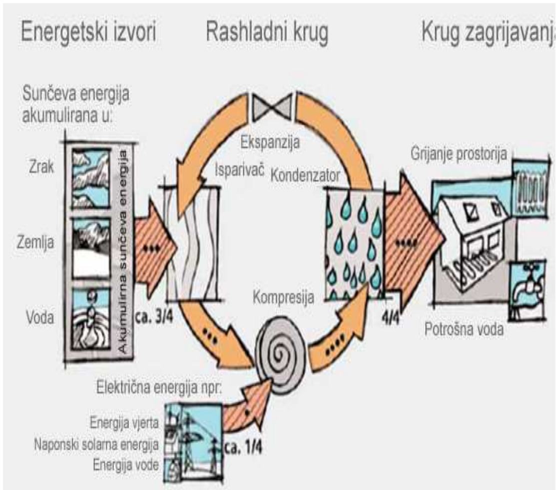
ABSTRACT
U radu je dat princip rada kompresione toplotne pumpe i značaj njene upotrebe u smanjenju troškova energije. Navedeni su statistički podaci o upotrebi toplotnih pumpi i trendu njihovog razvoja u svijetu.
Keywords: toplotna pumpa

1. TOPLOTNA PUMPA
Princip rada toplotne pumpe bazira se na oduzimanju toplote od okoline (odnosno nosioca energije na nižoj temperaturi) i njenom prenošenju drugom nosiocu energije na višoj temperaturi. U kružnom procesu oduzima se toplota iz okoline (zemlje, vode ili vazduha), predaje rashladnom mediju, koji isparava. Ispareno rashladno sredstvo usisava kompresor i sabija na pritisak kondenzacije. Na taj način se dobija viša temperatura u kondenzatoru. Vrela para struji u kondenzatoru, kondenzuje se i oslobađa toplotu. Tako nastala toplota, kao i toplota dobivena iz pogonske energije kompresora, upotrebljava se zagrijavanje prostorija. U ekspanzionom ventilu se tečnom rashladnom sredstvu snižava pritisak na pritisak isparavanja, nakon čega se ono vraća u isparivač, te se na taj način zatvara kružni tok i cijeli proces ponavlja. Shematski prikaz kompresione toplotne pumpe dat je na Slici 1, a funkcionalni prikaz njenog rada na Slici 2.



Slika 1. Shema kompresione toplotne pumpe



Slika 2. Funkcionalni prikaz rada toplotne pumpe

Sistemi grijanja i hlađenja, koji se zasnivaju na tehnologiji toplotne pumpe predstavljaju fleksibilnu i ekonomičnu alternativu bojlerima na fosilno gorivo sa opcijom hlađenja. Toplotna pumpa izvlači energiju niske temperature iz okruženja i povećava njenu temperaturu radi grijanja. Efikasnost toplotne pumpe se obično navodi kao stepen efikasnosti sistema, koji može da iznosi od 3 do 5. Drugim rečima, izvlačenje toplote iz obnovljivih izvora zahtjeva samo 1 kW ulazne struje da bi učinak grijanja bio od 3kW do 5kW. Zbog toga su sistemi toplotne pumpe 3 do 5 puta efikasniji od bojlera na fosilno gorivo i više nego sposobni da potpuno zagriju kuću, čak i na najnižim zimskim temperaturama. Povećanu popularnost ovih sistema grijanja odražava njihova izuzetno uspješna primena u hladnim klimatskim uslovima Skandinavije.

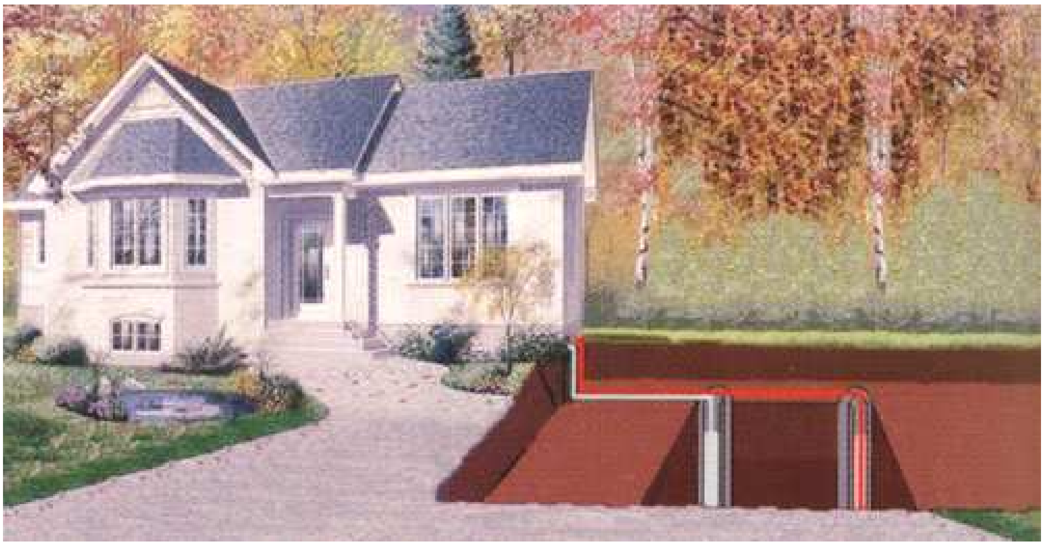
2. TIPOVI TOPLOTNIH PUMPI U ZAVISNOSTI OD IZVORA ENERGIJE ZA GRIJANJE

U zavisnosti od sredine iz koje se preuzima toplota i sredine u koju se ona prenosi, razvijene su tri vrste izvedbi sistema za zagrijavanje i hlađenje uz pomoć toplotne pumpe:

- sa inicijalnom energijom iz zemlje (sonda ili kolektor)
- sa inicijalnom energijom iz vode (jezera ili tekuće vode)
- sa inicijalnom energijom iz vazduha tzv. vazdušne toplotne pumpe (koje uspješno zagrijavaju oduzimajući toplotu iz vazduha temperature i do -20°C).

Izvori toplote koju koristi toplotna pumpa su neiscrpni i besplatni, za razliku od energenata (nafta, gas, ugalj), koji nisu obnovljivi i čije su rezerve ograničene.

Najefikasniji sistem se postiže upotrebom toplotne pumpe, koja energiju dobija iz podzemnih voda. Voda se uzima iz bušenih bunara, čija je temperatura od 10º do 14º C i ne mijenja se tokom godine. Voda protiče kroz izmenjivač toplote i od nje se oduzima toplota (hladi se), posle čega se vraća u zemlju tj. u drugi bunar (Slika 3).



Slika 3. Princip rada toplotne pumpe koja koristi energiju podzemnih voda

Toplota iz zemlje može se dobiti upotrebom horizontalno ili vertikalno postavljenih cijevi. Kod sistema sa horizontalno postavljenim cijevima u zemlju se postavlja više kružnih tokova, na dubinu od 1m do 1.5m, kroz koje protiče voda. Voda hladi zemlju i oduzima joj toplotu. Temperatura zemlje na dubini od 1m-1,5m se mijenja. Početkom jeseni, zemlja na dubini od 1 - 1,5 m je najtoplija (15ºC), dok je krajem zime zemlja najhladnija (5ºC). Za ovakav sistem potrebna veća površina zemljišta. Zato se ovakav sistem preporučuje za porodične kuće sa većim placem, kod izgradnje novih stambenih objekata gde će se vršiti veći zemljani radovi ili na mestima gdje nije moguće pronaći stabilni izvor vode (Slika 4.).

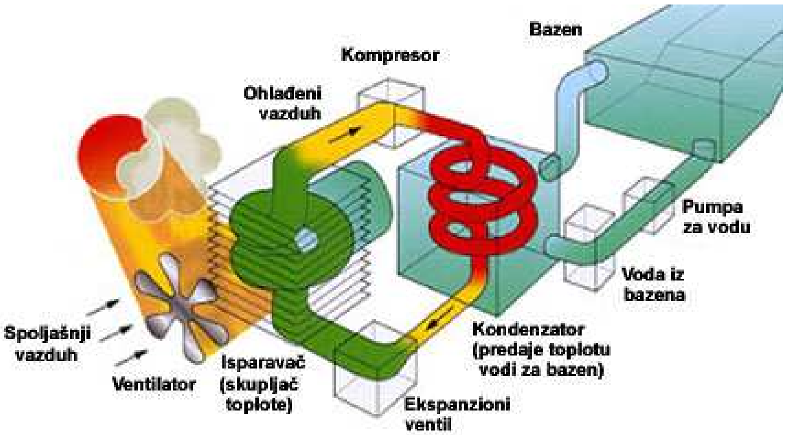
Toplota iz zemlje dobija se pomoću vertikalno postavljenih cijevi (sondi) (Slika 5). Sonde se postavljaju na dubinu od 40 - 100m, u kojima struji voda koja oduzima toplotu od zemlje. Ovakav sistem je veoma dobar, jer je temperatura zemljišta na dubinama većim od 20 m stabilna tokom cijele godine.

Ovaj sistem se dobro može koristiti za pasivno hlađenje u toku ljeta. Preporučuje se na mjestima gdje nije moguće imati stabilni izvor vode. Zbog relativno visoke cijene instaliranja ovaj sistem namjenjen je za veće objekte.

Slika 4. Princip rada toplotne pumpe sa horizontalnim kolektorom u zemlji.

Slika 5. Princip rada toplotne pumpe sa vertikalno postavljenim sondama u zemlji.

Kod toplotne pumpe koja energiju dobijaja iz spoljašnjeg vazduha nije potrebno bušenje bunara za vodu niti postavljanje horizontalnih cijevi u zemlju (Slika 6). Međutim, u zimskom periodu, pri nižim temperaturama spoljašnjeg vazduha, korisnost toplotne pumpe drastično opada. Ovaj tip toplotne pumpe je pogodan za zagrijavanje vode u bazenima kada temperatura spoljašnjeg vazduha nije niža od 10^{o} C.



Slika 6. Princip rada toplotne pumpe koja koristi energiju vazduha.

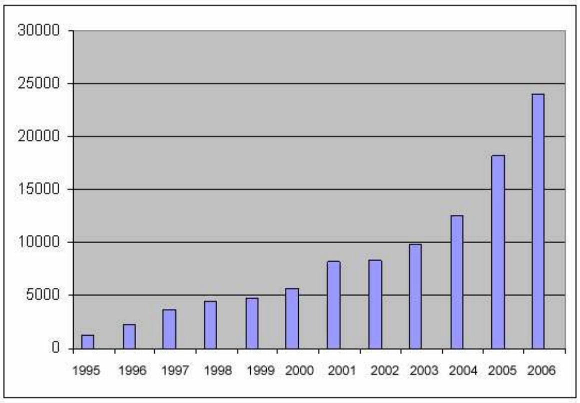
Toplota koja se dobija pomožu toplotne pumpe može se koristiti za zagrijavanje stambenih objekata, i to u slijedećim izvedbama: podno grijanje, zidno grijanje, ventilator konvektor, radijatorsko grijanje, kanalni sistem i zagrijavanje sanitarne vode.

Toplotna pumpa se može koristiti i u kombinaciji sa svim postojećim sistemima grijanja tako da se onda govori o bivalentnom ili polivalentnom sistemu grijanja. Najinteresantnija je opcija u kombinaciji sa suncem, odnosno uz korištenje jednog od gore navedenih načina uključiti i solarnu energiju, te tako dobiti još veću efikasnost kroz zagrijavanje tople potrošne vode od strane solarnih kolektora ili kao ispomoć solarne energije zimi za zagrijavanje, ili skladištenje solarne energije u zemlju onda kada je ima i korištenje u dane kada je nema.

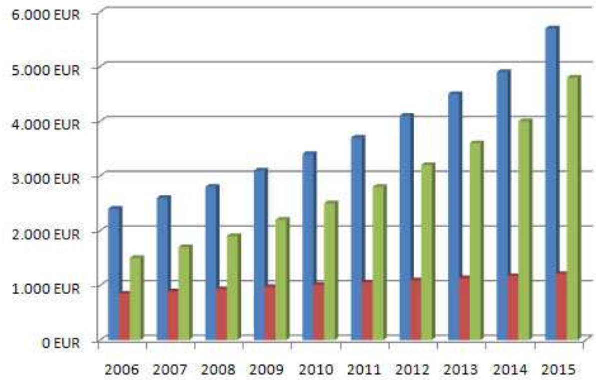
3. PRIMJENA TOPLOTNIH PUMPA U SVIJETU

Sistemi grijanja, koji koriste toplotne pumpe upotrebljavaju se više decenija u svijetu. U Tokiju je 1932. godine instalirana jedna od prvih toplotnih pumpi na svijetu. Gradska kuća u Cirihu se od 1938. godine grije toplotnom pumpom. Danas milioni toplotnih pumpi zagrijavaju stanove i kuće širom zapadne Evrope, Kanade i SAD-a. Od svih alternativnih grijanja najveću perspektivu imaju toplotne pumpe.

Prednosti toplotnih pumpi su daleko veće od njihovih mana, tako da njihova primjena naglo raste u razvijenim zemljama svijeta (Slika 7.). Ekonomska opravdanost upotrebe geotermalnih sistema i ušteda u odnosu na klasične sisteme grijanja prikazana je na dijagramu na Slici 8. Na ordinati je data godišnja potrošnja za grijanje i hlađenje za tri sistema (uobičajni sistemi -prirodni gas i električna energija, sistemi sa toplotnom pompom za grijanje na električnu energiju i sistemi sa toplotnom pumpom) , a na apscisi godina (Slika 8.).



Slika 7. Primjena toplotnih pumpi u svijetu



Slika 8. Troškovi korištenja uobičajnih i geotermalnih sistema

4. ZAKLJUČAK

Geotermalni sistemi omogućavaju grijanje i hlađenje, za razliku od uobičajenih sistema koji služe ili za grijanje ili za hlađenje. Za istu cijenu dobije se uređaj sa dvostrukom namjenom.

Pojačan trend rasta primjene toplotnih pumpi proizilazi iz njihovih prednosti: smanjuju troškove grijanja do 75%, zauzimaju mal prostor, imaju tih rad, ne zahtjevaju spremište goriva, u primjeni su bezopasne, u potpunosti su automatizirane, dugo traju bez većih kvarova, neovisne su o stalnom rastu cijena klasičnih energenata, niski pogonski troškovi i amortizacija za par godina ako su zadovoljeni uslovi toplotne izolacije zgrade.

Vlade zemalja Evropske unije zagovaraju korišćenje alternativnih i obnovljivih izvora energije (u koje primarno mesto zauzimaju toplotne pumpe) iz slijedećih razloga: velika ušteda energije, zaštita čovekove okoline, energetska nezavisnost u odnosu na druge uvozne energente npr. gas i nafta i isključena mogućnost od požara.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

STEPEN EFIKASNOSTI CROSS-FLOW TURBINE

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ABSTRAKT
Cross-flow turbine su naročito efikasne kada se koriste u protočnim malim hidroelektranama jer imaju skoro konstantan stepen efikasnosti za promjenu protoka od 15% do 100% od $Q_{inst.}$,[1] *, a što je najčešći slučaj u Bosni i Hercegovini, pa su i ove turbine veoma zanimljive za naše tržište. Relativno su jednostavne za izradu, u odnosu na druge turbine, a cjenom su dosta pristupačnije.*
Kao pokazatelj značaja ovih turbina, posebno za naše uslove, data je komparacija Francis i Cross-flow turbina za jednu aktuelnu malu hidroelektranu „Željeznica 1„, gdje se želi pokazati kako u slučaju protočne hidroelektrane, a što je za male HE u BiH najčešći slučaj, Cross-flow turbina daje dosta veću proizvodnju, znači bolje rezultate, a u isto vrijeme je njena cijena manja za oko 30% ,[3].
Ključne riječi: turbine 1, Cross – flow 2, stepen efikasnosti 3, protok 4.

1. UVOD

Sa tehnološkim razvojem čovječanstva, posebno u zadnje tri decenije, došlo je do naglog zaoštravanja problema koje čovjek svojim uticajem i načinom života ima na Planetu. Taj problem sastoji se u energiji, vodi i životnoj sredini kao tri najkrupnija globalna problema Planete, a od čijeg riješavanja sve neposrednije zavisi i sam opstanak naše civilizacije. Sadašnji način života i pogodnosti koje on pruža nezamislive su bez energije, koja na žalost da bi se iskoristila ima niz loših uticaja na našu životnu sredinu, kako direktno, zagađivanjem i uništavanjem prostora, tako i indirektno, globalnim zatopljavanjem i promjenom klime. Međutim, jasno je da energetika predstavlja ključni instrument privrednog i socijalnog razvoja, njegov podsticajni, ali i ograničavajući faktor.

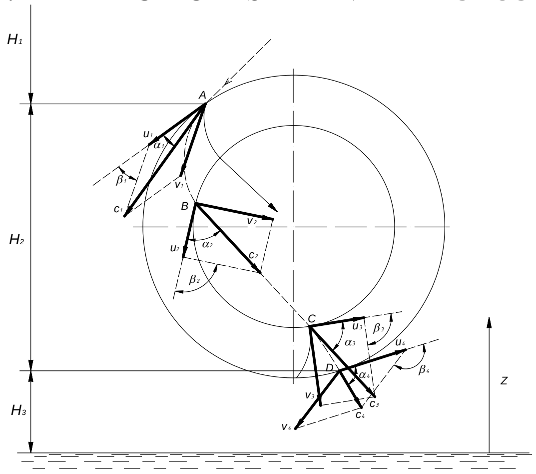
Istraživanja u energetici jasno su pokazala da su energetski resursi čitave Planete ograničeni, da su najvećim dijelom neobnovljivi i neravnomjerno raspoređeni, ali i da je intenzivna eksploatacija energenata, prije svega fosilnih goriva, glavni uzročnik ekoloških problema u atmosferi. Znači da je problem energije postao globalni problem naše planete.

Na Konvenciji koja je održana 11. decembra 1997. godine u Japanskom gradu Kjoto (Kyoto) nastao je Protokol iz Kjota. Predstavlja prvi međunarodni ugovor na globalnom nivou kojim se omogućava primjena ekonomskih instrumenta kroz različite mehanizme prilagodljivosti, a sve sa ciljem povećanog ulaganja u obnovljive izvore energije.

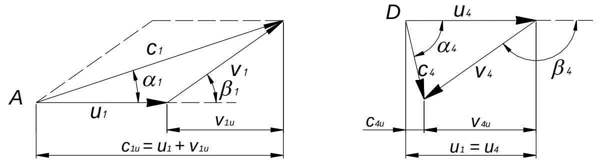
EU je predstavila vrlo ambiciozan plan u Kopenhagenu 2009. godine za smanjenje emisija štetnih plinova od 20% do 2020. godine u odnosu na referentnu 1990. godinu, a kako bi se taj cilj mogao postići jedan od glavnih uvjeta jeste nastavak i povećano investiranje u obnovljive izvore energije.Ovo energetsko otrežnjenje je uticalo da države, posebno one razvijene, počnu drugim mjerilima da razmatraju mogućnost iskorištenja svojih hidroenergetskih potencijala, kao najracionalnijeg i najčistijeg obnovljivog izvora energije, a prednosti ove energije su sljedeće:

- pogonsko „gorivo“ je neiscrpno i stalno na raspolaganju zahvaljujući energiji sunca,
- hidroenergetska postrojenja uz racionalno planiranje pomažu riješavanju vodoprivrednih problema vodotoka, odnosno vodnih snaga, a time i vodoprivrede u cjelini (navodnjavanje, rješavanje problema poplava, probleme plovidbe, zaštite od podzemnih voda, erozija, itd.)
- hidroenergetska postrojenja su izvori energije koji pomažu zaštiti čovjekove okoline, što je trenutno centralni problem u Svijetu.

2. HIDRAULIČKI STEPEN EFIKASNOSTI



Slika 1. Trouglovi brzina na rotoru [6]



Slika 2. Trouglovi brzina na rotoru u tačkama A i D [6]

Stepen efikasnosti turbine se dobija iz odnosa energije koja se preda radnom kolu L_{izl} i dovedene energije radnom kolu L_{ul} [4], [6]:

$$\eta = \frac{L_{izl}}{L_{ul}} \qquad ...(1)$$

Energija dovedena radnom kolu je:

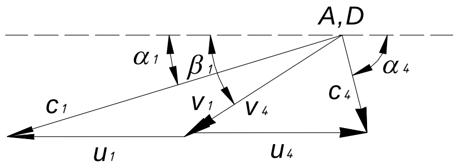
$$L_{ul} = \rho g Q H \qquad ...(2)$$

Uvrštavanjem u gornju jednačinu izraza za brzinu vode na ulazu u rotor $c_1 = \Psi\sqrt{2gH}$ dobijamo:

$$L_{ul} = \rho g Q \frac{c_1^2}{2g\Psi^2} = \rho Q \frac{c_1^2}{2\Psi^2} \qquad ...(3)$$

Radnom kolu se predaje energija:

$$L_{izl} = \rho g Q H_{th} = \frac{\rho g Q}{g}(u_1 c_{1u} - u_1 c_{4u}) = \rho Q u_1 (c_{1u} - c_{4u}) \qquad ...(4)$$



Slika 3. Trouglovi brzina u tačkama A i D (uzimajući koeficijent φ u obzir)[6]

Konaćni izraz za stepen efikasnosti se dobija iz trouglova brzina:

$$\eta = 2\Psi^2 \frac{u_1}{c_1}\left(1 + \varphi \frac{cos\beta_4}{cos\beta_1}\right)(cos\alpha_1 - \frac{u_1}{c_1})$$

...(7)

Za $\beta_4 = \beta_1$, slijedi:

$$\eta = 2\Psi^2 \frac{u_1}{c_1}(1 + \varphi)(cos\alpha_1 - \frac{u_1}{c_1})$$

...(8)

Kako su sve varijable konstantne osim stepena efikasnosti i $\frac{u_1}{c_1}$, diferenciranjem i izjednačavanjem sa nulom dobijamo izraz za maksimalni hidraulički stepen efikasnosti:

$$\frac{d\eta}{d\left(\frac{u_1}{c_1}\right)} = 0$$

...(9)

Pa dobijamo:

$$\frac{u_1}{c_1} = \frac{cos\alpha_1}{2}$$

...(10)

Maksimalni hidraulički stepen efikasnosti je:

$$\eta_{max} = \frac{1}{2}\Psi^2 \frac{u_1}{c_1}(1 + \varphi)cos^2\alpha_1$$

...(11)

Uz pretpostavku da nemamo gubitaka usljed trenja u mlaznici i lopaticama, možemo uzeti da su empirijski koeficijenti Ψ i φ:

$$\Psi = 1, \varphi = 1,$$

...(12)

Onda je stepen efikasnosti [2]:

$$\eta_{max} = cos^2\alpha_1$$

...(13)

Da bi dobili najveći stepen efikasnsoti, ulazni ugao α_1 mora biti što manji. Preporučena optimalna vrijednost za ovaj ugao je 16°.

$$\eta_{max} = cos^2 16 = 0{,}92$$

...(14)

Uzimajući u obzir gubitke u mlaznici i lopaticama, vrijednosti empirijskih koeficijenata su:

$$\Psi = 0{,}98 \,, \varphi = 0{,}98$$

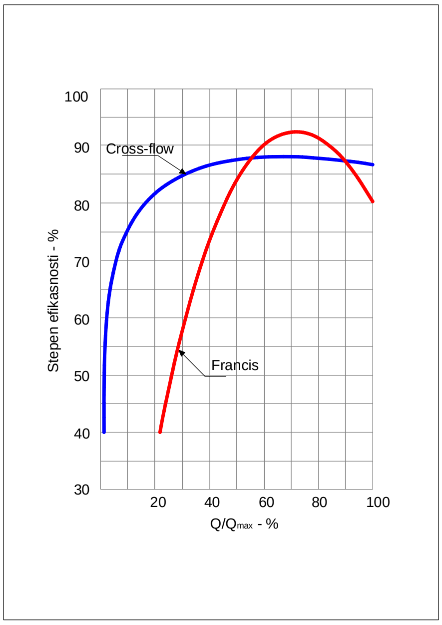
...(15)

Dobijamo:

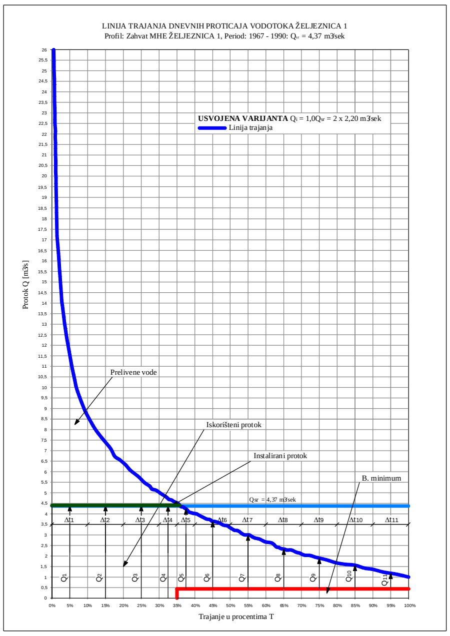
$$\eta_{max} = 0{,}878$$

...(16)

3. MHE ŽELJEZNICA 1: PRORAČUN I KOMPARATIVNA ANALIZA OSNOVNIH ENERGETSKIH PARAMETARA ELEKTRANE SA FRANCIS , ODNOSNO CROSS-FLOW TURBINAMA



Slika 4.Krive stepena iskorištenja Francis i Cross-flow turbina – novelirani podaci [3]



Slika 5. Usvojena linija trajanja dnevnih proticaja vodotoka Željeznica 1 [3]

3.1. MHE Željeznica 1 opremljena sa Francis turbinom

Za mHE Željeznica 1 sačinjeno je Idejno riješenje elektrane. Elektrana se nalazi na rijeci Željeznici, koja zajedno sa rijekom Dragačom čini Fojničku rijeku, lijevu pritoku rijeke Bosne. Srednji protok na zahvatu je 4,37 m^3/s, a bruto pad 33,85 m. Od zahvata do strojare, rade se dovodni tlačni cjevovodi dužine 2853,6 m, promjera 1600 mm. Biološki minimum u premoštenom koritu je 0,44 m^3/s. Elektrana je opremljena sa dvije iste Francis turbine čiji su osnovni parametri kako slijedi:

- Bruto pad: H_{br} = 33,85 m,
- Gubici pada pri Q_{inst}: ΔH = 5,55 m,
- Nominalni pad: H_n = 28,30 m,
- Instalisani nazivni protok: $Q_{inst.}$ = 2 x 2,20 m^3/s,
- Instalisana nazivna snaga: P_n = 2 x 492 kW,
- Stepen iskorištenja pri Q_n: η_n = 0,80
- Tehnički minimum: Q_{min} = 0,20 Q_{inst},

- **Stepen iskorištenja u %:**	**35**	**58**	**74**	**84**	**90**	**92**	**91**	**87**	**80**
- **Za odnos Q/Q_n u %:**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**

- Brzina vrtnje: n_n = 750 o/min,
- Promjer rotora: D = 600 mm
- Troškovi nabavke i montaže turbine C = 2 x 270.000 KM

Na bazi prethodnih parametara noveliranih krivulja stepena iskorištenja hidrauličnih turbina i krive trajanja dnevnih proticaja, Profil – Zahvat mHE Željeznice 1, za period 1967 – 1990.god, izračunate su snage i proizvodnje mHE Željeznica 1, te sačinjeni godišnji bilansi energije i dati u tabeli 1. Novelirane krive stepena iskorištenja su nastale na bazi odgovarajućih proračuna stepena iskorištenja (poglavlje br.

2) i na bazi detaljnih hidrauličkih ispitivanja modela u laboratorijama kao i montiranih turbina u hidroelektranama (feeld test).

MHE ŽELJEZNICA 1

USVOJENA VARIJANTA Qi=1,0 Qsr=2x2,20 m^3/sek, TURBINE TIPA FRANCIS

SNAGE I PROIZVODNJE ELEKTRANE

Tabela br.

Redn i br.	Q_{isk} [m^3/sec]	Q_{isk} [%]	Hbr [m]	ΔH [m]	Hn [m]	η_{turb}	$\eta_{mul.}$	η_{gen}	η_{tran}	P [kW]	Δt_{isk} [h]	E_{isk} [kWh]	V_{isk} [m^3]
1	4,40	100	33,85	5,55	28,30	0,80	-	0,93	0,99	899,74	876	788.171	13.875.840
2	4,40	100	33,85	5,55	28,30	0,80	-	0,93	0,99	899,74	876	788.171	13.875.840
3	4,40	100	33,85	5,55	28,30	0,80	-	0,93	0,99	899,74	876	788.171	13.875.840
4	4,40	100	33,85	5,55	28,30	0,80	-	0,93	0,99	899,74	438	394.085	6.937.920
5	3,60	82	33,85	3,72	30,13	0,90	-	0,93	0,99	881,86	438	386.254	5.676.480
6	3,10	70	33,85	2,75	31,10	0,92	-	0,93	0,99	800,99	876	701.669	9.776.160
7	2,40	55	33,85	1,65	32,20	0,88	-	0,93	0,99	614,21	876	538.052	7.568.640
8	1,80	41	33,85	0,93	32,92	0,75	-	0,93	0,99	401,42	876	351.642	5.676.480
9	1,40	32	33,85	0,56	33,29	0,61	-	0,93	0,99	256,76	876	224.925	4.415.040
10	1,10	25	33,85	0,35	33,50	0,47	-	0,93	0,99	156,45	876	137.046	3.468.960
11	0,80	18	33,85	0,18	33,67	0,30	-	0,93	0,99	72,98	876	63.929	2.522.880
											8.760	**5.162.116**	**87.670.080**

BILANS ENERGIJE

Koeficjent iskorištenja;	$K = E_{isk} \times 3.600 / V_{isk} \times H_n = 7,5$
Mugući godišnja proizvodnja;	E_{is}= Er-Epmv-Epvv-Evm=5.169.543 kWh
Energija v.minimuma	E_{vm}=7,5 x 0.44 x 28,30 x 0,65 x 8.760 =531.067 kWh
Energija preljeva v. vode;	E_{pvv}=7,5 x 3,80 x 28,30 x 0,35 x 8.760 = 2.469.645 kWh
Energija preljeva m.vode;	E_{pmv}=7,5 x 0,00 x 28,30 x 0,00 x 8.760 = 0 kWh

Tabela 1. Snage i proizvodnje MHE Željeznica 1 sa turbinom tipa Francis.

3.2. MHE Željeznica 1 opremljena sa Cross-flow turbinama

Parametri i troškovi izgradnje građevinskih objekata, zahvata, tlačnog cjevovoda i strojare ostaju nepromjenjeni. Neke manje promjene biti će na strojari, ali su i one zanemarene zbog približno istih gabarita Francis i Cross-flow turbina, odnosno strojare. Ugradnjom Cross-flow turbina, umjesto Francisovih, promijenit će se energetski parametri elektrane i troškovi izgradnje, budući da je cijena nabavke i montaže Cross-flow turbina manja od Francisovih za oko (20 do 30)%. mHE će sada biti opremljena sa dvije iste Cross-flow turbine čiji su osnovni energetski parametri kako slijedi:

- Bruto pad: H_{br} = 33,85 m,
- Gubici pada pri Q_{inst}: ΔH = 5,55 m,
- Nominalni pad: H_n = 28,30 m,
- Instalisani nazivni protok: Q_{inst} = 2 x 2,20 m^3/s,
- Instalisana nazivna snaga: P_n = 2 x 531 kW,
- Stepen iskorištenja pri Q_n: η_n = 0,87
- Tehnički minimum: Q_{min} = 0,10 Q_{inst},

- **Stepen iskorištenja u %:**	**75**	**82**	**85**	**87**	**88**	**88**	**88**	**88**	**87**	**87**
- **Za odnos Q/Q_n u %:**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**

- Brzina vrtnje: n_n = 220 o/min,
- Promjer rotora: D/l = 960/1160 mm
- Troškovi nabavke i montaže turbine C = 2 x 190.000 KM
-

Na bazi prethodnih parametara noveliranih krivulja stepena iskorištenja hidrauličkih turbina i krive trajanja dnevnih proticaja, Profil – Zahvat mHE Željeznica 1, za period 1967 – 1990.god izračunate su snage i proizvodnje mHE Željeznica 1, te sačinjeni godišnji bilansi energije i dati u tabeli 2. Nivelirane krive stepena iskorištenja su nastale na bazi odgovarajućih proračuna stepena iskorištenja (poglavlje br.2) i na bazi detaljnih hidrauličkih ispitivanja modela u laboratorijama i montiranih turbina u hidroelektranama (feeld test). Zbog malog broja okretaja, oko 220 o/min, mora se ugraditi multiplikator broja okretaja prenosnog odnosa $n_1/n_2 = 220/1000\ o/min$. Prosječan stepen iskorištenja multiplikatora, η_{mp} je oko 98% što će biti uzeto u obzir kod izračunavanja godišnjeg bilansa energije i snage.

MHE ŽELJEZNICA 1
USVOJENA VARIJANTA Qi=1,0 Qsr=2x2,20 m^3/sek, TURBINE TIPA CROSS-FLOW
SNAGE I PROIZVODNJE ELEKTRANE
Tabela br.

Redn i br.	Q_{isk} [m^3/sec]	Q_{isk} [%]	Hbr [m]	ΔH [m]	Hn [m]	η_{turb}	$\eta_{mul.}$	η_{gen}	η_{tran}	P [kW]	Δt_{isk} [h]	E_{isk} [kWh]	V_{isk} [m^3]
1	4,40	100	33,85	5,55	28,30	0,87	0,98	0,93	0,99	958,90	876	839.993	13.875.840
2	4,40	100	33,85	5,55	28,30	0,87	0,98	0,93	0,99	958,90	876	839.993	13.875.840
3	4,40	100	33,85	5,55	28,30	0,87	0,98	0,93	0,99	958,90	876	839.993	13.875.840
4	4,40	100	33,85	5,55	28,30	0,87	0,98	0,93	0,99	958,90	438	419.997	6.937.920
5	3,60	82	33,85	3,72	30,13	0,88	0,98	0,93	0,99	845,02	438	370.117	5.676.480
6	3,10	70	33,85	2,75	31,10	0,88	0,98	0,93	0,99	750,84	876	657.738	9.776.160
7	2,40	55	33,85	1,65	32,20	0,88	0,98	0,93	0,99	601,93	876	527.291	7.568.640
8	1,80	41	33,85	0,93	32,92	0,87	0,98	0,93	0,99	456,33	876	399.746	5.676.480
9	1,40	32	33,85	0,56	33,29	0,85	0,98	0,93	0,99	350,63	876	307.152	4.415.040
10	1,10	25	33,85	0,35	33,50	0,83	0,98	0,93	0,99	270,75	876	237.177	3.468.960
11	0,80	18	33,85	0,18	33,67	0,81	0,98	0,93	0,99	193,10	876	169.157	2.522.880
											8.760	**5.608.356**	**87.670.080**

BILANS ENERGIJE

Koeficjent iskorištenja;	$K = E_{isk}$ x 3.600 / V_{isk} x H_n = 8,1
Muguća godišnja proizvodnja;	E_{is}= Er-Epmv-Epvv-Evm=5.616.425 kWh
Energija v.minimuma	E_{vm}=8,1 x 0.44 x 28,30 x 0,65 x 8.760 =576.975 kWh
Energija preljeva v. vode;	E_{pvv}=8,1 x 3,80 x 28,30 x 0,35 x 8.760 = 2.683.134 kWh
Energija preljeva m.vode;	E_{pmv}=7,5 x 0,00 x 28,30 x 0,00 x 8.760 = 0 kWh

Tabela 2. Snage i proizvodnje MHE Željeznica 1 sa turbinom tipa Cross-flow.

4. ANALIZA I UPOREDBA DOBIJENIH REZULTATA

Snage, proizvodnje i bilansi energija za mHE Željeznica 1, opremljene sa Francis turbinom su date u tabeli 1, a za mHE Željeznicu 1 opremljenu sa Cross-flow turbinama u tabeli 2. Analizirajući i upoređujući dobijene rezultate može se konstatovati da su prednosti ugradnje Cross-flow turbina, u odnosu na Francis turbine kako slijedi:

- veći stepen iskorištenja raspoložive hidroenergije za:

$$[(8{,}10 - 7{,}50)/7{,}50] \cdot 100 = 8{,}00\%$$

- veća godišnja proizvodnja elektrane za:

$$[(5{,}61 - 5{,}16)/5{,}16] \cdot 100 = 8{,}72\%$$

- veća instalisana snaga elektrane za:

$$[(2 \cdot 479 - 2 \cdot 450)/2 \cdot 450] \cdot 100 = 6{,}44\%$$

- manji tehnički minimum za 10% Q_{inst}
- manja brzina pobjega i jeftiniji generator
- manji troškovi nabavke i montaže turbine za (20 do 30)%

5. ZAKLJUČAK

Shodno analizama i proračunima datim u ovom radu može se donijeti sljedeći zaključak : Zbog mogućnosti velikog područja upotrebe Cross-flow turbine s protokom od 0,050 do 10,2 m^3/s i visinom pada od 1,5 do 120 m, one mogu praktično da zamjene sve tipove turbina, i zbog toga se budućim investitorima i projektantima MHE predlaže da obavezno, prije donošenja konačne odluke o odabiru turbine, naprave odgovarajuće proračune i snage kao što je to urađeno u poglavlju 3. ovog rada.

6. REFERENCE

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ENERGETSKI I EKOLOŠKI EFEKTI PRIMJENE BIODIZELA U DRUMSKOM TRANSPORTU

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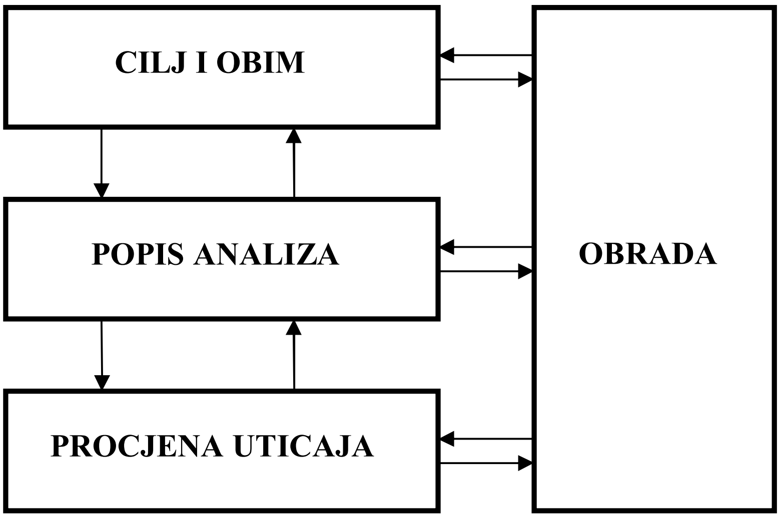
REZIME
S obzirom da su rezerve konvencionalnih goriva fosilnog porijekla ograničene, a da je drumski transport i dalje skoro u potpunosti zavisan od fosilnih goriva, automobilska industrija je prinuđena na pronalaženje novih rješenja u vidu primjene alternativnih goriva, iz obnovljivih energetskih izvora.
Biodizel je već neko vrijeme prepoznat kao ozbiljna alternativa klasičnom gorivu za dizel motore, a njegovo korišćenje ima veliki potencijalni značaj i sa energetskog i sa ekološkog aspekta.
Studije koje su rađene za biodizel, pokazuju da je njegov ukupni energetski bilans pozitivan, iako je gorivo nižeg energetskog sadržaja u odnosu na klasični dizel.
Primjena biodizela u poređenju sa klasičnim dizelom, takođe, obezbjeđuje smanjenje emisije sumpornih oksida, suspendovanih čestica i ugljenmonoksida.
Imajući to u vidu, u ovom radu je analiziran energetski potencijal biodizela, kao i uticaj biodizela na životnu sredinu, sa stanovišta njegove primjene kao pogonskog goriva u drumskom transportu.
Ključne riječi: drumski transport, biodizel, energetski bilans, životna sredina

1. UVOD
Potrošnja energije u svijetu je u stalnom porastu i pored niza mjera koje se preduzimaju u cilju racionalnijeg i efikasnijeg njenog korišćenja u svim oblastima. Istovremeno se zalihe fosilnih goriva značajno smanjuju, tako da će većina zemalja biti primorana da koristi alternativne, obnovljive izvore energije za podmirivanje svojih energetskih potreba, posebno u sektoru transporta.
Značajno mjesto u zamjeni klasičnih fosilnih goriva sa novim, obnovljivim gorivima zauzima biodizel. Biodizel je ekološki prihvatljivo gorivo za dizel motore. Dobija se procesom transesterifikacije iz biljnih ulja i životinjskih masti. Ima visok energetski potencijal, budući da su biljna ulja jedna od najbogatijih organskih materija (sagorijevanjem 1 g ulja dobija se oko 9.6 kCal ili 38.7 kJ energije). Pozitivnom energetskom i ekonomskom bilansu proizvodnje biodizela doprinosi i mogućnost efektivnog korišćenja nusproizvoda.
Druga važna karakteristika biodizela je da zatvara krug proizvodnje i potrošnje CO_2, čime se obezbjeđuje minimalan efekat staklene bašte. Biodizel je biorazgradiv, ne sadrži sumpor, smanjuje dimnost, nije toksičan, poboljšava mazivost a istovremeno obezbjeđuje dobre performanse motora i visoku pouzdanost u radu. Koristi se kao čist ili se miješa sa gorivima fosilnog porijekla u odgovarajućim odnosima. Može se bez problema koristiti na klasičnim dizel motorima bez bitnijih prepravki (dovoljna je zamjena zaptivača i crijeva u sistemu za napajanje motora gorivom).
U ovom radu je analiziran energetski bilans biodizela dobijenog iz ulja uljane repice, kao i ekološki efekti njegove primjene u drumskom transportu.

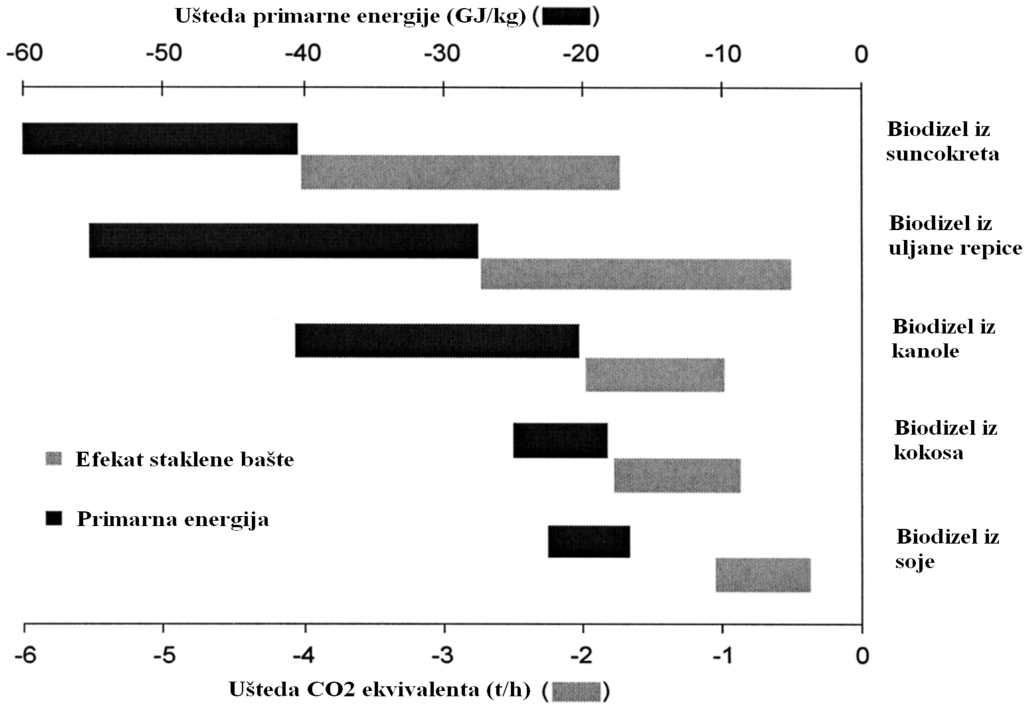
2. ENERGETSKI BILANS BIODIZELA

Procjena energetskog bilansa goriva ne uključuje samo energetski sadržaj biodizela i energiju koja se neposredno utroši u njegovoj proizvodnji, nego i energiju koja se odaje ili apsorbuje od strane svih procesa potrebnih za dobijanje biodizela. Većina studija rađenih sa ciljem davanja odgovora o energetskom stanju biodizela pokazuje da je ukupni energetski bilans biodizela pozitivan, [5].
Postoji veliki broj metoda o procjeni energetskog bilansa biodizela i njegovog uticaja na životnu sredinu. Standardizovan pristup (ISO 14040-43) predstavlja LCA (life-cycle assessment) metoda.
U osnovi, LCA metoda se sprovodi u četiri koraka, kao što je prikazano na slici 1.

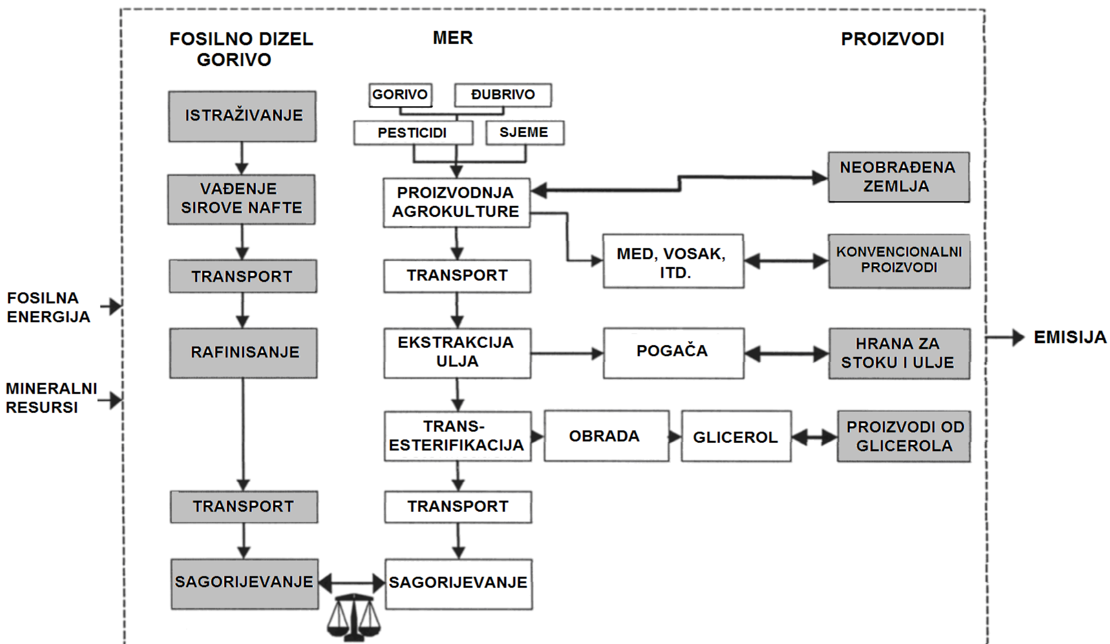


Slika 1. LCA metoda po ISO 14040-43

Za dobijanje biodizela moguće je koristiti više kultura (uljana repica, suncokret, kanola, kokos, soja, palma,...). Izbor kultura zavisi od područja u kojima se uzgajaju, tj. od klimatskih uslova. Različite kulture imaju i različit energetski potencijal, pa tako npr. metil ester uljane repice i suncokreta ima znatno veći energetski potencijal od npr. soje (slika 2). Upravo zbog toga, najveći procenat biodizela (oko 82 %) dobija se iz uljane repice.
Proces dobijanja biodizela iz uljane repice počinje korišćenjem dizel goriva i đubriva u procesu obrade zemljišta na kojem se uzgaja repa. Sa slike 3 se vidi da se u cjelokupnom procesu dobijanja biodizela (RME – repični metil-estar), počevši od pripreme zemljišta i sjetve repice, može dobiti niz drugih proizvoda. Tako na primjer, repa je u procesu cvjetanja veoma povoljna za proizvodnju meda i drugih pčelinjih prizvoda. Na kraju se izdvajaju pogača i sačma kao ostatak, a kao finalni proizvod biodizel i glicerin. Upotreba pogače i sačme u ishrani stoke je zbog svojih energetskih vrijednosti postala veoma važna, tako da je njihova proizvodnja u nekim postrojenjima za proizvodnju biodizelskog goriva u Evropskoj uniji postala primarni proizvod. Glicerol koji se dobija u postupku proizvodnje biodizela može se koristiti u mnoge svhe, prije svega u hemijskoj industriji, a zamjenjuje sintetički proizveden glicerol.



Slika 2. Energetski bilans i ekološki efekti biodizela u poređenju sa klasičnim dizel gorivom



Slika 3. Uporedni prikaz procesa dobijanja dizela i biodizela iz uljane repice (RME)

U tabeli 1 su dati rezultati uporednog ispitivanja LCA metodom za biodizel i klasični dizel, za slučaj modernih dizel vozila (Euro 4 standard) na evropskim drumovima, [1]. U tabeli su prvo prikazane energetske vrijednosti u cjelokupnom postupku dobijanja biodizela, a zatim i odgovarajući ekološki efekti. Vidi se da ukupan energetski ulaz obuhvata: energiju potrebnu za proizvodnju uljane repice (obrada zemljišta, đubrivo, agro-hemija, sjeme), energiju potrebnu za proces dobijanja ulja iz uljane repice (ekstrakcija, rafinacija, esterifikacija) kao i energiju potrebnu za skladištenje, treansport itd. Energetski izlaz, dakle, obuhvata biodizel, pogaču, stabljiku i glicerol.

Korak u LCA	Ukupna potrebna energija (MJ/kg)	CO2 ekvivalent (g/kg)	NOx (g/kg)	SO2 ekvivalent (g/kg)
Proizvodnja uljane repice				
Drljanje	0.86	66	0.638	0.488
Oranje	0.66	50	0.486	0.372
Sjetva	0.33	25	0.263	0.2
Žetva	0.67	51	0.482	0.369
Sjeme	0.01	2	0.004	0.017
N đubrivo	7.19	1,124	2.303	4.216
P đubrivo	0.95	64	0.235	0.598
K đubrivo	0.31	20	0.034	0.032
Ca đubrivo	0.04	6	0.01	0.009
Biocidi	0.33	15	0.019	0.059
Emisija	0	619	0	11.079
Ukupno	11.36	2,042	4.474	17.441
Snabdjevanje				
Čuvanje pčela	0.32	29	0.064	0.121
Skladištenje	1.36	98	0.066	0.186
Transport	0.42	32	0.417	0.313
Ekstrakcija ulja	3.05	181	0.261	0.41
Heksan	0.16	2	0.003	0.007
Prečišćavanje	0.54	31	0.043	0.064
Valjanje zemlje	0.02	1	0.008	0.011
Fosforna kisjelina	0.01	1	0.003	0.013
Esterifikacija	2.44	143	0.191	0.303
Metanol	4.81	352	0.136	0.347
Masna soda	0.12	8	0.009	0.027
Tretman glicerola	0.24	14	0.019	0.026
Ukupno	13.49	893	1.219	1.83
Upotrebljena energija				
Transport	0.22	17	0.158	0.12
Utrošak	0	216	10.19	7.316
Ukupno	0.22	233	10.348	7.437
Dodatni proizvodi				
Referentni sistem	–0.83	–67	–0.616	–0.485
Med	–0.24	–17	–0.059	–0.090
Proizvodi od meda	–0.03	–2	–0.003	–0.006
Pogača (agrik.)	–4.46	–318	–1.305	–1.485
Hrana za stoku (transp.)	–2.03	–162	–1.263	–1.697
Energija glicerola	–10.30	–758	–1.015	–4.421
Hlor	–4.01	–275	–0.293	–0.918
Masna soda	–2.68	–184	–0.197	–0.614
Propilen	–7.03	–188	–0.247	–0.751
Subtotal	–31.61	–1,971	–4.998	–10.467
Dizel gorivo				
Snabdjevanje	4.82	374	0.649	1.825
Utrošak	42.96	3,392	10.19	8.101
Ukupno	47.78	3,766	10.839	9.925
RME minus dizel gorivo	–54.32	–2,569	0.204	6.316

Tabela 1. Uporedni prikaz utroška energije i odgovarajuće emisije (CO_2, NO_X, SO_2) u postupku dobijanja biodizela iz uljane repice (RME) i dizel goriva, po LCA metodi

Sve vrijednosti u tabeli 1 se odnose na 1 kg dizel goriva, odnosno, 1 kg dizel goriva ekvivalentnog sa RME, uz istu količinu korisne energije. Negativne vrijednosti predstavljaju prednosti biodizela.

Evidentno je sledeće:

- RME (metil-ester repičnog ulja) prikazuje pozitivan energetski bilans i ravnotežu gasova koji utiču na klimatske promjene. RME čuva rezerve energije iz fosilnih izvora i pomaže u smanjenju štetnih gasova koji stvaraju efekat staklene bašte.
- Sa druge strane, RME povećava emisiju u procesima acidifikacije i eutrofikacije u poređenju sa dizel gorivom.
- O uticaju razmatranih goriva na stvaranja smoga i ozona nema preciznih podataka, jer ne postoji precizno utvrđen model analize. Različiti modeli daju različite rezultate.

3. EKOLOŠKI ASPEKTI PRIMJENE BIODIZELA

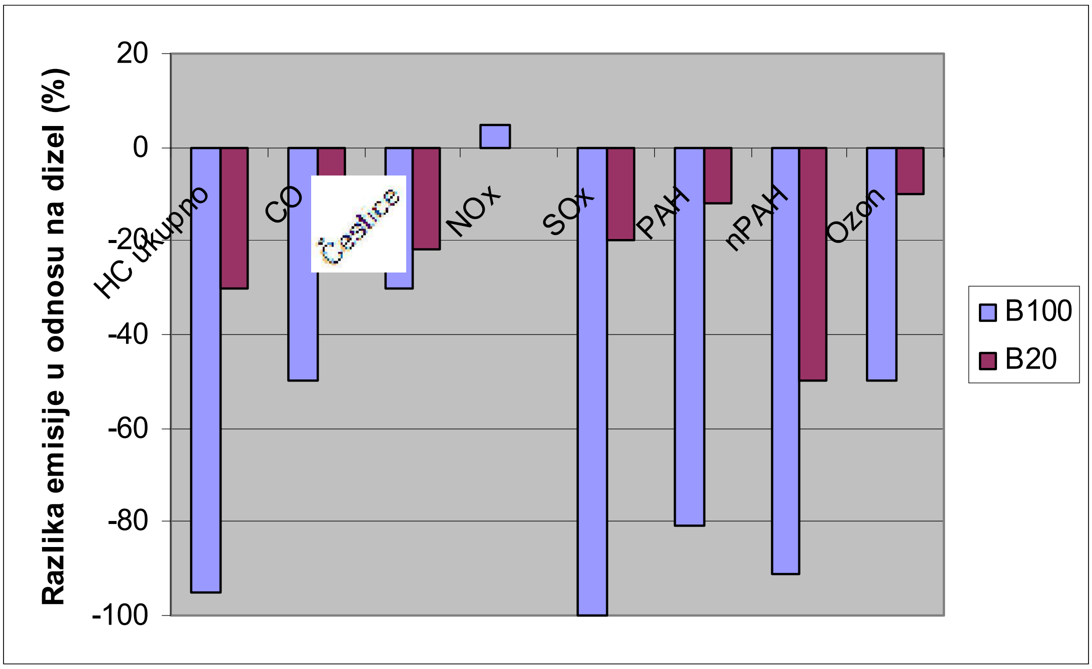
Povećana emisija gasova koji učestvuju u stvaranju efekta staklene bašte i njihov uticaj na globalnu klimu su razlozi zbog kojih se Evropska unija obavezala da smanji ukupnu emisiju gasova. U skladu sa konferencijom iz Rio de Žaneira i Kjoto protokolom, potrebno je smanjiti emisiju gasova staklene bašte za 8 % do 2012-te godine, u poređenju sa 1990-om.
Korišćenje biodizela u poređenju sa fosilnim dizelom je veoma povoljno sa stanovišta zaštite životne sredine jer značajno utiče na smanjenje efekta staklene bašte i emisiju drugih zagađujućih materija. Biodizel ima odgovarajuće prednosti i mane u poređenju sa dizel gorivom fosilnog porijekla. Prednosti koje se mogu kvantitativno opisati su očuvanje ograničenih energetskih resursa i smanjenje efekta staklene bašte a ekološki nedostaci su eutrofikacija i acidifikacija. Ostali efekti se uobičajeno kvalitativno procjenjuju.
U tabeli 2 prikazane su neke prednosti i nedostaci korišćenja biodizela.

	Prednosti biodizela	**Nedostaci biodizela**
Potražnja resursa	Očuvanje ograničenih energetskih resursa	Potrošnja mineralnih resursa
Efekat staklene bašte	Niža emisija gasova staklene bašte	
Potrošnja ozona		Povečana emisija N_2O
Acidifikacija		Povećana acidifikacija
Eutrofikacija		- Povećana emisija NO_x - Eutrofikacija površinskih voda
Uticaj toksičnih materija na čovjeka i životnu sredinu	- Niža emisija SO_2 - Nižaemisija čestica u naseljenim područijima - Nema zagađenje okeana usled ekstrakcije i transporta sirove nafte - Nema zagađenja usled prolivanja nafte poslije nezgoda - Netoksičan/bolje biorazgradiv	- Zagađenje površinskih voda pesticidima - Zagađenje podzemnih voda nitratima

Tabela 2. Prednosti i nedostaci biodizela dobijenog iz ulja uljane repice, u poređenju sa konvencionalnim dizel gorivom

Pored LCA metode, najčešće korišćeni pristup u analizi uticaja na životnu sredinu je tzv. WTW (Well-to-Wheel) pristup, gdje se vrši mjerenje neto emisije tokom cjelokupnog lanca: primarna proizvodnja – krajnja potrošnja. Osnovna prednost upotrebe biodizela je u značajnom smanjenju emisije ugljen-dioksida, redukovanoj emisiji oksida sumpora, suspendovanih čestica i ugljen-monoksida (slika 4).
Na WTW bazi, svaka tona fosilnog dizela odaje oko 2.8 t ugljen-dioksida u atmosferu, dok jedna tona biodizela odaje oko 2.4 t ugljen-dioksida. Međutim, ovaj ugljen-dioksid će skoro u potpunosti biti iskorišćen od strane usjeva koji će dati sirovinu za proizvodnju ulja i apsorbovan kroz ugljenični ciklus (kao glicerol i čvrsti otpad). Prema tome, uzgajanjem uljane repice i proizvodnjom ekološki

prihvatljivog goriva, njegovim sagorijevanjem i ponovnim uzgajanjem repice, stvara se djelimično zatvoren i ekološki povoljan lanac nastajanja i potrošnje ugljen-dioksida.



Slika 4. Emisija različitih supstanci pri korišćenju biodizela, u poređenju sa klasičnim dizelom

Oksidi sumpora koji se oslobađaju u atmosferu, sagorijevanjem goriva, doprinose stvaranju kisjelih kiša. i sa tog stanovišta biodizel je u prednosti, jer gotovo da i ne sadrži sumpor.
Jedino je u porastu emisija oksida azota, usled visokih temperatura u procesu sagorijevanja i povećanog prisustva kiseonika u gorivu. Koncentracija azotnih oksida se povećava sa povećanjem udjela biodizela u dizelskom gorivu. Međutim, novija istraživanja pokazujuda se emisija NO_x može smanjiti korišćenjem odgovarajućih tehnologija proizvodnje biodizela.
Na osnovu istraživanja Američke agencije za zaštitu životne sredine (EPA) količina smoga se smanjuje za čak 50 %, a emisija čađi se smanjuje za 51-54 %.
Pored toga, biodizel ne sadrži fosfor i olovo koji opterećuju životnu okolinu i ima mnogo bolju biorazgradivost u vodi i zemljištu, za razliku od klasičnog dizela. Fosilni dizel se razlaže samo 50% u toku prvih 21 dan poslije prosipanja, dok se biodizel razlaže 98% bez posledica, za isto vrijeme.

4. ZAKLJUČAK

Drumski transport skoro u potpunosti zavisi od fosilnih goriva. Uzimajući u obzir ograničenost rezervi konvencionalnih goriva fosilnog porijekla i pojačanu svijest o globalnim ekološkim izazovima s kojima se svijet suočava, mnoge zemlje su se opredjelile za korišćenje biodizela u drumskom transportu. Uz činjenicu da se biodizel dobija iz obnovljivih sirovina, da je razlika u energetskom potencijalu u odnosu na dizel gorivo neznatna i da upotreba biodizela ne zahtjeva nove konstrukcije motora za vozila, jasno je da biodizel predstavlja pravo rešenje u prelaznom periodu dok se ne operacionalizuju drugi vidovi energije.

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SOLUTION OF LICENSE GIVING PROBLEM TO RECYCLE FACILITIES BY THE FUZZY ANP AND AHP METHOD

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ABSTRACT
This study handles the decision making to select the best recycle facilities which are regaining (organic regain excluding energy regain) the goods that are no more in use to give the license in order to have the correct and effective recycling within the framework of the standards created by European Union. By the definition in the package contaminants regulation of Republic of Turkey Ministry of Environment and Forestry, a recycle facility is the place where package contaminants are recycled except the recycle in the industry or at the selling points. The presence of the license shows that the facility fulfills the criteria, is managed as needed and taking precautions to save the environmental health; without this license facility is not allowed to operate. In decision making process we use Fuzzy Analytical Hierarchy Process and Fuzzy Analytical Network Process by the help of Chang's Extent Analysis and finally evaluate the best alternative of chosen three recycle facilities in, Turkey's one of the most rapid grown city, Samsun.
Keywords: Recycle facilities, Fuzzy Analytical Hierarchy Process, Fuzzy Analytical Network Process, Chang's Extent Analysis

1. INTRODUCTION
In our living area natural resources is limited. Population of earth is rising, with unconscious rapid consumption the products which are still useful are thrown away as rubbish. The resources spending up like that affect not only our life but also affect our children's life. Thinking on that side the importance of recyclable refuse can be understood easily. For this reason we must notice recyclable wastes such as paper, plastics, metal and be aware of these are useful and reusable. In addition to this, Concern of environment as well as commercial and economic factors has led to an increased importance in recycling.

Recycling is considered as an effective way of waste management with its expanded benefit from resources conservation and indirect energy saving from avoiding raw material exploitation [1]. By the definition in Republic of Turkey Ministry of Environment and Forestry's package contaminants regulations, a recycle facility is the place where package contaminants are recycled except the recycle in the industry or at the selling points [1].

In Turkey, it is still not well studied that how recycling systems run and what are the main impact factors to the structure and characteristics of recycling system. This study is aimed to close a gap in recycling sector and help decisions planners to give their decisions in a scientific way.

Environment has become a popular issue for researchers and scientists especially in European Countries. Turkish Republic as a candidate country targeting a full membership of European Union, Turkey is planning to pass some environmental directives such as package waste regulations. By the help of these regulations the recycle sector takes precautions to save the environmental health, fulfills the standards and open to audits. The general name of these standards is license. The presence of the license shows that the facility fulfills the desirable criteria and allows operating legally.

2. LITERATURE

In literature there so many studies including different types of methods used in recycle facilities. One of them is Realff et al.(1990) who designed a mixed integer program model to build an efficient inverse network for carpet recycling. Another one is processed by Güngör and Gupta (1999) which is generally based on environment friendly production and product recycling. Flahaut et al. (2002), in their site selection study, handled the pollution that the facility can cause and the penalty of this harm in addition to their transportation costs by using a simple site selection model.

Lu et al. (2004) used a general network design for products like container, bottle and pallets which are directly recyclable and built a model to select the best facility location. Optimum location of asphalt recycling facility is determined with Gustafson-Kessel algorithm-convex programming hybrid model based simulation after that optimum facility location which has parameters like logistics; performance, cost, bottle neck points and machine equipment need are examined by simulation application.

Pati et al. (2008) built a multi objective programming model to maximize the recycled paper while minimizing the inconvenient waste paper as well as total system cost. Şengül (2010) investigated reverse logistics in terms of waste recycle and considered the optimization methods used in this kind of recycle networks.
[2, 3, 4, 5, 6, 7, 8]. This research is necessary because, in literature there is no thesis similar to this. Recycle facilities are new and there is limited unity between public and private sector.

3. FUZZY ANP AND FUZZY AHP METHOD

Analytic network process (ANP), as a multiple criteria decision making (MCDM) method, is a relatively simple and systematic approach that can be used by decision makers. Essentially, it is a more general form of the Analytical Hierarchy Process (AHP), which was first introduced by Thomas L. Saaty.

The AHP is a special case of the ANP and it does not contain feedback loops among the factors. Both the ANP and the AHP obtain ratio scale priorities for each element and cluster of elements by making paired comparisons of elements on a common criterion. The ANP is different from the AHP in that decision models can be built as complex networks of decision objectives, alternatives, scenarios, criteria and the other factors that all have an influence on another's priorities.[9].Similarly to the AHP, the performance of weights of criteria and the scores of alternatives in ANP are assessed indirectly from pair wise comparison judgements.The pair wise comparison process assumes that the decision maker can compare any two criteria, and provide a numerical value aij for the ratio of their importance [10].

However, in many cases the preference model of the human decision maker is uncertain, and it is relatively difficult for the decision maker to provide exact numerical values for the comparison ratios. The decision makers could be uncertain about their own level of performance, due to the incomplete information or knowledge, complexity and uncertainty within the decision environment, or a lack of an appropriate measurement units and scale [10].Therefore this research proposes FANP and FAHP models base to evaluate license giving problem in recycle facilities. With fuzzy logic, proposed models are more sensitive to choosing best alternative and monitoring the results

The Fuzzy ANP methodology is capable of taking into consideration both tangible and intangible criteria without sacrificing their relationships and it can deal with all kinds of dependencies systematically. Unlike traditional multicriteria decision making methods which are generally based on the independence assumption, the Fuzzy ANP is a relatively new methodology, incorporating feedback and interdependent relationships between decision attributes and alternatives [9].

In Fuzzy AHP model, it has its hierarchic structure, includes a control hierarchy of criteria and sub criteria and goal which is placed at the top of the hierarchy. FAHP model decision making structure uses uni-directional hierarchical relationships among decision levels. Furthermore, the FANP does not require a strictly hierarchical structure but uses a ratio scale formed by human judgments instead of arbitrary scales. Using ratio scales to capture all kinds of interactions and human judgments, and making accurate predictions by making use of these scales is the powerful side of the FANP. Priorities as ratio scales are a fundamental kind of number amenable to performing the basic arithmetic operations of adding within the same scale and multiplying different scales meaningfully as required by the ANP.

Other methods that have been developed generally based on the concepts of accurate measurements. However, most of the selection parameters cannot be given precisely in evaluation of data in decision problem. Suitability for various subjective criteria is usually expressed by using the decision maker's judgments so they are subjective. In addition to this, AHP and ANP are easy to calculate and widely used for researchers.

4. GIVING LICENCE DECISION PROBLEM FOR RCYCLE FACILITIES

The main purpose of the study is to provide assistance for planners and decision makers in scientific and technical ways. The study addresses the problem of giving license to recycle facilities by using FANP and FAHP with the help of Chang's Extent Analysis.

The FANP technique enables us to consider both qualitative and quantitative criteria as well as the interdependencies and feedbacks [9].Five main criteria and their sub-criteria are considered for choosing the best alternative with which this study has dealt. The questions of what criteria would be considered and what the interdependencies between these criteria and their weights would be were discussed and determined via interviews with some expert authorities of the Samsun Environment and Forestry Department and academic organizations.

Three alternative recycle facilities where located in Samsun were evaluated and the most convenient one was selected according the result weights. This was followed by, FAHP. It was used to compare the results of the FANP and give consistency to the calculations.

Selection of the appropriate recycle facility from alternatives is a complex problem and requires an extensive evaluation process. In this study we develop a model (Table 1.) which considers with the requirements of municipal, governmental and environmental regulations.

Table 1. Evaluation Criteria of Giving License Problem Model To Recycle Facilities [1]

Physical Requirements	Closed area
	Facility floor
Personnel Services	Personnel education program
	Information of employees
	Private area of employees
Hygiene	Ventilation
	Daily cleanup
	External servicing cleanup
Information Record System	Proceeding of packaging waste
	Proceeding of machines and equipment
Procedure	Operation certificate
	Applcation of taking license

This research was conducted in three facilities in Samsun Industrial Zone which are named as RF1, RF2 and RF3.The chosen facilities are examined by experts according to above model via interviews and surveys.

4.1. Fuzzy ANP And Fuzzy AHP Calculations
By the help of the Fuzzy ANP technique, the interdependencies between criteria formed and their weights were calculated. Then raw data is entered to the software Super Decisions. The output display screens as follows: The FANP network structure can be seen in Figure 1. With FAHP technique the hierarchy structure can be seen in Figure 2.

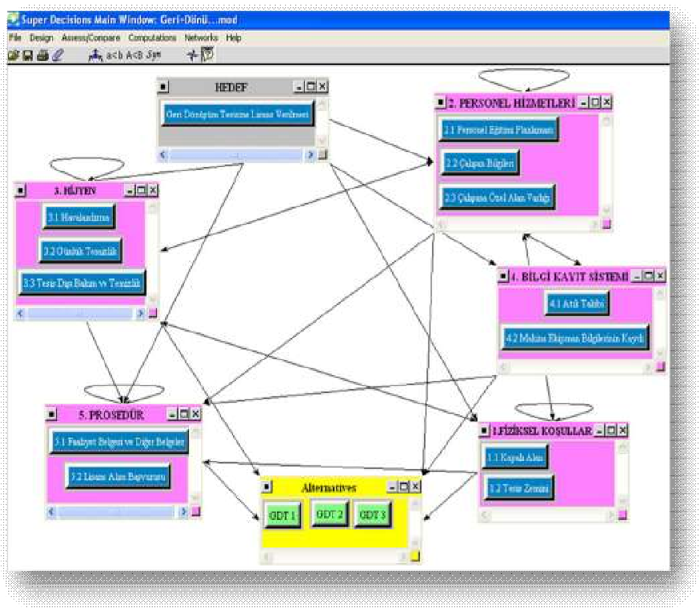

Figure 1. FANP Network Structure of Model

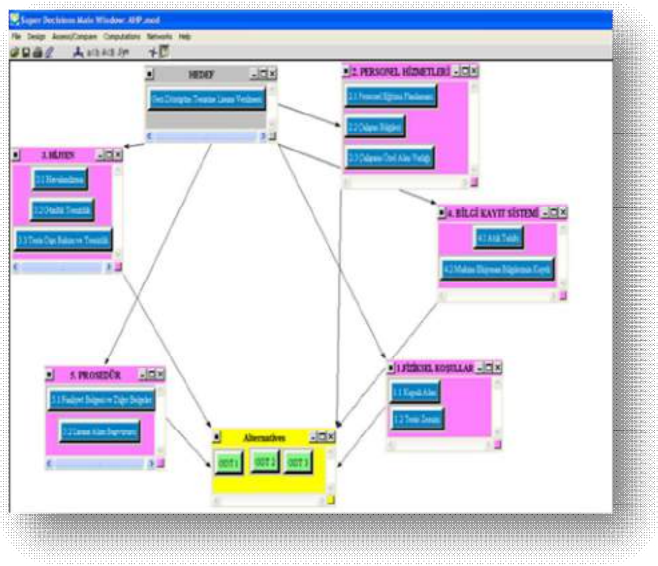

Figure 2. FAHP Hierarchy Structure of Model

These calculations give us the best alternative of license giving decision problem for public side.

Table 2.Calculations of FANP

NAME	IDEAL DATA	NORMAL DATA	RAW DATA
RF1	0.526124	0.231439	0.103302
RF2	0.747153	0.328668	0.146700
RF3	1.000.000	0.439893	0.196345

Table 2.Calculations of FAHP

NAME	IDEAL DATA	NORMAL DATA	RAW DATA
RF1	0.420336	0.184166	0.092083
RF2	0.862037	0.377693	0.188847
RF3	1.000.000	0.438141	0.219070

The best alternative of FANP is weighted as 0.439893, which means Recycle Facility 3 is the most convenient for license. Again in FAHP method Recycle Facility 3 is the best for license with the result of 0.438141.

5. CONCLUSION AND PROPOSITION

License giving was based on decision maker's information about the sector, their experience and intuition before this method. After applying proposed model they have chance to solve this problem as a scientific way with given methods. The application of FANP and FAHP in giving license decision problem, the best alternative is Recycle Facility 3.

The second alternative is Recycle Facility 2 and the last one is Recycle Facility 1. This solution gives us some implications about sector. First of all, we have found that the most weighted criterion is procedure. It is true that without these criteria the facilities can not be operated legally. Secondly, Turkish Government must support the recyclers for example giving those incentives in equipment, tax deduction or protecting against the illegal facilities.

Third one is the Turkish Government must make an audit periodically, if not the recycle facilities have tendency to not to meet requirements of laws. Regulations, laws and directives are alternating and changeable structures so in future research new criteria can be added and calculated. The factor of human consciousness about the environment always takes an important part for recycling of wastes. Finally, a comparative study may be performed on different techniques. The FANP and FAHP model can be adapted to different data set and Decision Making System. This study is also hoped to be a pioneer in Turkey, where surveys on giving license problem are limited and has high uncertainty.

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1st International Scientific Conference on Engineering
”Manufacturing and Advanced Technologies”
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

DIZAJNIRANJE VJETRENJAČE SA VERTIKALNOM OSOM ROTACIJE

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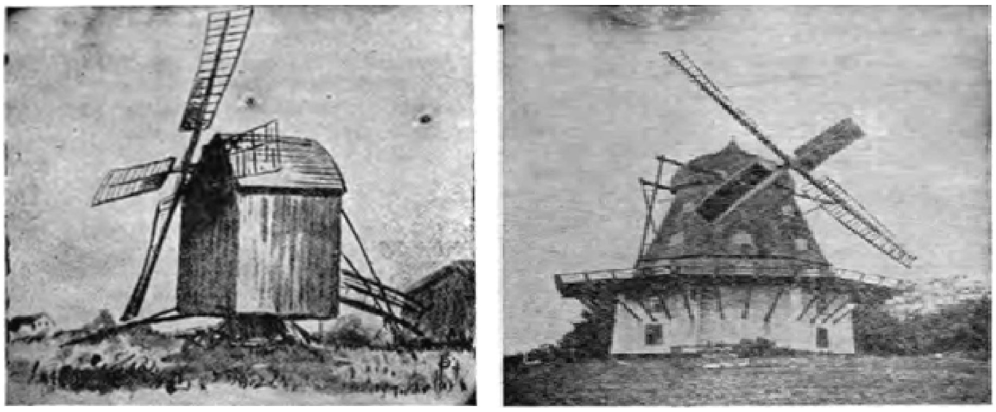
SAŽETAK
Energetska pitanja, osobito pitanja o obnovljivim izvorima energije postala su od vitalnog značaja, ne samo zbog lošeg ekološkog stanja i rastućih cijena sirove nafte, nego i zbog uvijek rastućih potreba za energijom. Svi ovi negativni trendovi prisiljavaju čovječanstvo da tradicionalna fosilna goriva zamijene ekološki prihvatljivijim alternativama. Iako su fosilna goriva (nafta, ugljen i prirodni plin) trenutno dominantna, stvari počinju ići nabolje zbog toga jer sve više država počinje priznavati problem s fosilnim gorivima i polako usmjeravaju svoju pažnju u razvoj obnovljivih izvora energije. Jedan od obnovljivih izvora energije koji najviše obećava je svakako energija vjetra koju je moguće iskoristiti za generiranje električne energije. U radu je prikazan dizajniranje vjetrenjače sa vertikalnom osom rotacije.
Ključne riječi: vjetrenjača, vjetar, dizajniranje.

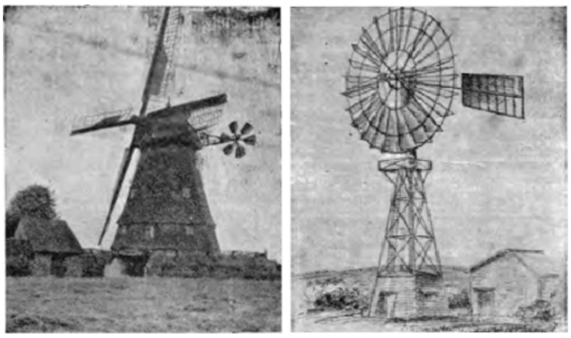
1. UVOD

Relativno davno postojala su samo dva tipa vjetrenača. Tadašnje vjetrenjače sastojale su se iz tri dijela: tijela, kape i jedra. Jedna vrsta vjetrenjača (slika 1. lijevo) je konstruisana tako da je se tijelo vjetrenjače koje se još zvalo i ″radno odijelo″ okretalo na drvenom nosaču, da bi se vjetrenjača usmjerila u pravcu vjetra, dok je druga vrsta vjetrenjača (slika 1. desno) bila konstruisana tako da je se ″kapa″ vjetrenjače okretala na tijelu. [1]



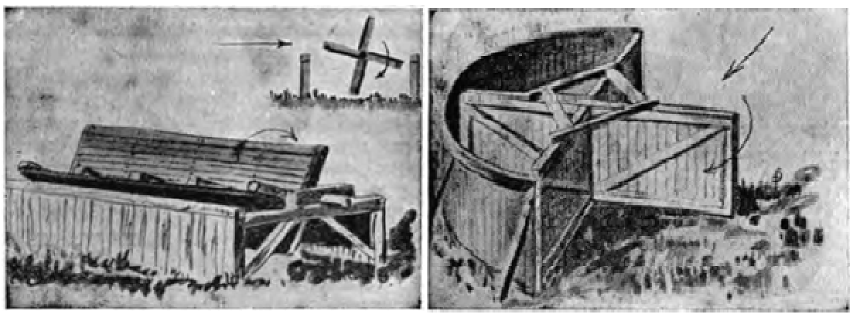
Slika 1. Stare vjetrenjače u Danskoj

Kao što se vidi na gore navedenim primjerima, regulacija ovih vjetrenjača tj. njihovo usmjeravanje prema ″licu vjetra″ vršeno je ručno, jer se metod automatske regulacije usmjeravanja vjetrenjača javlja sredinom osamnaestog stoljeća, kada Andrew Meikel predstavlja danas dobro poznatu regulaciju pomočnim točkom (slika 2. lijevo). [2]



Slika 2. Regulacija pomočnim točkom i lopaticom

Slijedeći napredak u razvoju vjetrenjača dogodio se 1807 g. kada je Sir W. Cubitt uveo sistem regulacije brzine. Prije tog otkriča regulacija brzine nije bila moguča, a operater je mogao samo da pusti vjetrenjaču u rad ili da je zakoči. Kao izumitelj modernih vjetrenjača sredinom devetnaestog stoljeća navodi se amerikanac John Burnham, a razlika se ogledala po broju i položaju jedara i relativno uskih sistema za usmjeravanje, gdje je točak zamjenjen sa lopaticama (slika 2. desno).
Od Burnham-a pa do danas postoji mnoštvo sličnih tzv. američkih mlinova, a jedina razlika je u dizajnu, regulaciji brzine jedara i zakretanja prema ″licu″ vjetra, ali bitnih razlika nema. Prednost ″američkih mlinova″ isključivo je bila niska cijena proizvodnje, a do potpune afirmacije vjetrenjača dolazi kada danski naučnik Poul la Cour otkriva mogučnost iskorištenja energije vjetra za dobivanje električne energije. Vjetrenjača ″Jumbo″ je imala horizontalnu osu rotacije i mogla je da radi samo pri određenim smjerovima vjetra i pri tome je se morala nalaziti na otvorenom prostoru, bez obližnjih zgrada ili drveča. Modificirana verzija ″Jumbo″-a je vjetrenjača sa vertikalnom osom rotacije, koja je mogla da reaguje na sve smjerove vjetra.

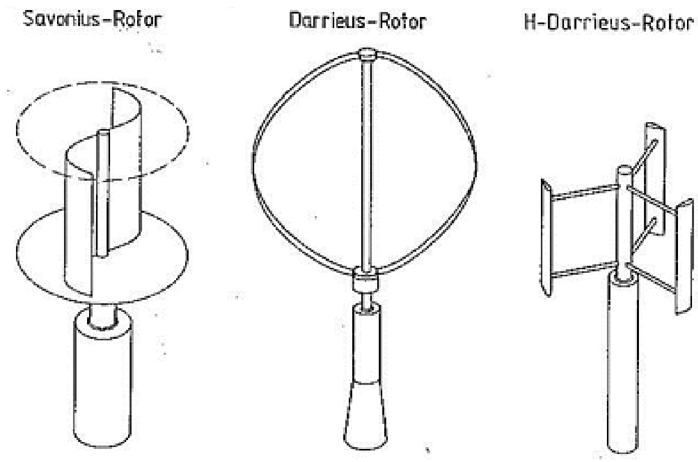


Slika 3. Vjetrenjače sa horizontalnom i vertikalnom osom rotacije

2. VJETRENJAČE SA VERTIKALNOM OSOM ROTACIJE

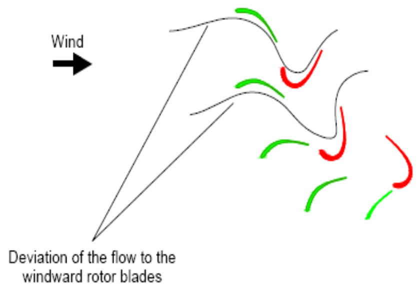
Kod vertikalnih vjetrenjača kao što sam naziv govori, glavni rotor je postavljen vertikalno. Ključna prednost ovog tipa vjetrenjača je da ne moraju biti usmjerene prema vjetru da bi reagovale. Ovo osobina je veoma bitna na mjestima koje karakterišu velike promjene pravca vjetra. Pored navedene osobine, prednost im je sto ih je moguče postaviti na male visine, što olakšava njihovo održavanje. Obićno se montiraju na tornjeve ili krovove zgrada, pa ovisno od toga zavisi kojom količinom energije vjetra će da raspolažu. Pri manjim visinama, protok zraka preko tla i obližnjih objekata može da izazove turbulencije, pa kao posljedica tih turbulencija nastaju vibracije koje dovode do trošenja ležajeva i stvaranje velike buke, što za posljedicu ima veće troškove održavanja i kraći vijek trajanja.
Međutim, ukoliko je vjetrenjača postavljena na krov zgrade, zgrada usmjerava vjetar preko krova, što izaziva dvostruko veće brzine vjetra i veliki stepen iskorištenja vjetrenjače uz minimalne turbulencije.

Postoje dva različita tipa VAWT vjetrenjača (slika 4.). Prvi, tzv. Savonius model, koji je sličan presječenoj bačvi, gdje su joj polovice postavljene na rotor i drugi tip vjetrenjača je Darrieus model (francuski inžinjer Georges Darrieus), gdje su na vertikalnu rotor postavljene vertikalne lopatice koje se okreču oko nje (vjetrenjača na kojoj mi radimo). [3]



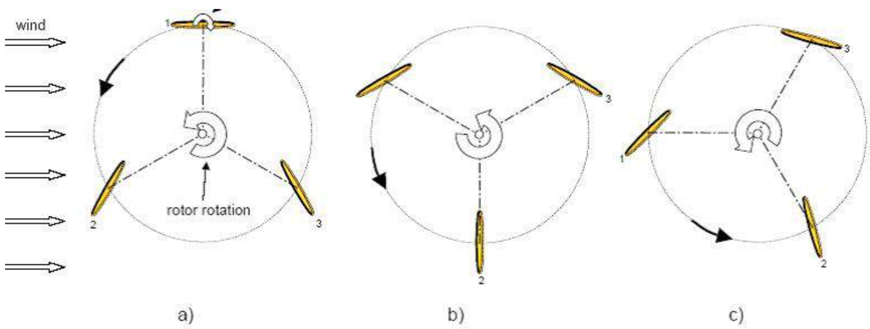
Slika 4. Savanius rotor (lijevo); Darrieus rotor desno- jaje i H model

Darrieus modeli koriste aeroprofilni dizajn koji funkcionišu na istom principu kao i krila aviona. Vjetar koji udara na lopatice stvara silu pritiska koji koja izaziva rotacijski moment, što uzrokuje okretanje lopatica oko osovine (slika 5.).



Slika 5.Udar vjetra na lopatice

Ovo istraživanje opisuje rad vjetrenjače sa vertikalnom osom rotacije. Vjetrenjača je dizajnirana za rad na malom broju obrtaja, sa lopaticama simetričnim na osu rotacije. Pokreče se automatski i ima relativno velik obrtni moment. Ovaj model se sastoji od tri lopatice koje su paralelne osi okretanja i svaka lopatica napravi svoj radni hod zakretanjem od 180°. Lopatice su jednostavne ravne ploče, koje su učvršćene nosačima na rotor. Na slici 6. prikazano je kretanje lopatica.



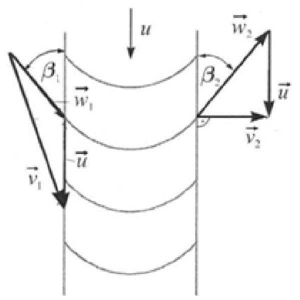
Slika 6. Kretanje lopatica pod dejstvom vjetra

Iako na prvi pogled izgleda da će se lopatica (1) (slika 6 a.) suprostavljati zakretanju rotora, to se neće dogoditi, jer ona stoji paralelno sa kretanjem vjetra, dok lopatica (2) stoji okomito na vjetar i omgučava rotaciju. Izgradnja ovakve vjetrenjače ja predstavljala korak naprijed, zbog male cijene sirovina, kao i stepena iskorištenja od 0,2-0,3%; što je bio dovoljan razlog za nastavak razvijanja vjetrenjača sa vertikalnom osom rotacije. Međutim, tri lopatice paralelne sa osom rotacija nisu dovljno i optimalno riješenje, jer je potreban i uređaj koji ce zakretati te lopatice okomito na pravac kretanja vjetra, a to predstavlja dodatni materijal sto što povećava težinu konstrukcija kao i samu cijenu izrade

3. PRORAČUN SNAGE VIJETRENJAČE

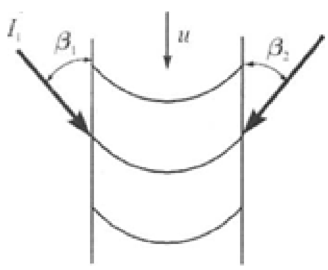
Izvršit ćemo proračun snage vjetrenjače na osnovu jednačine kontinuiteta iz poznatih podataka dobijenih samom konstrukcijom vjetrenjače kao i na osnovu poznatih uslova okoline u kojima se vjetrenjača može naći. Ovaj proračun ne vrijedi u realnim uslovima, ali se može uzeti u razmatranje kao podloga za dalja istraživanja, gdje je potrebno uzeti u obzir promjenu pritiska, turbulencije, raspodjela protoka na inicijalni i korisni, promjenu brzine vjetra, kao i mnoge druge faktore.

Pošto je širina lopatice puno manja od srednjeg polupručnika, to se strujanje može smatrati ravanskim. Predpostavka beskonačnog broja beskonačno tankih lopatica osigurava da se sve strujnice u strujanju kroz prostor između lopatica imaju oblik lopatice, tj. relativna brzina strujanja zraka kroz lopaticu je tangencijalna na lopaticu.



Slika 7. Lopatica rotora sa prikazanim brzinam

Slika 7. prikazuje trokut brzina na ulazu u vijenac lopatica (gdje relativna brzina w_1 gleda u kontrolni volumen) i na izlazu iz vijenca (gdje relativna brzina w_2 gleda od kontrolnog volumena). Relativna brzina w_1 čini s obodnim smjerom ugao β_1,a na izlazu brzina w_2 čini ugao β_2. Obodna brzina (u) je jednaka na ulaznom i izlaznom presjeku kontrolnog volumena koji obuhvaća unutarnjost vijenca lopatica. Osnovni zakoni u dinamičkom koordinatnom sistemu čvrsto vezanom za vijenac lopatica koji se kreče stalnom brzinom (u), imaju isti oblik kao i u statičkom koordinatnom sistemu s jedinom razlikom da se umjesto apsolutne brzine koristi relativna brzina.



Slika 8. Lopatica sa ucrtanim impulsnim funkcijama

Prema jednačini kontinuiteta je protok Q kroz izlaznu površinu jednak je protoku Q kroz ulaznu površinu tj. $Q = A_1w_1\sin\beta_1 = A_2w_2\sin\beta_2$, a uglovi β_1 i β_2 su jednaki. Slika 8. prikazuje kontrolni volumen s ucrtanim impulsnim funkcijama $I_1=\rho Qw_1$ i $I_2 = \rho Qw_2$. U impulsnim funkcijama se ne pojavljuje pritisak p jer je pretpostavljeno strujanje pri konstantnom pritisku, te se sile pritiska međusobno poništavaju. Množenjem pw u impulsnoj funkciji s ukupnim protokom Q impulsna funkcija je obračunata po čitavoj površini. Aksijalna sila koja djeluje od ulazne prema izlaznoj površini je:

$$F_a = I_1 \sin \beta_1 - I_2 \sin\beta_2 \qquad ...(1)$$

Očito će zbog $\beta_1=\beta_2$ aksijalna sila biti jednaka nuli. Sila F u obodnom smjeru u kojem se kreće vjenac lopatice je:

$$F = I_1 \cos\beta_1 + I2 \cos\beta_2 = \rho\ \ w\ (\cos\beta_1 + \cos\beta_2) \qquad ...(2)$$

Vrijednost obodne brzine se računa:

$$u = \omega \qquad ...(3)$$

Pa je jednačina za snagu vjetrenjače :

$$P = Fu \qquad ...(4)$$

Snagu vjetrenjače mozemo izračunati i preko visine pada energije rotora:

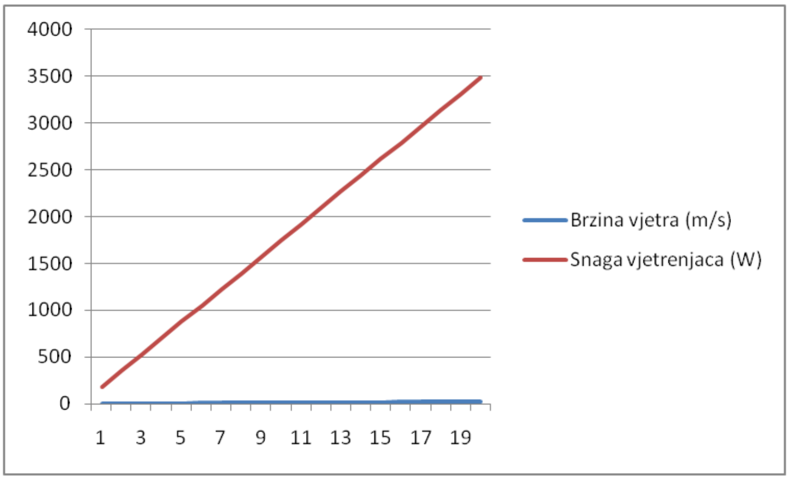
$$h_t = \ \ (\cos \beta_1 + \cos \beta_2) \qquad ...(5)$$

A jednačina za snagu je:

$$P = h_t\ \rho\ g \qquad ...(6)$$

Jednačina (6) predstavlja snagu vjetrenjače preko jednačine kontinuiteta, dok ćemo u slijedećem primjeru izracunati snagu vjetrenjače preko visine pada energije rotora:

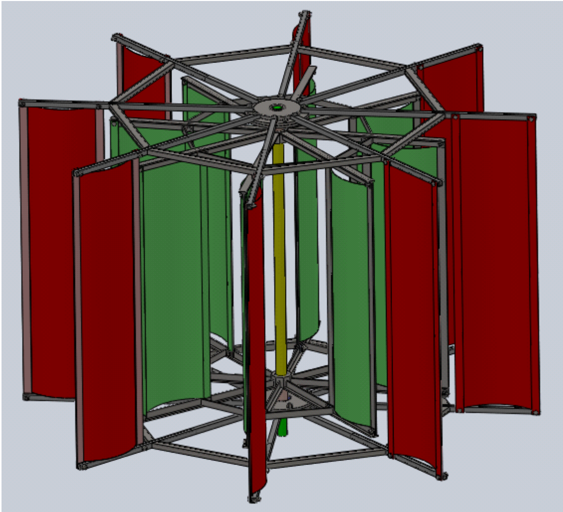
Kao što možemo vidjeti sa slike 9. snaga vjetrenjače raste sa porastom brzine vjetra. Tako da bi se pri brzinama vjeta od 20 m/s tj.72 km/h mogla očekivati snaga do 3,4 kW.



Slika 9. Zavisnost snage od brzine vjetra

Na slici 10 prikazan je sklop dizajnirane vjetrenjača sa vertikalnom osom rotacije koji se sastoji od dva podsklopa:

1) statora
2) rotora



Slika 10.Dizajnirana vjetrenjača sa vertikalnom osom rotacije

4. ZAKLJUČAK

Danas u svijetu postoji mnogo vrsta vjetrenjača, a glavna podjela je na vjetrenjače sa horizontalnom i vertikalnom osom rotacije. Vjetrenjače sa sa horizontalnom osom rotacije su već našle svoju upotrebnu vrijednost i mnoge ih zemlje koriste kao za proizvodnju električne energije, dok vjetrenjače sa vertikalno osom rotacije tek zadnjih godina pronalaze svoju upotrebnu vrijednost. U ovom radu je objašnjen princip dizajniranja vjetrenjače sa vertikalnom osom rotacije kao i proračun snage koju bi trebala vjetrenjača da daje na osnovu zadatih vrijednosti i predviđenih dimenzija. Proračun je rađen na idealnom modelu i napravljen je kao podloga za dalji razvoj vjetrenjače, jer nisu uzeti u obzir gubitci koji se javljaju uslijed turbulencije vjetra, promjene atmosferskog pritiska, promjene brzine generatora, trenja u ležajevima, rasipanja uhvaćene količine vjetra, kao i upotreba novih materijala za izradu itd.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

INTELLIGENT MANUFACTURING SYSTEMS AND MECHATRONICS – AN EDUCATIONAL APPROACH

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ABSTRACT

The new demand on engineers with interdisciplinary skills and knowledge and the ability to produce fresh ideas and products for the changing market caused the development of educational curricula in IMS and Mechatronics in many countries around the world. These curricula vary to some extent in their concepts and contents. Different universities offer whole undergraduate or graduate courses or just separate disciplines in these specialties. However almost all educating institutions stress on the integration of the basic engineering areas: Mechanical, Electrical, Computer and Control Engineering. Another common feature of the proposed curricula is the need for hands-on experience that allows the students gain the ability to design intelligent manufacturing systems and mechatronic systems on their own and the perspective to start promising engineering careers. There are differences in the number and kind of taught disciplines, the instruction approach, and the structure of laboratory exercises, the projects tasks and requirements. This paper reviews attitudes toward and curricula features of IMS and Mechatronics education in some countries. It also presents the concepts and the curriculum of the master course of Mechatronics in the Faculty Mechanical Engineering at the Technical University Sofia (Bulgaria) and the IMS discipline incorporated in this course.

Keywords: academic net, engineering education, intelligent manufacturing systems, Mechatronics

1. INTELLIGENT MANUFACTURING SYSTEMS AND MECHATRONICS EDUCATION AROUND THE WORLD

The broad areas of Intelligent Manufacturing Systems (IMS) and Mechatronics education provide for the different approaches of preparing students for the dynamic market of highly integrated products. Some universities organize such education programs within a given department (Mechanical, Electrical, or Control) or with the cooperated efforts of several departments. Some curricula include subjects not from all four basic engineering areas or are concentrated around one spinal discipline (e. g. control engineering). The differences are caused by the views of the educating bodies and by the needs of the local industries.

In [1] Craig puts the stress on the "balance between modelling/analysis skills and hardware implementation skills". He also asserts the need for mechanical engineers to be proficient in control design in order to produce novel concepts in their design activities. They should include modelling, simulation, and analysis together with their former hardware experience in generating new prototypes together with engineers from other areas. There are two senior elective courses in the Rensselaer Polytechnic Institute, "Mechatronics" and "Mechatronic System Design", each lasting for one semester. Craig describes the programs as helpful for the engineers in learning how to apply the classical control designs as an incorporated part of their own design. Students are taught with an emphasis on understanding the physical and mathematical fundamentals. The main issues are Modelling and Analysis of Dynamic Systems, Feedback Control of Dynamic Systems, analogue and digital electronics and control implementation and simulation with latest software. The first course includes lab exercises with five Mechatronic systems, while the second one includes projects for four-

person teams that fully develop Mechatronic systems and present them in written and oral form. Craig also emphasizes on the need of experience of the instructing stuff in order to teach modelling.
Wikander et al. [2] claim that a new Mechatronic approach is needed where a shift from mechanical hardware to computer software is established in implementation of functionality. The older subsystem-based approach of designing the separate homogeneous subsystems and interfacing them afterwards does not provide the full integration of the design process of a given Mechatronic system. They propose as an educational approach the system in the Swedish Royal Institute of Technology with a five-year curriculum where interdisciplinary courses are integrated in an existing program of mechanical engineering. The courses usually deal mostly with the design process and the acquired knowledge of the various engineering disciplines by the students is achieved by problem-based learning, with team organization. Examples of courses in the Institute above following the given principles are: “Microcomputers in Embedded Systems”, “Advanced Course in Mechatronic System Design”, “Real-Time Control and Programming”. Alciatore [3] asserts restructuring the core mechanical engineering undergraduate curriculum toward Mechatronics program, as well.
Siegwart [4] provides a discussion on Mechatronics education in the Swiss Federal Institute of Technology of Lausanne (EPFL) and ETHZ, Zurich, and particularly the “Smart Product Design” course in the latter one. Students there “bond” their basic interdisciplinary knowledge of elements of Mechatronic systems, electric circuits, sensors, actuators, controllers, control and artificial intelligence, etc. with the help of design, system integration, teamwork, project management, communication and controlling activities. They gain all the skills through projects where theory meets practical illustration. The projects consist of building mobile robots, where every student team receives a kit (“smartROB design kit”) and an assignment for the tasks the robot should be able to fulfil. Before starting, the participants in the “Smart Product Design” course have both lecture and laboratory work. Various subjects are covered that are not all familiar to the students and the latter communicate with engineers from different areas in order to achieve the integration required in the Mechatronic system design. In the end of each course, all robots from the projects participate in a contest. This element adds more motivation to the studies.
The practical education is an emphasis also in the Ritsumeikan’s Department of Robotics [5]. The exercises in the courses of advanced robotics there are held from the second until the last year in the university. As for the previous case system, integration is a basic purpose for the students to achieve. Despite the great difficulties they meet, they receive background knowledge and experience in order to proceed with their careers and research in robotics.
Tomizuka [6] states: “Issues surrounding integration as well as working in team cannot be taught in lecture courses. Students must experience them, and in this regard laboratory courses are essential in Mechatronics education”. In addition, he emphasizes on the need for drawing the attention of students toward Mechatronics at an early stage (high school and college) and that IT tools have to be broadly incorporated into engineering education. Tomizuka describes a 15-week course in Mechatronics design that covers various disciplines and ends with the presentation of projects developed by 3-4-person teams.
Brown et al. [7] express their preference toward the approach of project based practical engineering and to support it with theoretical learning. They place the basic questions concerning Mechatronics education about the owner of this type of courses, the contents, and the way to “teach such a different philosophy with such a wide range of diverse subjects”. The solution attained at Hull University is the control engineering part to be the spinal subject and other subjects come from other departments. The four-year Mechatronics program contains mostly project work and supporting lectures. Active learning and quick adaptation are aimed by solving a large-scale design problem, which is put in place of traditional predetermined lab exercises. According to the representatives of the university, self-reliance, motivation, creativity and understanding are built in students by following that approach.
Mechatronic education at the University of South Carolina is being developed together with programs of Smart Structures and Adaptive Materials in the Mechanical Engineering in cooperation with the departments of Electrical Engineering and Computer Science. Giurgiutiu et al. [8] discuss the work at the university toward finding methods to teach multidisciplinary courses and organizing multidisciplinary project working teams. They state: “Today’s and tomorrow’s products are intertwined blend of mechanisms, sensors, actuators, electronics, and information technology. The ideal graduate should be able to hit the ground running in all these areas concurrently in order to

achieve maximum performance with minimum training time. Of course the "ideal graduate" is not a physical reality but a graduate with a broad Mechatronics education will come pretty close to it". A track system, similar to that in the University of Washington, is proposed, where the courses are to be covered by the Electrical and Mechanical Engineering and the one of the tracks is Mechatronics.

The course sequence in Mechatronics in the University of Arkansas at Little Rock described by Wright [9] is a supplementary one for the system-engineering program there. The pursued task is to teach mechanical design to the students of that program. The multidisciplinary character of this type of undergraduate education is formed by the following sequence: Introduction to Engineering, C Programming, Elements of Mechanical Design, Circuits and Systems, Digital Systems, Control Theory, Instrumentation and Measurements, and Mechatronics (in the senior level) together with CAD/CAM laboratories and lectures. The design skills are the target of a free-form design project where students have to develop, analyze, simulate and produce a prototype, concerning also cost and budgets. A special competition (US FIRST design competition) in building a teleoperated mobile robot in 42 days is an additional task for the students of the university to enhance their training in cooperation with pre-college students.

The graduate Mechatronics course in the Woodruff School of Mechanical Engineering at Georgia Institute of Technology [10] is concentrated on the microprocessors and microcontrollers in mechanical systems. The course contains considerable part of hands-on design and work (usually in teams of couples of students) and ends with a final project also organized in teams. Computer programming and electrical engineering disciplines are mostly covered. Laboratories have large workspace and are devoted to particular skills. The projects are given additional time so that the students can develop proper aesthetic and packing features of their Mechatronic products.

An open-ended project is developed for the undergraduate Mechatronics course of Stanford University. Carryer [11] describes it: "The intent is to teach mechanical Engineering students enough about electronics and software so that they will be able to be effective interdisciplinary team members and leaders. The philosophy is that the best way to learn the capabilities of the technology is to actually learn to apply them oneself". One-quarter course contains this project, while a four-quarter sequence in Mechatronics is provided at the same university at the same graduate level.

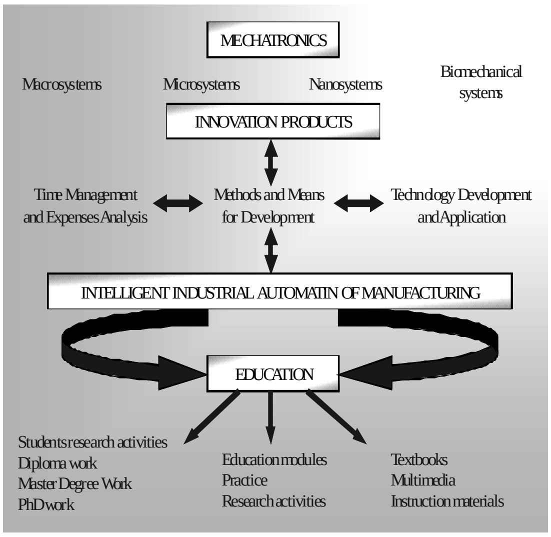
2. IMS AND MECHATRONICS IN TECHNICAL UNIVERSITY – SOFIA, BULGARIA

The education in IMS and Mechatronics emerged gradually in Bulgaria during the last ten years in the Mechanical Engineering Faculty and in the English Language Faculty of Engineering (ELFE) of Technical University of Sofia [12,13].

The basics of IMS and Mechatronics have been seeded during the last decade with the fast changing demands of engineering specialists in automation and computer integrated manufacturing. Still in 1997 an educational concept in this area exists although the interdisciplinary idea is not yet well estimated. An emphasis is placed on the students' preparation for increased computer technology application, broad technical knowledge, and design skills concerning functionality and improvement tendencies, CAD, manufacturing processes development and control, basic economic knowledge. The educational process is proposed to be more problem-oriented and less specialized. A training complex is integrated in the training programs that contains modules for producing and assembling small wooden or plastic parts and is used to simulate a real computer integrated manufacturing system. The discipline of adaptive control has been included in the education program of the Mechanical Engineering Faculty with the help of the Department of "Automation of Discrete Manufacturing", and the disciplines of Technical Image Processing and Artificial Intelligence in Manufacturing have been developed with the help of a TEMPUS projects. There has been useful collaboration within the TEMPUS program with CCTA – Wales and De Monfort University, Leicester, UK that have been supplying the department with modern computers, software didactic materials and scientific literature.

In February 2000, a symposium has been held in Sofia on the theme of "Mechatronics Education". The participants have been from: the Faculties of Mechanical Engineering and Electrical Engineering, Technical University of Sofia, the Departments of Mechanical Engineering of Technical University - Illmenau, Germany, Technical University - Nish, Yugoslavia, and Technical University - Skopie, Macedonia. The reports have been connected with the research and educational experience of the different universities. A mutual intention has appeared for the creation of a net of universities to cooperate in this area. The purpose of the future cooperation is to provide for the basis of

Mechatronics education aimed at application in the machine building, automatic and precise devices, as well as in micro-technologies and bio-technologies. Another important purpose is to create a common taxonomy for teaching Mechatronics.



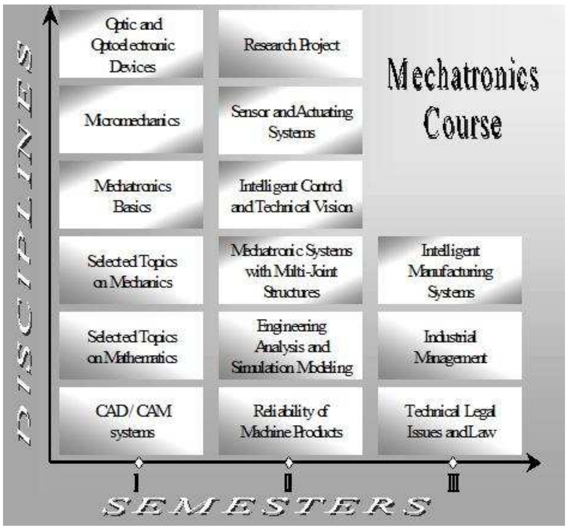


Figure 1. The Concept of the Future Activities in the Mechatronics Education

Figure 2. The Mechatronics Course Program in the Mechanical Engineering Department of Engineering

The Department of "Automation of Discrete Manufacturing" has training and research laboratories in CAD, Assembly Automation, Control Systems and CIM class where most of the practical exercises are held. The training in IMS and Mechatronics is combined with intensive use of information technologies, multimedia, teamwork, and reports preparation, making successful presentations.

Strategies for IMS and Mechatronics education have been blended with those for CIM course. Some special modules introduced there are Hardware and Software CIM Platforms, Integrated Manufacturing, Non-automated Factory of the Future, Multimedia Technologies in Design, Concurrent Engineering, and Low Cost CIM for Small and Medium Enterprises. The existing teaching experience is proposed to be transferred to IMS courses concerning the following problems: the use of systematic approach for successful and effective automation; application of optimization techniques; analysis of artificial intelligence application in manufacturing systems in the aspects of adaptive control in production and assembling, artificial vision, intelligent CAD/CAM/CAE systems.

The Mechatronics program at the Mechanical Engineering Faculty is aimed at: providing students with interdisciplinary knowledge and skills, integrated design approach, manufacturing and maintenance of products and processes. More precisely the topics that are to be covered in this program include: system design (selection of sensors, actuators, electronic components and computer simulation), microprocessor technology (system architecture, digital systems, memory storage devices, input/output devices), interfacing techniques, digital communications, software development, and control systems. IMS education is incorporated as a subject in the course of Mechatronics in the department above and in the graduate course of ELDE.

Training in IMS and Mechatronics are supported still in the undergraduate level in both departments mentioned above. The first two years provide knowledge of fundamental principles of engineering sciences with the disciplines of Mathematics, Physics, Theory of Machines and Mechanisms, Electrical and Electronics Engineering, Computing, etc. The Mechanical Engineering Faculty offers for example Low Cost Automation, Design of Automatic Machines, Computer Science, Quality Control, Technology of Discrete Production, Computer Integrated Manufacturing, Control Systems, etc. The ELFE program ends with Bachelor Degree in Manufacturing Engineering and interdisciplinary subjects in the second two years include: Control Engineering, Measurement and Instrumentation, Elements of Industrial Automation, Computing, Industrial Electronics, Manufacturing Design with projects and course works, CIM, CAD, Advanced Control Theory, etc. Here follow details about the master Mechatronics course in the university:

The purpose of the CAD/CAM/CAE subject is to get the students familiar with the development and application of these systems and provide them with the ability to choose the suitable system for a given task. The laboratory exercises are devoted to work with AutoCAD, SolidEdge, NX, as well as to the use of the corresponding CAM systems and the generation of the program code for a given CNC machine. The Selected Topics in Mathematics are aimed at the increased practical knowledge of set theory, images, mathematic statistics, experiment planning, graph theory, probability theory, etc. Selected Topics on Mechanics is an extension of the “Mechanics I and II” from the undergraduate program. It contains topics from the analytical mechanics and vibrations theory, and discrete multimass systems connected with the design and analysis of transport and hoisting machines, building machines, robots and manipulators.

The Basics of Mechatronics course provides knowledge of the structure, functions, environment of the Mechatronic systems, as well as their basic elements. An emphasis is placed on the methods for Mechatronic systems design; concept preparation, planning, object design, etc. The theoretical bases for Mechatronic systems modelling and different models of mechanical building elements, electric actuators and machines are reviewed. Various technologies and technological processes are taught in the Micromechanics subject, which are used for the production of micromechanical structures. Technological equipment for their production and operations control means is reviewed. The design methods of micromechanical elements, the production technology development, and assembly methods are covered. The laboratory exercises provide an analysis of the available equipment design, optimal technological parameters settings of the equipment, and concrete production operations of the students for preparing micromechanical modules.

The theoretical issues of the optical and optoelectronic devices and specific solutions of some groups of such devices are covered in the subject Optic and Optoelectronic Devices. There are included the principle schemes of the basic types of optical, optoelectronic and laser systems that are used in industry and for research, the typical units of these systems, optical and fibre-optical sensors. The laboratory exercises give the students some skills in the operation in the use of optical and optoelectronic equipment, the ability to choose the right one for a given task in their future engineering careers, and to communicate with specialists in the given area.

The lecture material in Reliability of Machine Products deals with the problems and methods for planning, determining, normalizing, providing the reliability of products during their design, manufacturing and exploitation. Some issues here are basic reliability models, Markov models and processes application, processes that impede reliability and the influence of design and technology on them, methods for diagnostics of machines, systems and processes, etc. The laboratory exercises include some the investigation of the processes that impede reliability, calculation methods and the creation of algorithmic methods for reliability modelling and analysis, as well as diagnostic experiments with specialized equipment and software. The discipline of Engineering Analysis and Simulation Modelling covers the types of models, their application in engineering analysis, practical problems in machine and appliance building through static and dynamic models, stochastic processes, experiment data analysis, regression analysis, dispersion analysis, correlation analysis, experiment planning, simulation methods. Students are provided with skills in working with the basic software products in this area.

The purpose of the subject Mechatronic Systems with Multi-joint Structures is to introduce the students with the kinematics and dynamics of these Mechatronic systems, the method of impedance control, Mechatronic systems with closed multi-joint structures, and new types of Mechatronic systems. The experimental work is carried out with software programs for dynamic modelling and simulation and analysis of the results is made. Intelligent Control and Technical Vision subject covers topics on the methods of modelling, identification, and simulation of incompletely defined structures, digital, adaptive and intelligent control, synthesis and optimization in control problems, increase of system autonomy through artificial intelligence and acquisition of sensor information, technical vision systems, object recognition, video information processing, communication and integration of these systems with the other components of the Mechatronic systems. Both laboratory models and industrial devices and software are used. Sensor and Actuating Systems contains issues on acquisition, conversion and processing of information from sensors, integrated sensor schemes, integration of sensor, actuator and control systems. The laboratory exercises improve the understanding of the theoretical material.

The subject of Technical Legal Issues and Law presents basic knowledge about the application of normative acts in two directions: the normative order of the firms and economic units according to the issues of the civil and trades law; the obligatory and the voluntary regulations for manufacturing and selling safe ant qualitative machine products. The purpose of the Industrial Management discipline is to provide knowledge about the basic problems in managing the industrial organizations, management thinking and functions. The lectures review also the contemporary concepts and systems for the effective business management. The practical exercises are in the form of cases, tests and problems.

Intelligent Manufacturing Systems provides the students with knowledge about the application of artificial intelligence and the integration of manufacturing and computer systems. Main issues are: historical development and today's problems of artificial intelligence, data bases, and knowledge bases connected with machine building, expert systems, IMS in robotics, etc. An emphasis is placed on the application of IMS as a base for the "Factory of the Future".

3. CONCLUSION

The most important features of the education in Mechatronics concerning the world experience according to the information we have gathered are: project-oriented programs, team working and communication with engineers from different areas, systems integration in the design process, competitive approach in pursuing project tasks.

The education in IMS and Mechatronics in Technical University Sofia has started its development, but it still lacks the hands-on approach because of the economic difficulties that all the country meets today.

It is extremely useful for us to become familiar with the foreign programs and experience and to implant them in our programs for Mechatronics and IMS engineers. It is essential for our university to have cooperation in the education of such specialists. Furthermore, our graduate and undergraduate students can work on projects connected with their own studies in Bulgarian and foreign firms in our country. These initiatives are the steps we can make to produce competitive Mechatronic engineers.

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1st International Scientific Conference on Engineering
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MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

APPLICATION OF THE SMED METHOD IN THE INJECTION MOLDING PROCESS

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ABSTRACT
The paper deals with application of SMED method in the actual process of injection molding. SMED and quick changeover are the practice of reducing the time it takes to change a line or machine from running one product to the next. The successful implementation of SMED and quick changeover is the key to a competitive advantage for any manufacturer that produces, prepares, processes or packages a variety of products on a single machine, line or cell. SMED and quick changeover allows manufacturers to keep less inventory while supporting customer demand for products with even slight variations. It also allows manufacturers to keep expensive equipment running because it can produce a variety of products, [1].
Keywords: changeover, setup, SMED, injection molding

1. INTRODUCTION
A manufacturing process is a continuous flow by which raw materials are converted into finished goods, i.e. product. An operation is any action performed by man, machine, or equipment on raw materials, intermediate, or finished product. Production is a network of operations and processes, with one or more operations corresponding to each step in the process. Manufacturing process can be divided into four distinct phases, [2]:
1. Processing: assembly, disassembly, alteration of shape or quality.
2. Inspection: comparison with a standard.
3. Transportation: change of location.
4. Storage: a period of time during which no work, transportation, or inspection is performed on the product.

Each phase of the manufacturing process has a corresponding operation, i.e. work or processing operations, inspection operations, transportation operations, and storage operations. An important part of each of these operations is the time of preparation, i.e. setup time.
In manufacturing process, changeover is elapsed time from the last good unit of one production lot to the first good unit of the next production lot.

Changeover time includes setup time and run-up time, Figure 1. Setup time refers to the time taken to physically make the changes to the machine or production line in order to run the new product. Clean-up is a one part of the setup and includes removal of previous product, materials and components from the machine or line. It may range from minor, if only the label of a package is being changed to major, requiring complete disassembly of the equipment, cleaning and sterilizing of the line components. Run-up time is the time taken to make fine adjustments to the machine or line in order to produce products of the specified quality at the specified production speed. Run-up time is characterized by frequent stoppages, jams, quality rejects and other problems. It is generally caused by variability in setup or by variability in the product or its components.

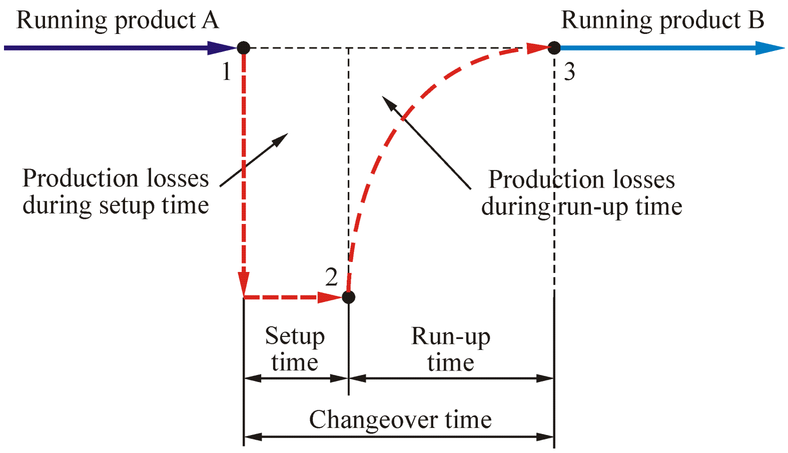

Figure 1. Changeover time

1. Manufacture of product A ceases
2. Manufacture of product B commences
3. First product B is completed, i.e. manufacture of product B reaches set output quality rates

Changeover reduction simply refers to attempts to reduce the time taken to carry out the changeover process. There are a number of potential advantages to reducing the time taken to changeover a production line. These include, [1, 3]:

1. Increased profitability without new capital equipment purchase;
2. Reduced stock requirement;
3. Increased capacity;
4. Work in progress (WIP) and lot size reduction;
5. Increased flexibility.

Table 1 presents relationship between changeover time and lot size

Table 1. Relationship between changeover time and lot size

Changeover Time (hours)	Lot Size (pcs)	Operational Time per Item (min)	Total Operational Time (min)	Total Operational Time per Item (min)	Improvement %
5	100	1	400	4	–
5	1 000	1	1 300	1.3	68
5	10 000	1	10 300	1.03	74

2. SMED

Single Minute Exchange of Die (SMED) is a powerful technique used to reduce the amount of time required for equipment or machine setup, or line changeover. It was first developed by Shigeo Shingo of Toyota in the 1950's, with the aim of reducing downtime from more than few hours to less than 10 minutes for the changing of die on press tools. The need for SMED and quick changeover programs is more popular now than ever due to increased demand for product variability, reduced product life cycles and the need to significantly reduce inventories.

To understand how SMED can help we have to look at the changeover process. Typically when the last product of a run has been made the equipment is shut down and locked out, the machine or line is cleaned, tooling is removed or adjusted, new tooling may be installed to accommodate the next scheduled product. Adjustments are made, critical values are met (die temperature, accumulators filled, hoppers loaded, etc.) and eventually the startup process begins – running product while performing adjustments and bringing the quality and speed up to standard. This process takes time, time that can be reduced through SMED.

SMED method identifies and separates the changeover process into two key activities (operations):

1. External Setup (IED – Inside Exchange of Die) involves activities that can be done while the machine is running and before the changeover process begins, and
2. Internal Setup (OED – Outside Exchange of Die) involves those activities that must take place when the equipment is stopped.

Application of SMED method can be implemented in four main stages (Figure 2), [2]:

Preliminary stage: Observation and analysis of current process. Internal and external setup conditions are not distinguished.

Stage 1: Separating internal and external setup.

Stage 2: Converting internal to external operations.

Stage 3: Improving and simplification internal and external operations.

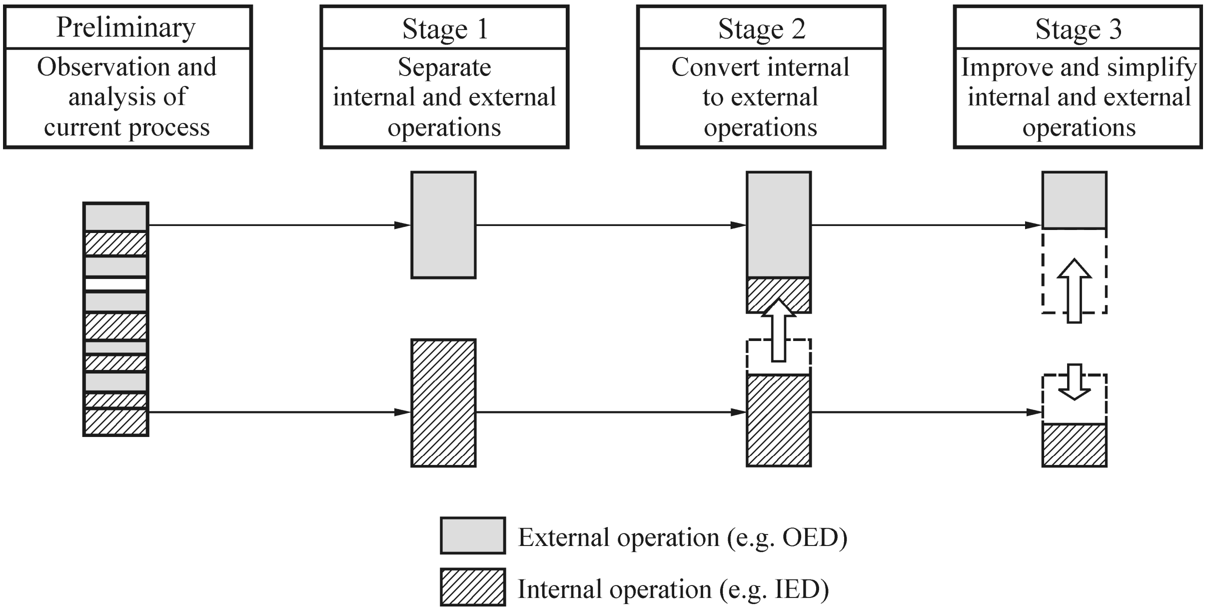

Figure 2. Main stages in SMED method application

Preliminary: Observation and analysis of current process

- Continuous production analysis performed with stopwatch
- Use work sampling study
- Interviewing workers
- Recording setup with camera

Stage 1: Separating internal and external operations

- Stage all items before shutting down the machine (develop checklist for needed changeover items, store high-use items at the machine, use die charts and tool boards, use visual management, place tools and parts in order of usage)
- Check all items to ensure proper fit and function (sharpen and preset tools, clean fixtures and verify free of defects)
- Cleanup and return removed tools after first good part

Stage 2: Converting internal to external operations

- Standardize operations to minimize internal adjustments (die pressures, size and shape, height and stroke)
- Stage materials to avoid vertical and horizontal motion

– Prepare operating conditions prior to changeover (preheat, pre-set, pre-cut, or pre-adjust, form dress grinding wheels offline)
– Use intermediary fixture/jigs (presetting tools, positioning dies)
– Replace fewest parts possible
– Position dies or tooling for quick insertion into machine

Stage 3: Improving and simplification internal and external operations

Internal operations:

– Eliminate time lost removing and installing bolts
– Replace bolts with functional clamps
– Eliminate all adjustments
– Motion element analysis
– Perform parallel operations
– Develop team work
– Highlight internal time

External operations:

– Avoid time lost looking for or verifying correct items
– Use intermediary fixture/jigs
– Proper arrangement and orderliness
– Carts reserved for changeovers
– Material flow racks
– Go-no go gauges
– Simplify adjustments
– Dedicated setup equipment and carts
– Continuously collect ideas to improve setup

3. INJECTION MOLDING

Injection molding is the most widely used process for thermoplastics in discrete parts manufacturing industries. It is based on the ability of thermoplastic materials to be softened by heat and to harden when cooled. Injection molding is accomplished by machines called injection molding machines. The process thus consists essentially of softening the material in a heated cylinder and injecting it under pressure into the mold cavity, where it hardens by cooling. Each step is carried out in a separate zone of the same apparatus in the cyclic operation.

The basic steps of injection molding are (Figure 3), [4]:

1. The transfer of resin (pure polymer or composite mixture) into a plasticizing chamber;
2. Plasticizing of the resin and its transfer to the injection chamber (utilizing an extrusion screw or a cylinder);
3. Pressurized injection of molten material into a closed mold (held tightly shut under great clamping forces);
4. Solidification and cooling in the mold;
5. Ejection of parts from the cavities.

Mold presents a tool that is fitted on the injection molding machine. In the most cases, the mold consists of the two plates: one movable plates and one stationary plate. The mold is cooled constantly to a temperature that allows the resin to solidify and be cool to the touch. The mold plates are held together by hydraulic or mechanical force. The clamping force is defined as the injection pressure multiplied by the total cavity projected area. Typically molds are overdesigned depending on the resin to be used. Each resin has a calculated shrinkage value associated with in.

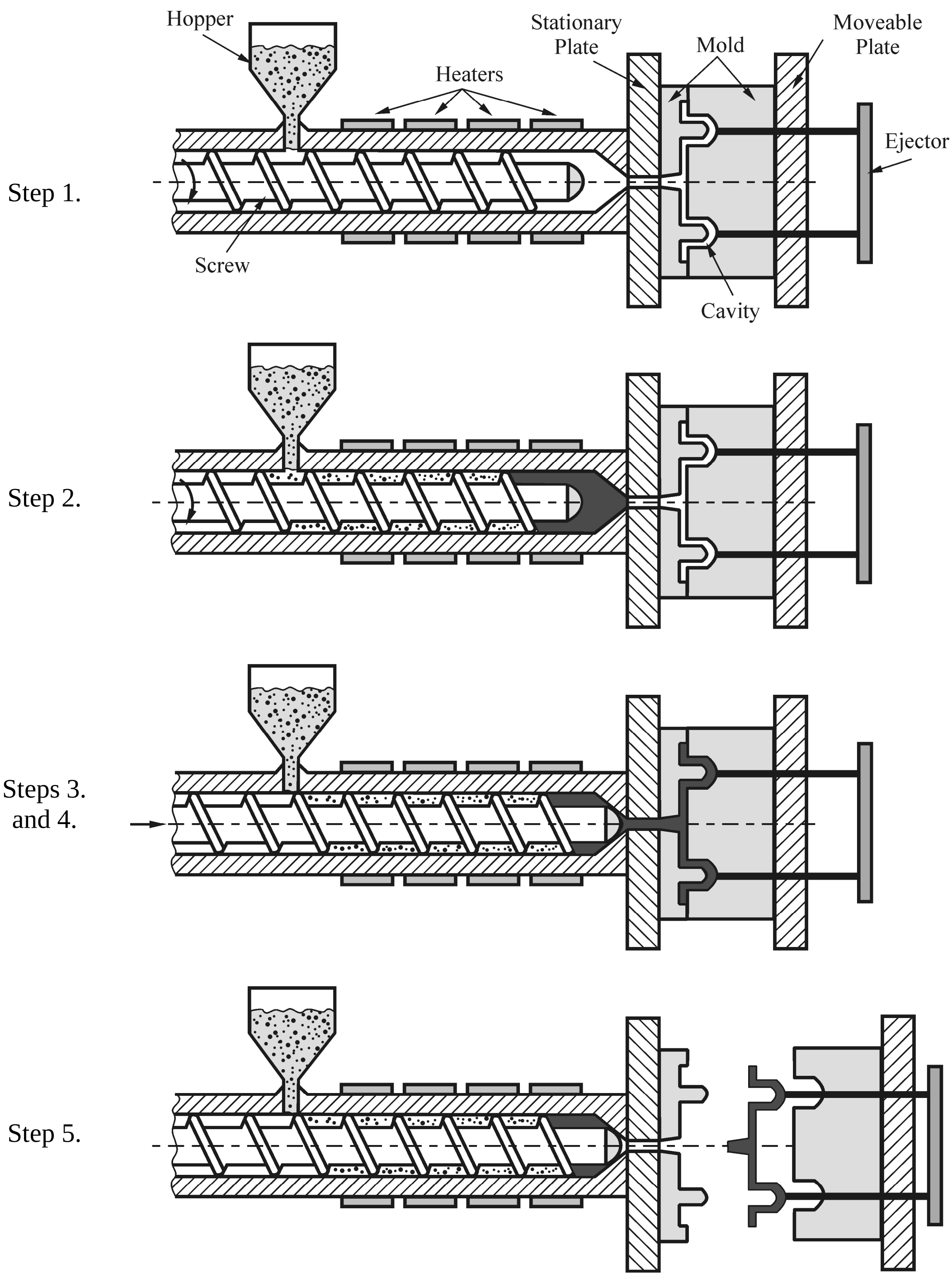

Figure 3. Injection molding process

4. APPLICATION OF SMED METHOD

SMED method was used in process of mould changeover on injection molding machine “KraussMaffei KM 2000" in factory that produces automotive parts from thermoplastic, [5].

Preliminary stage: The changeover process was recorded with a video camera. Changeover time was 216 minutes. The process included eight workers. Gantt chart of process based on data recorded was developed. Meeting was carried out with employees that work on mould changeover, together with head of technical and production department. Conclusion has been made that there is technical and organizational issues in changeover process. Because of that, some of the actions were lasting longer then planed, and in some cases, overlaying of changeover processes on two machines occurred.

Stage 1: Based on records and Gantt chart, OED and IED actions were separated. Order of some actions execution was changed on following way:

– Before changeover start, crane brings next mould and leaves it near of the machine.
– Workers detach previous mould and leave it near of machine using crane.
– Workers attach next mould on machine using crane.
– After end of changeover, crane takes away previous mould to warehouse.

Stage 2: Some of IED actions were converted to OED actions. For example, preheating of mould was done outside of the machine. In machine hopper, exact amount of raw material has to be located needed for finishing of current item production. Raw material excess has to be ejected from hopper before start of changeover process. Raw material for next product was prepared in advance. Function standardization was implemented. Function standardization requires the maximum possible standardization of parts with function that is important for changeover process. To implement function standardization, individual functions has to be analyzed and considered one by one.

Stage 3: Organizational improvement in better timing was implemented to avoid actions overlaying of mould changeover on two or more machines in same time. Simple technical or technological improvements are introduced in hydraulics, water system and electrical system connection processes. Supplements are welded on moulds to help in faster and simpler attaching process. Order of actions during mould changeover was changed. Every worker is supplied with precise working tasks. Number of workers necessary was reduced to 6. With these simple improvements, mostly without any investments, changeover time was reduced on 47 minutes. In comparison to current state, reduction was 169 minutes or 78%.

5. CONCLUSION

Changeover procedure during injection molding process is recognized as possible area for reducing machine time consumption. Successful implementation of SMED method is based on implementation of 5S concept (Sort, Set in order, Shine, Standardize, Sustain) in same time.

In this paper, first iteration of SMED implementation was shown in changeover process for injection molding machine. In second and every following iteration, reached time could be reduced even more. Except further organizational changes, small investment will be necessary in assisting equipment. Overall, key for even better results will be:

– Desire and ambitious,
– Organization and communication,
– Training, harmonized work and just in time principle,
– Continuous improvement (kaizen),
– Stimulation.

SMED is not the only approach for reducing setup time. Some other alternatives are, [6]:

– Production planning - reduce the number of setups;
– Group technology/cell formation - reduce the number of setups;
– Design standardization - reduce the number of setups;
– Use standard module - reduce the number of setups;
– Work simplification;
– Mechanization or automation - an expensive option.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

TECHNOLOGY OF THE PORT AND LOGISTIC SYSTEM

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ABSTRACT
Purpose of this research is the identification and analysis of the key process indicators which significantly contribute to the benefits of the business processes exploitation in the Luka Koper, d.d., and, to display the importance of the systematic process approach. With this case study we attempted to get deeper understanding, and to evaluate the relations between the enablers and results in the frame of the implemented EFQM business excellence model. Medium framed qualitative and quantitative analyses indicate the benefit of the identificated key processes indicators and their influence on the monitoring of the strategic directions.
Keywords: MOT, business processes, capabilities of technology

1. INTRODUCTION
The Port of Koper was established in 1957. Since then they developed into the significant port and logistic system in the Adriatic maritime market. Company Luka Koper, d.d. was the winner of the Slovenian national quality award (PRSPO) in 2002 and finalist in the European Excellence Award 2006 (EEA). With the European Foundation for Quality Management (EFQM) model integration in management system, the company develops a holistic measurement system, continuous improvements, self-assessment, benchmarking, inter-organizational learning and good practice transfer. EFQM model is usually implemented within the pilot project. Most frequent purpose for such approach is bound to participation in a national quality award (NQA) process.
EFQM model, when used in practice, shows that is difficult to determine transparent relations of enablers (causes) with business results (effects). Connecting approaches are undefined [1] and the problem lies in the structure of the EFQM model [2]. However, the implemented model doesn't enable the identification of all information on the relationships (correlations) between process Key Performance Indicators (KPI's) and the business results. In this manner company doesn't have transparent evaluation of resource inputs in efficiency of the implemented EFQM model in the management system. Diagnostic activities, in this context, are usually "too expensive" to the company and it's usually overworked employees. Because of the latter's outlook, diagnostic is regarded as being time-consuming activity. With the development and application of a model for identification of the influential processes KPIs' which gives important contribution to the business results, company can perform its own diagnostic activities and focus on improvements of the key processes in a short and long-time period.
Analysis of researches, documents and records, semi-structured questionnaires and processes KPI's values indicates the latter's significant influence on the business results. Qualitative and quantitative

analysis of many researches about excellence model implementation, performed all over the world i.e. Australia, China, EU, New Zealand and USA, indicates the general favorable influence of KPI's on the business results of organizations [3,4,5,6,7,8,9]..

2. LITERATURE REVIEW

EFQM model was developed, mainly from recommendations of dr. Tito Conti, at the beginning of ninety's of twentieth century, and introduced to the public at EFQM Forum 1991 in Paris. First European Quality Award, actual EFQM Excellence Award (EEA), was handed over in 1992 [2]. Slovenian first pilot project of National Quality Award (PRSPO) was accomplished in 1996, and first award was handed over in 1998. EFQM model is founded on the self-assessment likewise as other excellence models around the world i.e. Malcolm Baldrige NQA (MBNQA) in USA and Deming Prize (DP) in Japan [10]. Self-assessment contains regular activity review and identification of active inertia on every area of organization's activity against the nine criteria of EFQM model [11,12].

First five criteria represent enablers and the last four criteria represent business results of the organization. Enablers tell what organization is doing; meanwhile results indicate what organization achieves. In such a manner results are the consequence of enablers and enablers are improved on the feedback information's basis from the results. Model enables many approaches for the excellence achievement in all viewpoints of organization activities. Excellent results at key performance, customers, people and society are achieved with leadership which is the driving force of policy and strategy, people, partnerships and resources [13].

Self-assessment should be triggered from the management board when company defines key strategic objectives and directions. Triggering should be ended with the list of objectives which have the highest priority. At the same time the objectives list and priority tasks form the framework of the self-assessment process [11]. EFQM model is applicable also at definition of the Total Quality Management (TQM) philosophy. In that way represents a help at fostering TQM from the part of the management board [10,14].

American research about effective implementation of the management paradigm-TQM and its impact on the financial results of 600 quality award winners, showed, that all of them achieved significant improvement in stock returns, operating income, sales, total assets, employees, return on sales and return on assets [4,12].

In Europe, EFQM and BQF organizations sponsored the research for the identification of correlations between adopted principles of the EFQM model and improved business results. Research showed business performance improvement on a short and long-term for the companies which effectively implemented the principles of the EFQM model [9].

Results of PriceWaterHouseCoopers research on the sample of 3500 public sector organizations in the UK indicated that the tool for continuous improvements is the EFQM model in 56% [6].

Research, in the EU northern region, conducted by Kristensen, Juhl and Eskildsen showed that Danish companies, who applied Danish Business Excellence Index are achieving significantly better results than other companies [15]. Sweden Institute for Quality performed equal research for the Swedish companies which showed similar results [5]. Likewise the results of researches in Australia, New Zealand and China confirmed positive effects of systematic application of the excellence model [3,7,8].

Winning the Slovenian PRSPO means to get the highest national quality award of the Republic of Slovenia, which basis on the EFQM model. Research about registered competitors in the frame of Slovenian PRSPO and comparative data from the EEA showed that main motives and benefits of the EFQM model application in the EEA frame are self-assessment, benchmarking, employee engagement and feedback information's. Meanwhile the Slovenian PRSPO competitors emphasized excellence as a part of the strategy, continuous improvements and good practice exchange [16]. In Slovenia we have, after more than a decade of PRSPO existence, some cases of excellent companies which achieved exceptional success also on the European level and placement among the EEA finalists. This are: Hermes Softlab, d.d., in 1998, Luka Koper d.d. in 2006, and Trimo Trebnje d.d. in 2007.

Adaptation of the EFQM model to the company and its capabilities [2,13] with regularly usage of self-assessment [16,17] is essential for the successful companies. Prestigious award winner's cases all over the world are confirming that organizations with the systematic use of tools for continuous improvements are achieving lasting operational excellence. In the last 19 years the EFQM model showed validity in excellence recognition, as an informal standard for assessment and benchmarking tool [2]. At this segment excellence project represents important contribution to the measures for carefully planned operations, quality increasing as well as assurance for uniformed platform for benchmarking and understanding the business excellence achievement in EU space and wider.

3. METHODOLOGY

Main purpose of the research was to establish if it is possible to set up an adequate model for identification of the processes KPIs' which have significant influence on the business results. Based on problem identification and purpose of the research, the following specific objectives were defined: (1) Determination of the groups of processes KPIs' and groups of results, (2) Determination of the cause-effect relations between processes KPIs' and results. (3) Identification of influential processes KPIs' which gives important contribution to the key performance results of the company. (4) Setting up and the application of the model for identification of the KPI's in correlation with the results of the company.

The paradigmatic orientation of this research is quantitative, because the influence of the process KPIs' on the company's business results is discussed. As a research method was chosen case study [18] which is based on the following criteria: self-assessments are performed regularly since 1999, participation in PRSPO competitions (PRSPO winners in 2002) and participation in EEA competitions (R4E in 2005, Finalist in 2006 and participation in 2009).

Documents and records were studied closely and included analysis of public available data from company's application reports for PRSPO and EEA competition, web sites and annual reports. Observations were performed during research which is still being continued. Employees who participated into the research were mainly from the middle management level and some experts which are acquainted with the EFQM model and its terminology [14,18,19]. Data for the model testing, application and analyses were gathered in September and October 2009.

4. EMPIRICAL FINDINGS

With the NCCA method we discussed non-linear relationships among four groups of variables, on the nominal and/or ordinal and numerical level [20,21,22]. All observed variables are processes KPI's, which are measured in eight Profit Centres (PC) for maritime throughput. The values of the general canonical correlations, implemented in the three year analyses, are relatively high and somewhat different. In most, the difference is expressed between the analyses of the years 2006 and 2007 and also between 2007 and 2008. In addition to the high canonical correlations are also high Eigenvalues, which show the suitability of the NCCA method (analysis 2007 Fit = 1,996). Loss or unexplained variance is relatively evenly distributed by the two dimensions and groups of variables, and is low (analysis 2007 Loss = 0,004).

Table 1. - General canonical correlations ρ, Fit and Mean Loss

General canonical correlations Analysis and optimal scaling level	ρ_1	ρ_2	Fit	Mean Loss
1. Analysis 2006				
Ordinal	1,000	0,667	1,750	0,250
Numerical	0,893	0,665	1,669	0,331
2. Analysis 2007				
Ordinal	0,999	0,667	1,749	0,251
Ordinal and Multiple Nominal	0,997	0,996	1,996	0,004
Numerical	0,937	0,608	1,659	0,341
Numerical and Multiple Nominal	0,989	0,952	1,956	0,044
3. Analysis 2008				
Ordinal	1	0,667	1,750	0,250
Numerical	0,831	0,592	1,567	0,433

The findings of the parameters calculation are represented in some detail with analysis of 2007, which had the highest general canonical correlation with ordinal and multiple nominal optimal scaling levels (see Table 1).

Direction through 1st. and 3rd. quadrant is set by following variables (KPI's): number of improvements NIm4, Fuel consumption FC3 (Explained Variance (EV) 100% *), which are associated with higher values and the Correlation Coefficient (CC) 100*, while the number of improvements NIm4 and Maritime throughput MT2 (EV 14.15%) are correlated with the CC 0.3762. Maritime throughput MT2 is associated with lower levels with electricity consumption EC3 (the CC between MT2 and EC3 is 0.1045). On the other hand are, the added value per employee AV1 (EV 96.82%) and revenue per unit RU1 (EV 58.98%), which are correlated with a CC of 0.7557. AV1 and total costs per unit TCU3 (EV 30.02%) are correlated with the CC of 0.5391. All these variables are associated with higher values. Displayed variables (Figure 1) explain the increased fuel consumption in 2007 as well as maritime throughput, added value per employee and operating costs, compared to 2006.

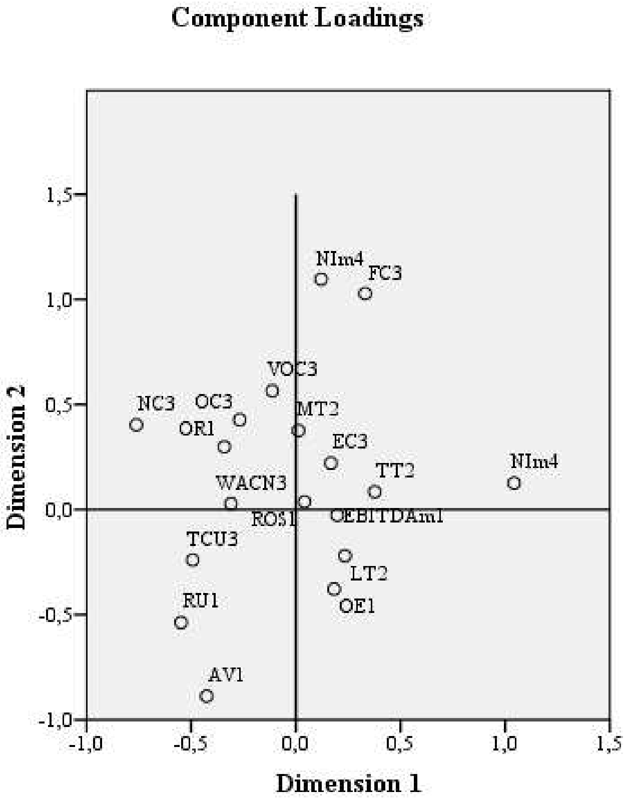

Figure 1 *– NCC Analysis 2007 (Ordinal and Multiple Nominal)*

The direction through 2nd and 4th quadrant is set by variables (KPI's): Number of complaints on billing NC3 (EV 74.31%), variable operating costs VOC3 (EV 33.2%; NC3 and VOC3 are correlated with a CC of 0.4967) and operating costs OC3* (EV 25.47%; NC3 and OC3* are correlated with a CC of 0.434) are associated with higher values.

On the other side are, the Operating Efficiency OE1 (ev 17.64%) and Land throughput LT 2 (ev 10.32%e; OE1 and LT2 are associated with CC equal to 0.1349) which are associated with higher values. The variables in the Figure 1 are explaining the decline in the number of complaints, increase in operating efficiency and land throughput compared to 2006 (22,23,24]. The results of calculation in this case, are certainly more reliable due to the chosen optimal scaling level and calculated Fit. In this case, the relationships between the variables, taken into account in the calculation, are treated as a non-linear what is in practice more likely. In a similar way we analyzed the KPI's from the 2006 and 2008. Variables (KPI's) have been arranged somehow differently than in 2007 (see Table 1).

All three analyses show the correlation and explained variance of variables which varies from fair to very good. On the basis of analysis carried out, we conclude on the importance of the observed variables (KPI's) which are monitored in the frame of the EFQM model and narrower in the four perspectives of business performance (BSC). Namely the length of the vectors from the origin to the coordinates (Figure 1) of each variable indicates its explained variance by all the other variables. The scalar product between any two observed variables indicates the correlation between them [25]. For further in-depth analysis of the relationships between variables is recommended to perform analyses at the level of quarters of a year or even months.

5. CONCLUSION

With the increasing complexity of the business environment and actual global crisis, companies focuses more and more on managing the processes and employees who are involved with them. Holistic approach (i.e. EFQM model implementation) is the challenge to support development of the Integrated Management System (IMS) in order to encourage nourishment of adopted values, technology exploitation, innovation, productivity, social responsibility and preservation of the environment.

While fostering exploitation of the resources and key processes, companies frequently integrate standards (i.e. ISO 22000, BS OHSAS 18001, BSC, and EMAS) into their management system. In the case of Luka Koper, d.d., standards and models enables basis for identification and implementation of the strategic projects like: managing land terminals which are linking Koper Bay with Central and Eastern Europe, boosting the volume of quality cargoes by introducing new capacities, becoming the driving force of development in railway cargo transport, contributing to the development of the passenger port in Koper; and providing sea protection in the whole of the Slovenian sea.

Many researches of the excellence model indicate the general favorable influence of the EFQM model implementation [3,4,5,6,7,8,9,22]. Regarding to the ascertainments of the NCC analysis above, we confirmed the model employability and identified their relationships in sense of explained variance of the observed variables (KPI's) and their correlations. Analyses findings represent the confirmation of the successful business model harmonization which has opportunities for improvements too. In this paper we represented only a part of our research findings because research is still being performed. From the actual analysis we ascertained that implementation of the EFQM model fosters exploitation of the key business processes and all involved resources. With the application of a model for identification of the influential processes KPIs' which gives important contribution to the business results, company can perform its own diagnostic activities and focus on improvements of the key processes and consecutively on the results in a short and long-term.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

IMPLEMENTACIJA STANDARDA SERIJE ISO 9000ff PUT KA TQM U VISOKOM OBRAZOVANJU

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REZIME
U ovom radu su predstavljena iskustva implementacije BAS EN ISO 9001/2008 na visokoškolskim ustanovama u Bosni i Hercegovini i put ka TQM-u. Posebna pažnja je posvećena problemima s kojima su suočeni predstavnici rukovodstva u visokom obrazovanju pri implementaciji korjenitih promjena na putu iz statičnog u dinamički sistem.
Ključne riječi: standard, implementacija, TQM, visoko obrazovanje, kvalitet, metode.

1. UVOD
Poslije 2000. godine dolazi do uvođenja sistema upravljanja kvalitetom u visokoškolskim ustanovama. Permanentnim obrazovanjem kadrova od strane Evropske komisije i Vijeća Evrope, kroz projekat jačanja visokog obrazovanja u Bosni i Hercegovini, dolazi se do saznanja da kvalitetni univerziteti mogu postati i biti priznati isključivo implementacijom standarda koji se primjenjuju u Evropi. Tokom proteklih 10 godina nije bilo moguće ne primjetiti da je kvalitet izrastao u najkonkurentnije oružje i da su mnogi fakulteti shvatili da je put implementacije standarda serije ISO 9000ff temelj za primjenu Bolonjske deklaracije, ENQA standarda i smjernica za osiguranje kvaliteta u visokom obrazovanju, koji je usvojen i odobren 2007. godine od strane Evropske komisije i Vijeća Evrope.

Novi okvir za kvalifikacije BiH zamišljen je tako da jača visoko školstvo i djeluje kao pokretač koji pomaže organima i onima koji donose odluke u visokom obrazovanju u radu na reformama koje za cilj imaju promjenu akademske zajednice, njenih institucija i procesa. Implementacija ovih standarda je put ka TQM-a, a TQM je put upravljanja budućnosti. Ispunjavanje zahtjeva ovih standarda je najznačajnije za dobro funkcioniranje visokoškolske organizacije. Uloga visokoškolskog obrazovanja iz područja osiguranja kvaliteta treba da bude stalni cilj i zadatak rukovodstva visokoškolske ustanove. Posljednjih nekoliko godina, posebno u zemljama zapada, sve više visokoškolskih ustanova uvodi integrirani sistem kako bi se u potpunosti zadovoljili zahtjevi studenata, odnosno privrede i države, a u skladu sa zahtjevima ISO 9001 i ISO 14001 standarda, kao i primjenom ENQA standarda i smjernica za osiguranje kvalitete u visokom obrazovanju. Istorijski gledano, postoji visoki stepen autonomije svih fakulteta i odsjeka. Svaki fakultet je određivao svoje prioritete te je bilo veoma teško postići predstavljanje univerziteta kao cjeline. Iz navedenih razloga su do sada certificirani fakulteti, a ne univerziteti. Primjenom Bolonskog procesa univerziteti postaju pravna lica, a i sistem upravljanja kvalitetom se odvija na nivou univerziteta kao cjeline.

U okviru zajedničkog projekta 2006 - 2008. godine „Jačanja visokog obrazovanja u BiH“, pod pokroviteljstvom Vijeća Evrope, uloženo je sedam miliona eura. Rezultat ovog zajedničkog projekta je sedam osnovnih strategija i smjernica za implementaciju Bolonskog procesa.
TQM u visokom obrazovanju označava tri stvari, i to:

- filozofski pojam iz teorije kvaliteta,
- kulturu i ponašanje visokoškolske ustanove u odnosu na studenta ili korisnika, i
- model integriranog upravljanja sistemom kvaliteta u visokoškolskoj ustanovi.

Elementarno objašnjenje TQM-a može se dati prema šemi Demingovog kruga.

2. RAZVOJ KVALITETA

U BiH sistem upravljanja kvalitetom po seriji standarda ISO 9000ff uvela su dva fakulteta i to: Tehnički fakultet Bihać i Mašinski fakultet Zenica, što predstavlja veoma mali broj u odnosu na zemlje okruženja. Ova dva fakulteta su se opredjelila za recertificiranje po istom standardu, a implementacijom ENQA standarda i ISO IWA-2 je uspostavljen integrirani sistem. Ovakav integrirani sistem upravljanja kvalitetom je dobar put ka TQM-u, što je dokazano prilikom izvođenja samoevaluacija i institucionalnih procjena ovih fakulteta kao organizacionih jedinica univerziteta.

Provođenjem samoevalucije i institucionalnih procjena na ovim fakultetima se uvidjela prednost uvođenja integriranih sistema u odnosu na fakultete koji nemaju uveden sistem upravljanja kvalitetom po ISO 9000ff. U ovim fakultetima vidljiva je primjena osnovnih zajedničkih elemenata kod svih modela TQM-a koji se dijele u dvije grupe: sposobnost i rezultati. Kod modela TQM-a su ključni slijedeći zajednički elementi :

1. Opredjeljenost rukovodstva,
2. Politika i strategija organizacije,
3. Angažman svih zaposlenih,
4. Raspolaganje resursima,
5. Upravljanje procesima,
6. Zadovoljstvo kupca i korisnika,
7. Pozitivan utjecaj na društvo, i
8. Postignuto poboljšanje i poslovni uspjeh.

Ovakav pristup čini srž stvaranja Evropskog prostora visokog obrazovanja i razvoja osiguranja kvaliteta na institucionalnom, nacionalnom i Evropskom nivou. Razvoj zajedničkih kriterija i metodologija osiguranja kvaliteta je od izuzetne važnosti za prohodnost studenata i nastavnika.
Uloga najvišeg rukovodstva visokoškolskih ustanova ogleda se u slijedećem:

- definira politiku i ciljeve kvaliteta organizacije,
- promovira politiku i ciljeve kvaliteta u cijeloj visokoškolskoj organizaciji,
- obezbjeđuje usmjerenost na zahtjeve korisnika kroz cijelu organizaciju,
- obezbjeđuje da su primjenjeni odgovarajući procesi u cilju ispunjenja zahtjeva korisnika i postavljenih ciljeva,
- obezbjeđuje uspostavljanje i održavanje sistema upravljanja kvalitetom kako bi se ostvarili ovi ciljevi,
- obezbjeđuje raspoloživost potrebnih resursa,
- uspoređuje ostvarene rezultate u odnosu na postavljene ciljeve,
- donosi odluke u vezi sa mjerama koje se tiču politike i ciljeva kvaliteta, i
- donosi odluke u vezi sa aktivnostima poboljšavanja.

Kroz svoje liderstvo i profesionalni stav najviše rukovodstvo demonstrira svoju opredjeljenost za gore navedeno i stvara okruženje u kome vlada svijest o potrebi zadovoljenja zahtjeva i drugih zainteresiranih strana [2,3].

Prvi korak koji visokoškolska organizacija mora preduzeti je da definira i dokumentira svoju politiku menadžmenta/upravljanja kvalitetom. Drugim riječima, da proizvede izjavu o misiji koja pokriva ciljeve kvaliteta u organizaciji i njenu privrženost kvalitetu. Ova politika kvaliteta mora biti relevantna organizacionim ciljevima fakulteta i moraju se uzeti u obzir očekivanja i potrebe kupaca. Organizacija potom mora osigurati da cjelokupno osoblje i članovi shvate i implementiraju njenu politiku menadžmenta kvaliteta i da je koriste radi obezbjeđenja povjerenja da je primjena menadžmenta (kao što je opisano u Poslovniku o kvalitetu) efikasna, sveobuhvatna i efektivna u osiguranju da fakultet isporučuje dobre stručnjake po zahtjevima privrede i društva sa preciznim ishodima znanja u okviru sva tri stepena.

Politika kvaliteta organizacije mora uvijek biti takva da ostvaruje održiv rentabilni rast putem obezbjeđivanja znanja studenata koje zadovoljava potrebe i očekivanja privrede i države. Ovaj nivo kvaliteta je moguće postići usvajanjem sistema procedura koje održavaju kompententnost fakulteta u odnosu na njene postojeće kupce i nezavisna stručna lica koja obavljaju eksterne audite. Ukratko rečeno, politika rukovodstva kvaliteta mora obuhvatiti zahtjeve da se:

- razjasne odgovornosti za svaku aktivnost ili zadatak razvoja koji su identificirani,
- svaka aktivnost organizacije definira i kontrolira preko procesa kvaliteta, procedura kvaliteta ili plana kvaliteta,
- obuka zaposlenih odvija prema zahtjevima navedenim u Poslovniku o kvalitetu organizacije,
- preduzimaju akcije ispravke kad god je to potrebno, i
- procedure kvaliteta sadrže u Poslovniku o kvalitetu i da se prateći planovi redovno preispituju.

3. MINIMUM ZAHTJEVA ZA SISTEM UPRAVLJANJA KVALITETOM

3.1. Sistem upravljanja kvalitetom

Potrebno je uspostaviti, dokumentirati, uvesti i održavati sistem upravljanja kvalitetom koji stalno povećava svoju efektivnost, a to podrazumijeva slijedeće:

- identifikaciju procesa,
- definiranje redoslijeda i veza procesa,
- kriterujume za efektivno funkcioniranje i upravljanje procesima,
- obezbjeđenje resursa i informacija,
- definiranje mjerenja, praćenja i analize procesa, i
- primjenu aktivnosti za postizanje planiranih rezultata i stalnog poboljšavanja procesa.

Ako smo neke procese povjerili spoljnjoj organizaciji, a ti procesi imaju utjecaja na usaglašenost proizvoda sa zahtjevima, te procese je prethodno potrebno identificirati i vršiti upravljanje tim procesima.

Potrebno je izgraditi sistem kvaliteta i opisati ga u Poslovniku o kvalitetu, uvesti i sprovoditi sistemske, opće procedure i uputstva sistema upravljanja kvalitetom. Potrebno je izvršiti distribuciju dokumentacije sistema upravljanja kvalitetom i držati je pod kontrolom, te voditi uredno zapisnike s kojima dokazujemo da posjedujemo sistem upravljanja kvalitetom. Zapisnici moraju biti na raspolaganju svim korisnicima. Dokumentacijom jednoznačno definirati sve aktivnosti i odgovornosti po osnovu upravljanja zapisima o kvalitetu [6].

3.2. Odgovornost rukovodstva

- Najviše rukovodstvo treba da ima dokaz o svom angažiranju na razvoju, primjeni i poboljšanju sistema upravljanja kvalitetom.
- Kroz odnos prema studentima, zakonu i propisima, definirati jasnu politiku i ciljeve kvaliteta, preispitivanje i obezbjeđivanje neophodnih resursa. Jasno odrediti preispitivanje zadovoljstva studenata, privrede i države.
- Politika kvaliteta treba da odgovara svrsi visokoškolske ustanove, i da iskaže opredjeljenost zadovoljavanju zahtjeva korisnika i stalnim poboljšanjem.
- Rukovodstvo mora uspostaviti strateške, mjerljive i dostižne ciljeve za sve procese, a posebno za procese nastave, naučnoistraživačkog rada i transfera znanja. Ovi ciljevi moraju biti saglasni sa politikom kvaliteta. Planiranje kvaliteta mora obuhvatiti procese sistema upravljanja kvalitetom, materijalne i ljudske resurse i stalno poboljšanje.
- Izgraditi matricu odgovornosti koja jasno definira odgovornost i ovlaštenja u svim procesima, obezbjediti komunikaciju na svim nivoima i funkcijama putem sastanaka, oglasnih tabli i pisanih

informacija korištenjem elektronskih medija. Ovakav način odgovornosti, ovlaštenja i komunikacije treba da bude način poboljšanja i učešća svih zaposlenih u ostvarivanju ciljeva kvaliteta.

-Šefovi katedri, smjerova i odsjeka na sistemski i sistematski način prikupljaju određene informacije i vrše periodično preispitivanje sistema kvaliteta. Svoj izvještaj dostavljaju prodekanu za nastavu, a prodekan za nastavu pravi zbirni izvještaj i dostavlja ga rukovodiocu upravljanja kvalitetom. Ovi izvještaji su osnov za sprovođenje internih audita. Nakon provedenog internog audita, predstavnik rukovodstva za kvalitet piše svoj izvještaj prema zahtjevima standarda ISO 9001:2008 tačka 5.6. Ovaj izvještaj se dostavlja dekanu fakulteta i on čini osnov za preispitivanje sistema upravljanja kvalitetom od strane rukovodstva. Rezultati preispitivanja moraju biti pisani u vidu izvještaja pod nazivom „Ocjena efikasnosti i efektivnosti sistema upravljanja kvalitetom“[3,6].

3.3. Upravljanje resursima

Posebno bitan faktor osiguranja zadovoljstva studenata, privrede i zajednice su znanje, sposobnosti i visoka svijest nastavnog osoblja, te zbog toga uvijek težimo da aktivnosti vođenja, realizacije i kontrole izvođenja nastave radi kompententno i motivirano osoblje. Shodno posebnim potrebama za sticanjem novih znanja, kontinuirano se planira naučnoistraživački rad kod nastavnog osoblja.

Visokoškolska ustanova mora da utvrdi i na vrijeme obezbijedi potrebne resurse za izvođenje i poboljšanje nastave, naučnoistraživačkog rada i transfera znanja. Svi zaposleni moraju biti kompententni na osnovu svog obrazovanja, uvježbanosti, vještina i iskustava. Asistenti pripravnici moraju biti vođeni i kontrolirani od strane svojih mentora i šefova katedri. Moraju se identificirati potrebe za kompentencijama zaposlenih na poslovima koje utječu na kvalitet. Svake godine potrebno je izvršiti ocjenu efikasnosti provedene obuke pripravnika. Moraju se voditi zapisi o potrebama i rezultatima obrazovanja, obučenosti i iskustvu svih zaposlenih.
Visokoškolska ustanova mora obezbijediti i održavati infrastrukturu.
Visokoškolska ustanova mora obezbijediti radnu sredinu koja odgovara zakonskim propisima [6].

3.4. Upravljanje procesima

- Prodekan za nastavu i voditelji glavnih procesa planiraju realizaciju sva tri procesa u cilju zadovoljavanja studenata i drugih kupaca u pogledu: programa i resursa za realizaciju glavnih procesa, ciljeva i kvaliteta glavnih procesa i kriterija prihvatljivosti. Prilikom planiranja nastavnog plana i programa uzimaju se u obzir slijedeći podaci i zahtjevi: definirani godišnji ciljevi kvaliteta, interni zahtjevi za poboljšanje procesa, i zahtjevi i očekivanja kupaca. Potrebno je uraditi plan realizacije nastave, naučnoistraživačkog rada i transfera znanja.

Potrebno je utvrditi ciljeve za ishode znanja studenata, projekata i ugovora sa privredom. Definirati aktivnosti i kriterije prihvatljivosti za verifikaciju i validaciju ishoda znanja i usluga. Razmotriti zahtjeve korisnika za specifična zanimanja, projekat ili ugovor.

- Pri potpisivanju ugovora, potrebno je ugovoriti i zahtjeve kvalitete kod sva tri procesa. Definirati način preispitivanja ugovora i voditi zapise kao garanciju da su svi u reprodukcionom lancu, sagledati mogućnosti i dati saglasnost da će prihvaćene obaveze biti izvršene u skladu sa politikom i ciljevima kvaliteta. Eventualne izmjene ugovora vršiti uz obostranu saglasnost. O ovom obavezno voditi zapis, te stalno vršiti komunikaciju sa korisnicima.

- Potrebno je definirati ko je odgovoran za sve aktivnosti projektiranja i ko sve učestvuje u realizaciji i verifikaciji projekata. Definirati način razvoja novih odsjeka, a to znači da izlazni parametri ispunjavaju postavljene zahtjeve, a da konačnu odluku o učinjenom naporu donesu korisnici usluga.
- Kod nabavke je potrebno gajiti partnerske odnose sa srednjim školama kao našim isporučiocima, a nakon prijemnih ispita napraviti listu podobnih dobavljača. Definirati uslove prijama studenata.
U skladu sa uputom u nabavi, ustanoviti postupke za verifikaciju o odobravanje nabavljenih mašina u laboratorije.

- Sve aktivnosti u procesima gdje se ugrađuje kvalitet usluga pokrivati dokumentacijom. Laboratorijskom opremom upravljati na takav način da ona omogućava ostvarivanje postavljenih zahtjeva. Odrediti i izvršiti validaciju svih procesa čiji se izlazi ne mogu verificirati neposrednim mjerenjem ili praćenjem. Definirati i identificirati sljedljivosti. Sljedljivost pratiti dokumentacijom. Čuvati imovinu korisnika, a posebno kad se radi o studentskoj dokumentaciji. Voditi brigu i evidenciju studenata i nakon završetka studija.

- Upravljanje mjernom, ispitnom i kontrolnom opremom - znači označiti je i evidentirati, periodično je pregledati i zaštiti od odštećenja [4,6].

3.5. Mjerenje, analiza i poboljšanje

- Kvalitet naših usluga, kroz ovaj zahtjev, potrebno je na osnovu sistemskih procedura planirati i sprovoditi aktivnosti mjerenja, praćenja, analize i poboljšanja. Odrediti metodologiju rada, te uključiti primjenu metoda i tehnika.

- Na fakulltetima treba da se kontinuirano planiraju i pripremaju interni auditi svih procesa u cilju:

- utvrđivanja provedbe planiranih aktivnosti prema propisanim dokumentima SUK-a.,
- utvrđivanja da li se SUK efektivno primjenjuje i poboljšava, shodno poslovnim potrebama i zahtjevima referentnog standarda,
- utvrđivanja nivoa ostvarivanja ciljeva kvaliteta i provođenja utvrđene politike kvalitete,
- utvrrđivanja područja gdje su moguća, odnosno nužna poboljšanja i pokretanje potrebnih korekcija, korektivnih i preventivnih akcija.

Sprovoditi monitoring mjerenja, pratiti informacije o zadovoljstvu korisnika naših usluga. Najmanje dva puta godišnje sprovesti interni audit i jedan put eksterni audit sa obučenim auditorima. Rezultate internih i eksternih audita koristiti za poboljšanje procesa. Planirati i sprovoditi praćenje procesa, a posebno proces nastave, a u svrhu zadovoljstva studenata, privrede i društva. Redovno vršiti ulaznu, procesnu i završnu kontrolu. Analizirati zapise o kontroli kvaliteta i čuvati ih na određen period.

- Na osnovu SP (sistemske procedure) o neusklađenostima, redovno identificirati neusklađenosti, provoditi korektivne mjere, analizirati ih, otklanjati ih i dokumentirati. Pomoću FMA metode identificirati uzroke i ocjenjivati posljedice neusklađenosti.

- U svim procesima vršiti analizu podataka i koristiti ih za verificiranje i dalje upravljanje procesima, a posebnu pažnju obratiti zadovoljstvu naših korisnika.

- Izraditi godišnji plan poboljšanja, planirati i upravljati procesima stalnog poboljšanja.Vršiti analizu svih oblika neusklađenosti. Tražiti povratne informacije iz privrede i društvene zajednice o našim svršenicima i na osnovu njih sprovoditi preventivne i korektivne mjere. Na osnovu sistemske procedure o preventivnim i korektivnim mjerama sprovoditi te mjere na dokumentiran način i stalno vršiti kontrolu sprovedenosti i efikasnosti preventivnih i korektivnih mjera, a za sve ove aktivnosti voditi zapisnik kao dokaz da se ove aktivnosti sprovode [1,5,6].

- Dosljedno prilagođavanje sistema upravljanja kvalitetom zahtjevima standarda BAS EN ISO 9001/2008, samo je jedna od etapa na putu ka TQM-u, odnosno integriranom sistemu za upravljanje kvalitetom. Model integriranog sistema za upravljanje kvalitetom se može predstaviti nekom od metoda sa jasnom matricom odgovornosti, kako bi jasno bio vidljiv timski rad. Model čine hardverski, softverski i dio koji simbolizira odnos isporučioca i korisnika na relaciji sistem-okruženje. Hardverski dio predstavlja: sistem kvaliteta, alati, metode, tehnike poboljšanja sistema kvaliteta i timovi za pobolšanje sistema kvalitete.

4. ZAKLJUČAK

Ključ uspjeha svakog univerziteta je da proizvede stručnjake koji će biti vodilja društva i pokretač razvoja. Prvi zadatak u ostvarivanju tog cilja je da kreira atraktivnog stručnjaka svjetske klase i kvaliteta. Implementiranjem programa TQM stvara se fleksibilan univerzitet koji omogućava konstantan kvalitet studenata i svršenih diplomanata. Primjenom integriranog sistema upravljanja kvalitetom i putem ka TQM-u, stvara se mogućnost da se kroz kontinuirana poboljšanja povećava nivo izvrsnosti i mogućnost uvrštavanja na listu evropskih kvalitetnih univerziteta. Bez primjene pomenutih standarda nećemo učiniti pomake naprijed, a to znači neće biti poboljšanja koja su neophodna za bolju i sigurniju poziciju prilikom akreditiranja univerziteta. Ovakav pristup promjene dosadašnjih metoda rada, te primjenom novih tehnika i alata, je presudan za uspjeh svakog univerziteta. ENQA standardi nisu dobrovoljni već su obavezujući za potpisnike Bolonjske deklaracije.

TQM jeste akt dobrovoljnosti, ali bez njega neće brojne barijere, bilo tehničke, tehnološke, ekonomske, tržišne i slične, biti ažurnije i efikasnije otklonjene. Prema svim postojećim prognozama razvoj svjetskih modela TQM-a usmjeren je na takav oblik koji bi omogućio postizanje poslovne izvrsnosti na univerzitetima. Razvijanje teorije i prakse modernog kvaliteta praktično je nemoguće bez jasnog uvida u istorijsko i prostorno razvijanje osnovnih modela TQM-a. Evropska nagrada za kvalitet (EQA) je najmlađa nagrada za kvalitet. Asocijacija za kvalitet u Bosni i Hercegovini je 9.novembra 2009.godine, na Dan kvaliteta BiH, promovirala Nagradu za kvalitet u BiH [2].

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

MODEL ANALYSIS OF ROBOTIC SUPPLY – EXHAUSTING SYSTEMS OF MACHINING CENTRES, WITH COMPLEX SHAPE OF PARTS

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ABSTRACT
This paper presents a structural analysis – functional robotic systems used to manufacture complex shaped parts, starting from the feeding and ending with the exhausting. The processes involve aspects about the accuracy, regarding the operation of feeding, orientation, fixing and exhausting of the pieces. All systems supposed have a significant influence on manufacturing errors. Also, at all of these equipment exist the possibility to synchronize the movements by correlating the coordinated system that enable optimal operation with minimum error and lower manufacturing costs.
Keywords: robotic systems, supply, exhausting, machining centres.

1. INTRODUCTION
Necessity to produce intangible assets, with high productivity, has led to a tremendous development of modern concepts of structural performance processing centers, machine tools, which mostly depends on the specific technology of various parts to be processed and their production volume. Processing cost difference of making a piece is even greater as processed surface geometry becomes more complex.

1.1 Theoretical considerations regarding the construction and functioning of feeding, orientation, fixing and exhausting of the pieces
The existence of these systems into of machining centres and of machine tools with NC is useful because provide flexibility, modularity and interchangeability in that these systems can be replace function by the type and the dimensions of the pieces which are processed on machining centres. An important role in a correct chosen of the structure of machining centre, respectively of machine tools with NC consist in the coordinates system of this, which can be in five, four or three axis. Determinant factors in a correct establishment of the machining centre structure are consisting by the coordinates system of the robot, of device which can take one or two degree of freedom, and also, the coordinate system of the piece depending by the required processing on that.

An major advantage of use of machining centres is consist in fact that, can be realized pieces with complex shapes, useful examples in this way being NC applications in aeronautic and auto fields.
In the construction of the machining centres can retrieval pallets, which roll of them being to supply, transport and exhaust the pieces at the end of each manufacturing process. These are available in different constructions and in a various configurations function by the geometry of the pieces which are next to be used. Some examples of machining centres equipped with palletizing systems are illustrated in figure 1.

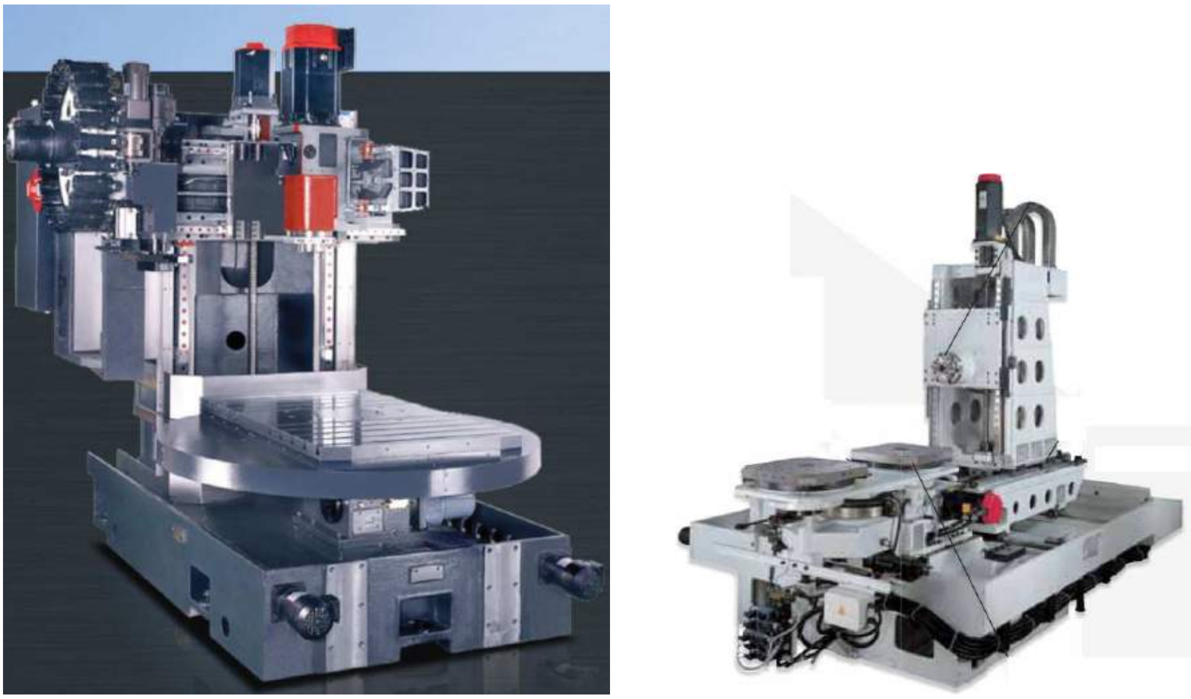

Figure 1. Examples of machining centres equipped with palletising systems [9]

Also, in this regard, the machining centres can be serve by an robot. Choosing the robot is based on its adaptability capacity and its construction and manipulation possibilities of the machine with parallel kinematics (the architecture of cinematic chain, degrees of freedom).

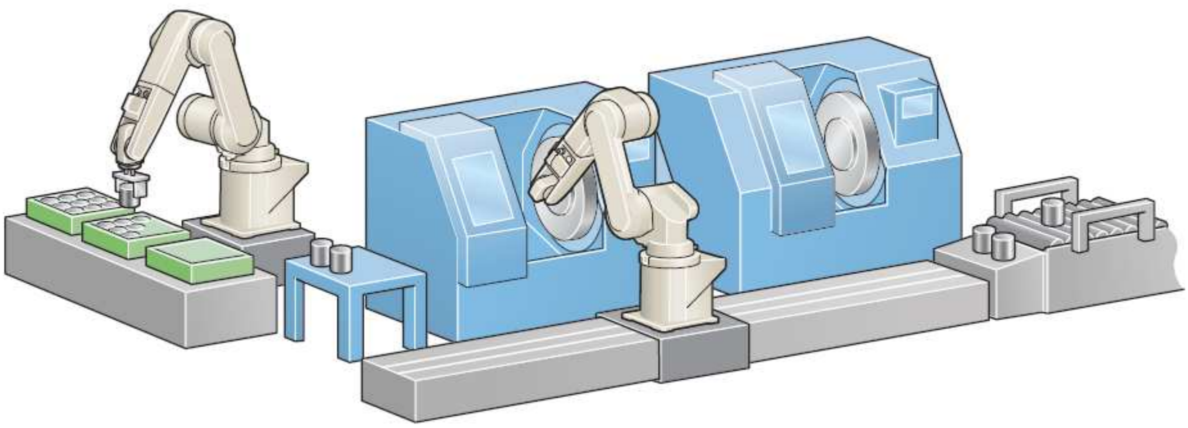

Figure 2. Example of machining centre – CNC turning served by robots [10]

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1.2 Conditions which must be accomplished by the robotized systems of supply – exhausting from the machining centres

Because these systems can function and exploit in optimal conditions are necessary to accomplish of several conditions like [1,3,4,5,6,7,8]:

- reducing to minimum of the friction forces between components with relative movement (bearing, guide-ways, screw-nut transmission), which is resulting in reducing of the wear of these elements and, also, of the clearances between them; that is determining to keep the accuracy of displacements of the elements. Given the need to move with small speeds of the sledges (at processing numerical outlining), must be avoid the appearance of the phenomena of the jerky motion caused by the interruption of fluid film;
- high accuracy of the translation and rotation movements, which is achieved by the elimination of montage clearances and the possibility to realize even a pre-tightening;
- thermal deformations lowers, deformations which determine change of relative position between tool and pieces, and thus machining error;
- high capacity to amortize the vibrations, resulting machining of surface at better quality;
- high stiffness of gantry system of machine-tool/machining centre, resulting lower elastic deformations.

To resolve these requirements, in construction of machining centres/machine-tools with NC are provided with a number of solutions which are not found in conventional construction of machine-tools with NC and namely:

- beared of the main axis of rolling bearings or hydrostatic which is lead to increase the accuracy of rotary motion, increase of bearings rigidity and reduce the heating, therefore are reducing the thermal deformations of the subassembly, deformations which have a particularly weight regarding in the balance of error processing;
- use of roll guide-ways and of hydrostatic guide-ways having effect about of accuracy of translation motion, the vibration damping coefficient, about reducing the heat by reduce the friction coefficient, regarding of rigidity of guide-way;
- use of lead screw-nut transmission with ball recirculation or even of hydrostatic nuts, having a major effect the transmission without clearances into the sledges, which is very important in case of numerical contouring (meaning processing displacements, realized with technological advance, on the one axe or more axis; in this case the achieved trajectory, respectively the fidelity with which is reproduce the optimal trajectory is essentially) when, depending by the gradient of piece's profile, frequently is having place direction changes of the advance motion;
- use of actuating motors with adjustable continue speed, in large areas, reversible (DC motors, asynchrony motors actuate by frequency converters, step motors), which allow shortening of kinematics advance, resulting the increase of cinematic accuracy;
- utilization of automated changing systems of large number of tools, which make possible the execution of complex and technological processes, with a large number of operations.

1.3 The advantages of use of robotized systems of supply – exhausting from the machining centres

The main object is that to realize machining centres/machine tools with NC with highest speeds working and high accuracy. This is difficult to obtain because at the high speeds occur vibrations in the moving components resulting the loss of machining accuracy.

The most significant advantages of use of these types of robotized systems are [6,7,8]:

- reducing of machining time;
- contouring of parts with complex shapes;
- high accuracy and repeatability;
- reducing the number of the catches of the part;
- simplification of the tools and of fixing devices;
- adaptation possibility of the program at the required concrete conditions through corrections;
- improvement of accuracy machining;
- increase the quality of machined surfaces;
- increase the tools life.

2. ASPECTS ABOUT THE KINEMATICS OF ROBOTIZED SYSTEMS OF SUPPLY – EXHAUSTING OF MACHINING CENTRES

Is use machine tools with NC into of fabrication processes because provide high working speeds, motion and high productivity. The functions of these robotized systems consist in [3,4,5,6]:

- realization of several movements which assure the relative displacement tool-pieces, after an predefined program;
- main motion – ensure the machining speed or the deformation energy;
- advance motion – ensure the displacement of the tool/piece in the successive positions imposed by the machining of the piece;
- supply with tools: is realized automatically, and is compose from a warehouse – for the depositing of the tools and a transferring device of tools from the warehouse at the tool and vice versa.

A short classification of the machining centres can be made by:

- after number of the axis: two, three or more;
- after the arrangement of axis: verticals and horizontals;
- after the presence or absence of automatic tool changer (fig. 3).

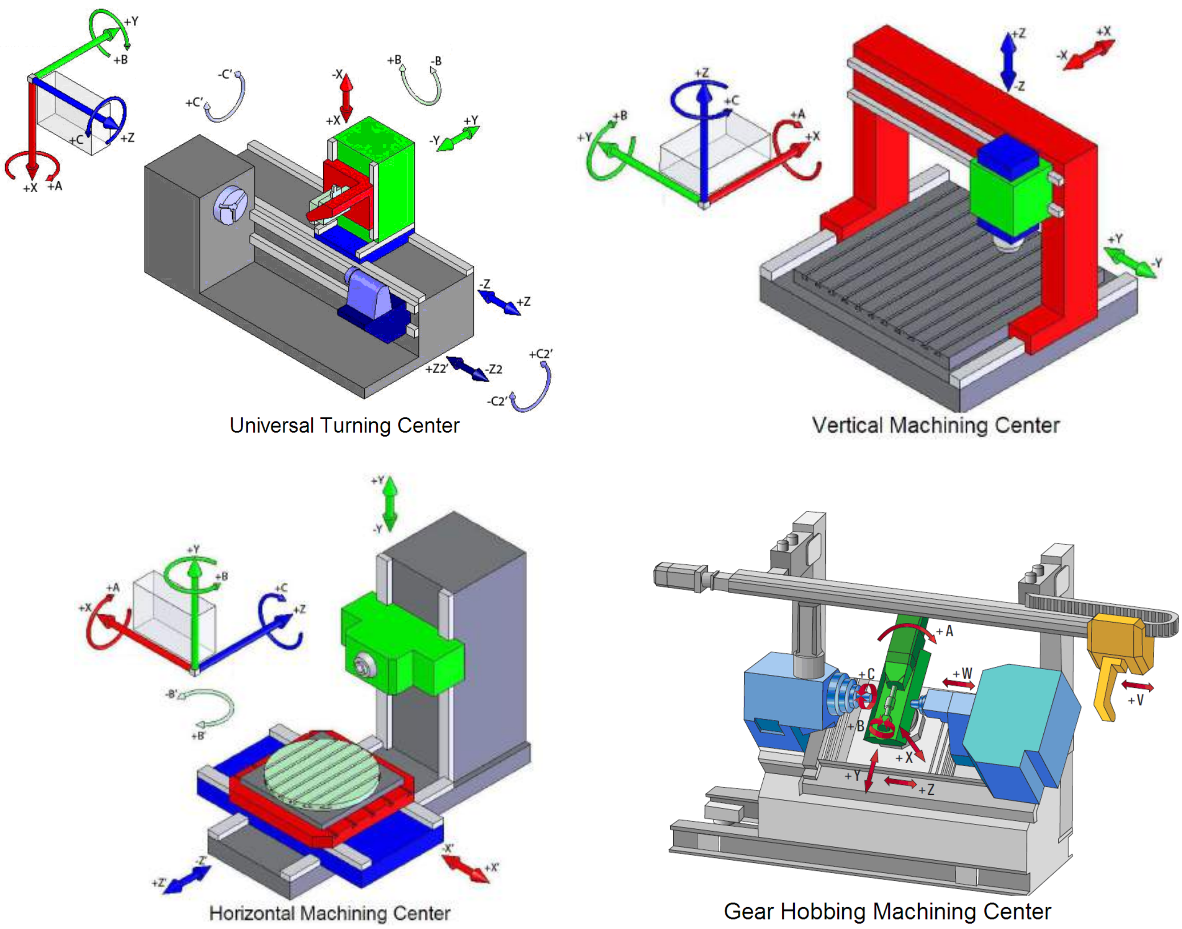


Figure 3. Several examples of machining centres [2, 10]

The most common machining centres/machine tools with numerical control are in variant with three axes, X and Y being the translations of the machine table and Z axe being the movement of the tool. Additional movements are obtained by the combination of several machines with more axes. Usually, the fourth axis consists by the rotation of a rotating chuck plate fixed on the table. The complexity of machines tools with NC, respectively of machining centres increases proportionally with the number of axes that they possess; as result increase the cost of some type of equipment, but the advantage of these is consist in that the can be processes pieces with complex geometry.

Inside of machining numerical system is defined a lot of points type “origin” and references positions. Some of them are well defined by the machine tool producer, others can be declared by the programmer. Thus, are distinguishing the next coordinates systems:

- coordinates system of the machine;
- coordinates system of the piece;
- current system of the piece.

The movements after circular trajectories of the tool are notify with A, B, C, and of the piece with A’, B’, C’, if are executed around of the axes X, Y, Z (X’, Y’, Z’) or are parallel with these.

Through the complexity of movements it is possible to execute by on NC machine tools, outside the above-mentioned directions X, Y, Z (X’, Y’, Z’) called primarly, are more defined the secondary directions (U, V, W) and tertiary (P, Q, R) parallel with the first (fig. 4).

For these main types of coordinates systems must be found solutions for an adequate correlation of all type of systems.

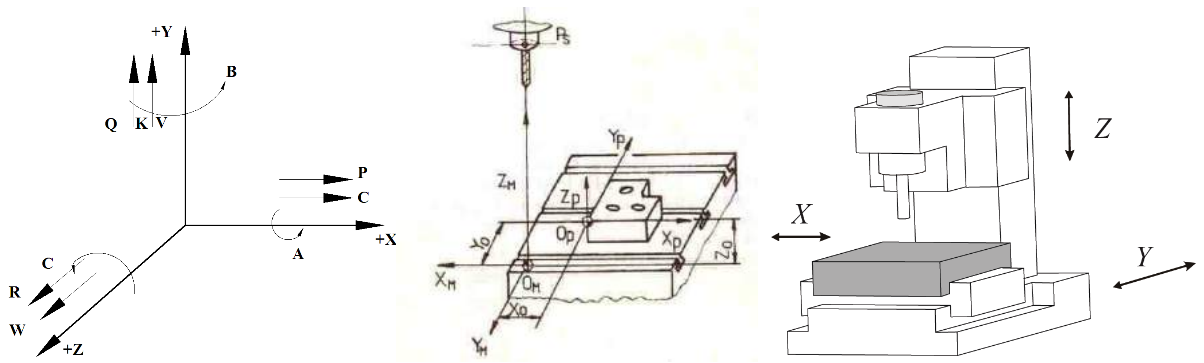


Figure 4. The main motions of one machining centre and an example of schematic representation of these on a piece, respectively on a machining centre/machine tools with NC [3, 4, 6]

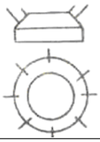
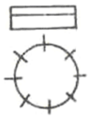
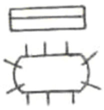
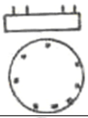
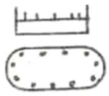
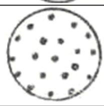
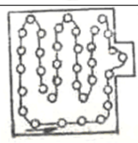
Bellow are illustrated the main motions realized by the robotized systems used in operations of supply, orientation, fixing and exhausting of the pieces in/from the tools warehouses of the machining centres and the types of warehouses used in construction of machining centres.

The shape and the position of the tools into the warehouses is dictated by the position of this toward by the working plane of the tool and also by the kinematics and the construction of the transfering mechanism.

Thus, the simplest are warehouses type disk. The maxim capacity of storage is given by the warehouses with tools arranged on more rows. The numebr of the places for tools can be significant much larger then warehouses with chain. The storage capacity of these types of warehouses can be increased by arranging of tools in turn. The speed drive of disk warehouses, and also the displacement speed of chain warehouses, is relatively small by dynamic reasons. At the warehouses type disk, the speed ussually does not exceed 10 rpm.

An major problem which must take in consideration during of functioning of machining centre is reffering to the symetrical loading with tools of the warehouses. Unequal distribution of tools, regarding weight of these, can lead to malfunctions in the operation of the warehouse [2].

These aspects are important because provide additional information’s about of automation of alimentation, orientation, fixing and exhausting of the pieces.

The position of the tool in the warehouse			Warehouse	
			Disc type	With chain
a	Angular			
b	Radial			
c	Axial	On single row		
		More rows		
		Loops		

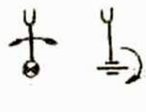
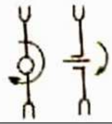
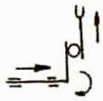
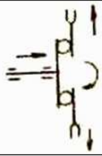
The type of movement	Robotized system of supply, orientation, jamming and exhausting	
	Singular actuation	Double actuation
Rotation		
Translation		
		
Rotation and translation		
Rotation and two translation		

Figure 5. The main types of the warehouses and of the main motions – translations and rotations of robotized systems of supply, orientation, fixing and exhausting of the pieces [4]

3. CONCLUSIONS

Presentation of these information's about the robotized systems of supply – exhausting into from machining centres is useful because present superior benefits (high accuracy and repeatability) comparatively with classical equipments. The possibility to realize an efficient correlation between all three main coordinates systems (of machine, device, respectively of the piece) lead in reducing of errors which can occur during the operating of these systems and implicit at technical and economical benefits.

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International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

AKREDITACIJA LABORATORIJA ZA DIMENZIONALNU METROLOGIJU SA ASPEKTA KVALITETA LABORATORIJA

Daut Denjo
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SAŽETAK
Kvalitet laboratorija za dimenzionalna mjerenja određuju i utjecajne veličine, koje utiču na rezultat mjerenja i njemu pridruženoj mjernoj nesigurnosti. Te utjecajne veličine su temperatura, vlažnost, čistoća zraka i vibracije. U preporukama VDI/VDE 2627 je po prvi put data klasifikacija mjernih laboratorija sa aspekta utjecajnih veličina.
Ključne riječi: akreditacija, kvalitet laboratorija

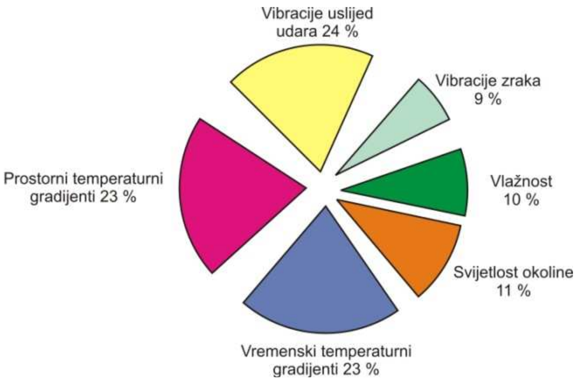
1.UVOD

Akreditacija je postupak kojim mjerodavno tijelo formalno priznaje da je ustanova ili osoba sposobna za obavljanje određenih zadataka. Zajedno sa certifikacijom predstavljaju postupke uspostave povjerenja nastali radi olakšavanja međunarodne trgovine, odnosno ukidanja tehničkih trgovinskih prepreka.

Standard ISO/IEC 17025 propisuje osnovne i opće zahtjeve zajedničke za sve oblasti i sektore, a u postupcima akreditiranja primjenjuju se i dokumenta koja daju dodatne kritrijume i smjernice na specifičnosti pojednih sektora i oblasti ispitivanja i mjerenja. Pored zahtjeva u ovom standardu, postoji i niz drugh zahtjeva koji se nalaze u raznim stručnim preporukama. Tu se prije svega misli na građevinsko – tehničke zahtjeve, zahtjeve za klimatizaciju, izolaciju od vibracija, zahtjeve u pogledu čistoće, rasvjete, uređaje za napajanje energijom, ergonomske zahtjeve, zaštitu od buke, termičku udobnost i sigurnost na radu. Sve to čini kvalitet laboratorija i određuje njihovo mjesto u sistemu mjeriteljstva kako nacionalnog, tako i međunarodnog nivoa.

2. UTJECAJNE VELIČINE OKOLINE

Okolina u kojoj se izvode mjerenja ima bitnog utjecaja na mjerni rezultat i predstavlja važnu komponentu mjerne nesigurnosti. Utjecajne veličine okoline, iako nisu predmet direktnog mjerenja, djeluju u mjernom prostoru na mjerne uređaje i objekte mjerenja. Stoga i ključni za klasificiranje kvaliteta mjernih prostora. Te veličine su temperatura, vlažnost, čistoća zraka, brzina strujanja zraka, vibracije i pritisak zraka. Temperatura je najznačajniji utjecajni parametar okoline u dimenzionalnoj metrologiji koji utječe na mjernu nesigurnost. Mjerna nesigurnost je veličina koja je karakteristika svake laboratorije, a u sistemu međulaboratorijskih poređenja se provjerava i dokazuje.
Na slici 1. su prikazane procentualno izražene utjecajne veličine okoline na posljednoj stepenici lanca prenošenja mjera [1].



Slika 1. Najvažniji utjecaji okoline procentualno izraženi [1]

3. KLASIFIKACIJA MJERNIH LABORATORIJA

Laboratoriji su ključni element tehničke infrastrukture kvalitete i glavna su potpora državnim ekonomijama i međunarodnoj trgovini. U današnje vrijeme se gotovo sve mjeri i ispituje i samo na temelju tačnih, pouzdanih i usporedivih rezultata mjerenja mogu se donositi ispravne odluke. Tačni, pouzdani i usporedivi rezultati mjerenja su proizvod osposobljenih laboratorija.

U standardima nekih razvijenih zemalja iz osamdesetih godina prošlog vijeka su uglavnom bile definirane tri klase mjernih laboratorija, pa se i nametnula potreba za novom klasifikacijom kvaliteta mjernih laboratorija. Tako su proizišle i smjernice VDI/VDE 2627, prema kojim je utvrđeno šest klasa kvaliteta mjernih laboratorija [2]. Svakoj klasi kvaliteta laboratorija su određene i klase utjecajnih veličina okoline, tabela 1. U tabeli 2 su navedene preporučene klase utjecajnih veličina za mjerne laboratorije u dimenzionalnoj metrologiji.

Tabela 1. Klase odlučujućih karakterističnih veličina mjernog prostora [2]

			Klasa karakteristične veličine				
Karakteristična veličina			***A***	***B***	***C***	***D***	***E***
Osnovna temperatura		^0C	t_0	**)*	**)*	**)*	**)*
Odstupanje osnovne temperature		^0C	*±0,25*	*±0,6*	*±1,25*	*±2,5*	*±5,0*
Vremenske promjene	*15 min*	^0C	*0,2*	*0,4*	-	-	-
	1 h	^0C	*0,2*	*0,4*	*1,0*	*2,0*	*2,0*
	4 h	^0C	*0,2*	*0,6*	*1,5*	*3,0*	*3,0*
	12 h	^0C	*0,2*	*0,8*	-	-	-
	24 h	^0C	*0,4*	*0,8*	*2,0*	*3,0*	*6,0*
	7 dana	^0C	*0,4*	*1,0*	*2,0*	*4,0*	*8,0*
Prostorne razlike		^0C	*0,1*	*0,2*	*0,5*	*1,0*	*2,0*
Rel. vlažnost (promjene i razlike)			*10*	*20*	*30*	-	-
Čistoća zraka		*1.step*	*EU4*	*EU7*	*EU7*	*EU5*	-
		2.step	*EU7*	*R4*	-	-	-
		3.step	*S*	-	-	-	-
Vibracije >70 Hz		m/s^2	*0,2*	*0,3*	*0,4*	-	-
*t_0 : referentna temperatura, *) – slobodno odabrana, ali fiksna*							

Tabela 2. Preporučeni karakteristični podaci za mjerne prostore u tehnici mjerenja dužine [2]

	Precizni mjerni prostor	*Fini mjerni prostor*	*Standardni mjerni prostor*	*Proizvodni mjerni prostor*	*Proizvodna mjerna mjesta*	*Posebni mjerni prostori*
Klasa kvaliteta mjernog prostora	1	2	3	4	5	6
Osnovna temp.	20^0C	*)	*)	*)	*)	*)
Odstupanja	A	*B*	*C*	*D*	*E*	*)
Vrem. promjene	A	*B*	*C*	*D*	*E*	*)
Prost. razlike	A	*B*	*C*	*D*	*E*	*)
Rel. vlažnost	A	*B*	*B*	*C*	*D*	*)
Čistoća zraka	B	*B/C*	*C/D*	*D*	-	*)
Vibracije	A	*B*	*B*	*C*	-	*)
Napomena: *) slobodno odabrana, ali fiksna						

4. AKREDITACIJA LABORATORIJA

Kvalitet mjerenja i mjerila ostvaruje se kroz uređenu metrološku strukturu. Prvi uslov za uređenu metrološku strukturu je postojanje nacionalnih etalona SI jedinica za koje je nadležan Nacionalni mjeriteljski institut. Pouzdani rezultati zahtjevaju kompetentno osoblje, validne metode, sveobuhvatno upravljanje kvalitetom kao i slijedivost u odnosu na konkretne mjerne reference. Kvalitetan i pouzdan rezultat mjerenja je onaj koji je obezbjedio tehnički kompetentni laboratorij i koji je svoju kompetentnost potvrdio na odgovarajući način – akreditacijom. Ključni metrološki aspekti potvrđivanja kompetentnosti laboratorija:

- metoda mjerenja (dobro odabrana i validna),
- slijedivost mjerenja i kalibracija,
- mjerna nesigurnost,
- obezbjeđenje kvaliteta rezultata (kontrola kvaliteta), upotreba referntnih materijala i međulaboratorijska poređenja.

Institut za akreditiranje BiH (BATA) i NMI moraju zajednički promovirati ojačavanje veza između metrologije i akreditacije u BiH:

- kroz svoje odgovarajuće pojedinačne i zajedničke aktivnosti po pitanjima značajnim za metrološku infrastrukturu uz poštivanje međunarodnih i evropskih smjernica i politike u ovoj oblasti, obezbjede pouzdanost i uporedivost rezultata mjerenja za sve korisnike u zemlji.
- da svaka institucija ponaosob koristi svoje stručno znanje i sposobnosti, a zajednički rade na ojačavanju efikasnosti metrološke infrastrukture, naročito na uspostavljanju mreže akreditiranih laboratorija za kalibracije,
- da osiguraju da su ocjenjivači za akreditirane laboratorije za kalibracije tehnički kompetentni, sa aktuelnim znanjem iz metrologije na najvišem nivou, prvenstveno o slijedivosti i mjernoj nesigurnosti i da su potpuno upoznati sa CIPM MRA i bazom podataka ključnih poređenja KCDB i njenim značajem za slijedivost do SI,
- promoviraju prihvatanje akreditacije i uloge ILAC MRA i EA MRA sporazuma,
- da promoviraju harmonizirane politike koje se odnose na pitanja od zajedničkog interesa, a posebno na ona koja se odnose na slijedivost i mjernu nesigurnost i da predstave te politike zainteresiranim stranama i svim korisnicima.

5. ZAKLJUČAK

Pored niza zahtjeva koji se postavljaju na tehničku kompetentnost laboratorija, veoma bitan je i zahtjev koji uključuje i prostor laboratorija sa aspekta utjecajnih parametara okoline. Da bi u mjernim laboratorijama mogli porediti mjerne rezultate, u njima moraju biti uporedive i utjecajne veličine okoline, što pretpostavlja jedinstvene definicije standardnih uvjeta i jedinstvene propise u pogledu planiranja, rada i nadzora mjernih laboratorija. Formiranje mjeriteljske infrastrukture u novonastalim državama koje žele da se industrijski razvijaju predstavlja veliku i skupu investiciju koja je istovremeno i nužna, ukoliko se želi pristupiti svjetskom tržištu i ravnopravno učestvovati u razmjeni roba i usluga. Podrazumjeva se da je u Bosni i Hercegovini, saglasno evropskoj praksi, pored institucija za akreditiranje i ovjeravanje (certificiranja) laboratorija, potrebno organizirati mrežu ovlaštenih laboratorija u kojima će se čuvati i održavati najvažniji mjerni etaloni i referentni materijali, ostvariti slijedivost rezultata mjerenja i ispitivanja i međunarodno priznavanje ovog sistema. To je dugoročan, ekspertni posao, koji će u budućnosti stvoriti osnovu za međunarodno priznatu garanciju kvaliteta bosansko - hercegovačkih proizvoda i organizacija i zaštitu kupaca od nekvalitetnih proizvoda i usluga.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

NOVE TEHNOLOGIJE KAO PRIJETNJA IMIDŽU I POSLOVANJU GRAĐEVINSKIH PREDUZEĆA BOSNE I HERCEGOVINE

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Bosna i Hercegovina

REZIME
Korištenje novih tehnologija u poslovanju i izgradnji imidža svih pa time i građevinskih preduzeća nesumnjivo predstavlja imperativ modernog poslovanja. Kao element imidža, tehničko-tehnološka savremenost BH građevinskih preduzeća u svim segmentima njihovog funkcionisanja i komuniciranja značajno utiče na sliku tih preduzeća u bitnim grupacijama javnosti. Međutim, kombinovana teorija tehnologije i odnosa s javnostima "The Technology – Image Expectancy Gap" (autora D. Kazoleasa i L.G.Teigena sa Državnog univerziteta Illinois) ukazuje na seriju procesa koji mogu dovesti do toga da pretjerano isticanje novih tehnologija u korporativnom komuniciranju stvara nerealna i previsoka očekivanja javnosti i postaje prijetnja imidžu i poslovanju preduzeća. Teorija daje i prijedlog kako da se neželjeni ciklus "tehnologija-očekivanje" prekine.
Ključne riječi: građevinska preduzeća, korporativni imidž, nove tehnologije

1. UVOD

Korporativni imidž predstavlja poslovnu kategoriju koja u procesu postizanja i poboljšanja efikasnosti poslovanja savremenih preduzeća neupitno ima veliku ulogu. Imidž preduzeća je danas ne samo centralna kategorija odnosa s javnostima nego i krucijalna poslovno-strateška kategorija pomoću koje se može uspješno pozicionirati na ciljnom segmentu tržišta, diferencirati od drugih ili čak postati lider na tržištu, kojom se mogu privući potencijalni klijenti i investitori i time direktno poboljšati rezultati poslovanja svih pa i građevinskih preduzeća. Značaj imidža je utoliko veći koliko je do navedenih poslovnih rezultata na današnjem tržištu teže doći isključivo cijenom, asortimanom ili kvalitetom usluga. Izgraditi pozitivan korporativni imidž u građevinskom sektoru privrede znači izgraditi sliku uspješnog, profesionalnog i poželjnog poslovnog partnera, privući investicije i dobiti šansu za njihovu realizaciju. Tako se istovremeno poboljšavaju ne samo vlastiti nego i ekonomsko-finansijski efekti poslovanja razmatranog sektora, ali i cijele privrede. Premda u formiranju pozitivnog korporativnog imidža najvidljiviju ulogu imaju njegovi komunikacijski elementi, pozitivan imidž se ne može dugoročno održati bez kvalitetne i kontinuirane podrške od strane osnovnih poslovnih aktivnosti jedne kompanije. Ove aktivnosti, sa aspekta teorija odnosa s javnostima i teorija imidža, predstavljaju tzv. stvarne elemente imidža. Kad je riječ o građevinskom sektoru BH privrede, tržišna istraživanja su pokazala da upravo tehničko-tehnološka savremenost BH građevinskih preduzeća u svim segmentima njihovog funkcionisanja predstavlja stvarni element imidža koji presudno utiče na sliku tih preduzeća u bitnim grupacijama njihovih javnosti. Korištenje novih tehnologija u poslovanju jednog građevinskog preduzeća predstavlja imperativ modernog poslovanja. Primjena savremenih tehnologija u građenju kao što su novi oplatni sistemi, sistemi horizontalnog i vertikalnog transporta, moćne betonske pumpe transportnih dužina preko 1000 m, savremeni sistemi fundiranja objekata, korištenje savremenih materijala kao što su SCC/samougradljivi betoni, premazi i slično, osnov je za napredovanje građevinarstva, ali i za zadovoljavanje sve zahtjevnijih i sve bolje educiranih investitora. Upravo nove tehnologije u građenju omogućavaju brzu, kvalitetnu i efikasnu gradnju koja zadovoljava interese investitora, samih građevinskih preduzeća, ali i ukupne društvene zajednice. Međutim, postavlja se pitanje da li nove tehnologije i novi mediji uvijek pomažu ili pod određenim okolnostima mogu postati prijetnja korporativnom imidžu i poslovanju? Teorija "The Technology – Image Expectancy Gap" kao kombinovana teorija tehnologije i odnosa s javnostima ukazuje da pod određenim okolnostima prekomjernog isticanja tehnologije u promociji odnosno korporativnom komuniciranju, kompanije stvaraju dva nivoa nerealnih/pretjeranih očekivanja: nerealna očekivanja u društvu uopće ("opća") i nerealna očekivanja od konkretnih preduzeća u bitnim grupacijama njihove javnosti ("specifična"). Kako već stvorena nerealna očekivanja građevinari svojim daljim poslovanjem gotovo nikad ne uspijevaju potpuno zadovoljiti, ove kompanije se počinju smatrati neprofesionalnim čime se direktno narušava njihov korporativni imidž i poslovanje. Teorija daje i prijedlog načina na koji se opisani neželjeni ciklus "tehnologija-očekivanje" može prekinuti. Napominjemo da ovaj rad ima za cilj skrenuti pažnju domaćih teoretičara na potrebu značajnijeg i kvalitetnijeg praćenja građevinskog sektora BH privrede s ciljem razrađivanja modela poboljšanja poslovne efikasnosti domaćih građevinskih preduzeća. To je posebno značajno kada se zna da je upravo ova grupacija preduzeća nosilac investicione izgradnje bez koje nema izlaska iz krize niti pokretanja kompletne privrede. Rad svakako ima za cilj i skretanje pažnje domaćih menadžera na pitanje tehnologije kako poslovanje svojih preduzeća ne bi ugrozili upadanjem u "zamku nove tehnologije" na način opisan u razmatranoj teoriji. U daljem razmatranju dajemo osvrt na pomenutu teoriju.

2. ISTRAŽIVANJE I METODE ISTRAŽIVANJA

2.1. Tehnologija kao prijetnja imidžu i poslovanju preduzeća sa aspekta teorije "TheTechnology-Image Expectancy Gap"

Korištenje savremenih tehnologija u svim aspektima poslovanja i korporativnog komuniciranja neophodan je uvjet za kreiranje pozitivnog korporativnog imidža svih privrednih subjekata pa dakle i onih u sektoru građevinarstva. Primjena multifunkcionalne, visoko sofisticirane i specijalizirane mehanizacije i savremenih tehnologija u građenju, primjena opreme sa tehničkim karakteristikama koje omogućavaju brzu i kvalitetnu realizaciju i najzahtjevnijih građevinskih poduhvata, građenje koje bukom, vibracijama, prašinom niti na bilo koji drugi način ne narušava okolinu, osnovni su uvjeti za prosperitet građevinarstva, zadovoljstvo investitora i društvene zajednice. Istraživanje provedeno na teritoriji Bosne i Hercegovine tokom 2008. godine od strane agencije Puls za potrebe magistarskog rada autora ovog teksta, pokazalo je da je čak 87 % menadžera domaćih građevinskih kompanija prepoznalo važnost savremene tehničke opreme za ukupan imidž i poslovanje preduzeća. Takođe, 86 % menadžera bi, u situacijama većih finansijskih budžeta, sav novac ulagali u osavremenjivanje vlastitih proizvodnih i uslužnih procesa. U privredi postoji i svijest da bez brojnih prednosti savremenih komunikacionih sistema i tehnika, privredni subjekti ne mogu ostvariti sve veće zahtjeve svog poslovanja, investitora i ostalih saradnika u pogledu brzine i kvaliteta protoka brojnih informacija neophodnih za uspješno poslovanje. Dakle, saglasnost o tome da nove tehnologije zaista gotovo svuda i uvijek pomažu postoji i na našem tržištu. Ali, postoje li limiti vezani za korištenje i isticanje novih tehnologija u poslovanju i komuniciranju? Nauka je potvrdila da na određenom stepenu pretjeranog isticanja tehnologije u korporativnom komuniciranju zapravo počinje opasnost da ovakve aktivnosti postanu prijetnja imidžu i poslovanju nekog preduzeća. Upravo "The Technology – Image Expectancy Gap" objašnjava na koji način tehnologija postaje opasnost za imidž i poslovanje. Pored kratke prezentacije same teorije, pogledaćemo da li i u kojoj mjeri BH građevinska preduzeća u izgradnji imidža ističu nove tehnologije i da li i na koji način pretjerano isticanje vlastitih tehnoloških sposobnosti u promociji može postati prijetnja za njihov imidž i poslovanje. Pomenuti problem u ovom će radu biti posmatran samo sa aspekta teorije "The Technology – Image Expectancy Gap".

2.2. Kombinovana tehnološka i PR teorija "The Technology-Image Expectancy Gap"

"The Technology – Image Expectancy Gap" je kombinovana teorija tehnologije i odnosa sa javnostima (PR) formulisana nakon poznatih događaja u SAD-u septembra 2001. g. Naime, upravo tada je proučavanje uticaja tehnoloških unapređenja posebno na imidž i poslovanje subjekata u američkom društvu, dobilo prvostepen značaj. Odjednom je postalo jasno da je visok nivo tehnološkog razvoja u Americi i neumjereno isticanje tehnologije u promotivne svrhe zapravo dovelo do izuzetno visokih očekivanja i vjerovanja u svemoćnost tehnologije. Nevjerica da su događaji iz septembra 2001. godine u uvjetima naprednih tehnologija i odbrambenih sistema SAD-a uopće mogući, bila je ogromna. Slijepo vjerovanje Amerikanaca da tehnologija može riješiti sve probleme potvrđuju i novija istraživanja centra "Pew Research Center for the People" koja ukazuju da čak 81 % Amerikanaca vjeruje da će se u skoro vrijeme otkriti lijek protiv karcinoma ili čak 76 % njih vjeruje da će Amerikanci uskoro poslati prvog čovjeka na Mars. Kao posljedica prevelikog vjerovanja u tehnologiju kao rješavača svih problema, svjetska javnost je teško prihvatila činjenicu da se ni uz pomoć savremene tehnologije nije moglo omogućiti normalno odvijanje avionskog saobraćaja nakon nedavne erupcije vulkana na Islandu. Ili brzo i efikasno riješiti problem naftne mrlje nastale nakon eksplozije naftne platforme i izlijevanja ogromne količine sirove nafte u Meksički zaliv proljeća 2010. godine. Šta se desilo sa imidžom British Petrola? Ocijenjen je ugroženim i uništenim upravo jer nije mogao odgovoriti velikim očekivanjima svjetske javnosti u vezi sa mogućnostima savremenih tehnologija u rješavanju problema naftne mrlje. Zajedno sa imidžom, ugroženo je i poslovanje ove kompanije jer nije ispunila očekivanja javnosti. Da li je moglo drugačije? Kako je društvo uopće došlo u situaciju apsolutnog vjerovanja u tehnologiju? Vjerovatno upravo njenim pretjeranim korištenjem u promotivne svrhe i kontinuiranim i nerijetko neumjerenim praćenjem tehnoloških dostignuća od strane medija.

Suprotno dotadašnjim preovlađujućim mišljenjima da nova tehnologija uvijek i svuda pomaže, teorija "The Technology – Image Expectancy Gap" identificira seriju procesa koji vode tome da isticanje tehnologije u mnogim slučajevima postaje prijetnja imidžu i poslovanju. Ova teorija ukazuje na to da visok nivo tehnološkog razvoja društva i jako (često i nerealno) medijsko praćenje tehnološkog napretka društva ili pojedinačnih preduzeća kreiraju nerealna/prevelika "opća" očekivanja od tehnologije u cijelom društvu. Šta se dalje dešava? Nakon općenitog fokusiranja društva na tehnologiju, da bi poboljšala vlastiti imidž, većina preduzeća reaguje isticanjem vlastitih postojećih ili nepostojećih tehnoloških sposobnosti. Međutim, problem u ovakvom pristupu imidžu, leži u tome što pretjeranim isticanjem novih tehnologija koje preduzeće koristi u svom poslovanju, komunikacijsko – promotivne aktivnosti preduzeća stvaraju prevelika, nerealna "specifična" očekivanja koja je dalje uglavnom nemoguće potpuno ispuniti. To neupitno vodi ka šteti u imidžu pojedinačnih preduzeća jer njihove bitne grupacije javnosti (investitori, dobavljači, banke, kooperanti, lokalna zajednica, ...) prestaju da im vjeruju. Počinju ih smatrati nepouzdanim i nesposobnim da održe obećanja i sljedstveno tome nepoželjnim za saradnju. Dalji efekat je smanjenje potražnje usluga od takvih preduzeća, nepružanje podrške njihovom radu, bojkot i slično što doprinosi i smanjenju finansijskih efekata njihovog poslovanja.

Da rezimiramo. Teorija "The Technology – Image Expectancy Gap" identificira dvije vrste nerealnih (prevelikih) očekivanja koja nastaju kao posljedica prekomjernog isticanja tehnologije u korporativnom komuniciranju i promociji preduzeća. Prva vrsta su opća nerealna očekivanja. Naime, kada su društvo i mediji fokusirani na tehnologiju, u društvu je razvijen generalno visok nivo očekivanja od tehnologije uopće. Međutim, kada preduzeća u svom komuniciranju sa javnostima dalje unaprijede svoje tehnološke sposobnosti te ih počnu neumjereno isticati u promotivne svrhe, nastaje i druga vrsta nerealnih očekivanja koja su označena kao specifična očekivanja od konkretnog subjekta. I jedna i druga vrsta nerealnih očekivanja, a koja preduzeća uglavnom ne uspijevaju zadovoljiti, vode ka njihovom sve težem opstanku na tržištu i dostizanju željenih poslovnih rezultata.

2.3. Prekid ciklusa "Tehnologija – očekivanje" - Grunigov model dvostrane komunikacije

Teorija "The Technology – Image Expectancy Gap" pokušava dati i odgovor kako se opisani opasni ciklus "tehnologija-očekivanja“ može prekinuti. Svakako da bi se kao najlakše rješenje za prekid pomenutog ciklusa moglo predložiti da preduzeća u korporativnom komuniciranju prestanu isticati savremenu tehnologiju koju koriste. Međutim, ta logika nije održiva. Naime, teorija ukazuje da društveni i medijski fokus na tehnologiju zapravo uspostavlja barem neki srednji nivo općih očekivanja u vezi sa djelatnošću preduzeća. Dakle, iako se pojedinačna preduzeća mogu odreći pretjeranog ili čak i bilo kakvog isticanja i korištenja tehnologije u promociji imidža (kako ne bi izazvale povećanje specifičnih očekivanja u bitnim grupacijama javnosti), njihove javnosti već ionako imaju povećan opći nivo očekivanja zbog društvene i medijske izloženosti tehnologiji.

Autori teorije smatraju da utvrđivanje nivoa potrebnog i opravdanog isticanja korištene tehnologije u promotivne svrhe treba tražiti u Grunigovom modelu dvostrane komunikacije. Taj model ukazuje na potrebu da preduzeća kontinuirano prikupljaju informacije od bitnih javnosti i da ih koriste u balansiranju dobrobiti za javnost i za vlastite aktivnosti. Da bi se izbjegao procjep između očekivanja i stvarnosti, preduzeća moraju pratiti očekivanja u vezi sa svojim proizvodima, uslugama ili ponašanjem. Komunikacijske strategije moraju reflektovati najbolje, ali stvarne tehnološke sposobnosti preduzeća bez kreiranja nerealno visokih očekivanja. Primjena ovog modela zahtijeva stalno praćenje bitnih/ciljnih javnosti radi ocjene nivoa općih i specifičnih očekivanja nastalih pojačanim fokusom na tehnologiju. Samo na taj način mogu se kreirati usmjerene komunikacijske poruke koje pomažu uspostavljanju i održavanju realnih očekivanja: takvih očekivanja koja će poslovnim subjektima biti poticaj, a ne limit za dalje osavremenjivanje tehnoloških procesa u svim segmentima njihovog poslovanja.

2.4. Primjeri djelatnosti u kojima najčešće nastaju nerealna očekivanja

U okviru razmatranja, autori teorije "The Technology-Image Expectancy Gap" navode primjere oblasti poslovanja u kojima postoji posebna opasnost od kreiranja previsokih, nerealnih očekivanja i percepcija. Kao najčešće oblasti američkog poslovanja u kojima nastaju takva očekivanja može se izdvojiti vojna industrija, proizvodnja računara, alarmnih, protivprovalnih i protivpožarnih sistema, video opreme, mobilnih telefona i drugih komunikacijskih tehnologija, proizvodnja zdrave hrane, autoindustrija, javna uprava, farmaceutska industrija, medicina - posebno neke grane kao što je plastična hirurgija, i sl. U ovim i nekim drugim djelatnostima, vrlo lako se stvaraju nerealna očekivanja koja potpuno ignorišu potencijalne limite novih tehnologija. Navedene oblasti privrednih i drugih aktivnosti, i u Bosni i Hercegovini se mogu smatrati poljem mogućeg nastanka nerealno visokih očekivanja od tehnologije. Uostalom, svjedoci smo agresivne promocije brojnih malih i srednjih preduzeća iz oblasti računarskih tehnologija koje na savremen način nude vrhunske usluge uz niske cijene, obezbijeđene kreditne aranžmane za kupovinu svojih proizvoda, autorizovani software, brand name računare, odličan servis i podršku i slično, a čiji se kupci veoma brzo uvjere da je sve navedeno bilo ipak samo nerealno obećanje. Međutim, praćenjem ovog segmenta tržišta koji je dat samo kao primjer iz domaće prakse, uočljivo je da upravo preduzeća koja najviše obećavaju, a data obećanja ne ispunjavaju, takvim ponašanjem veoma brzo ugroze svoj imidž te ubrzo nestaju sa tržišta. Krije li se razlog njihovog kolapsa i u postavkama teorije "The Technology-Image Expectancy Gap"? Ali, osvrnimo se pažljivije na građevinski sektor BH privrede.

3. REZULTATI ISTRAŽIVANJA I DISKUSIJA

3.1.Testiranje teorije "The Technology-Image Expectancy Gap" na BH investicionom tržištu

Rezultati istraživanja predstavljanja BH građevinskih preduzeća u klasičnim medijima i njihove internet prezentacije, ukazuju da ova preduzeća u vlastitoj promociji i izgradnji imidža ne samo da ne pretjeruju nego čak nedovoljno koriste i ističu savremena tehnološka dostignuća koja koriste u redovnom poslovanju. Iz prizme teorije "The Technology-Image Expectancy Gap", to bi značilo da vlastitim promotivnim aktivnostima pomenuta preduzeća ne kreiraju niti pojačavaju nerealna specifična očekivanja kod svojih javnosti. S druge strane, kako ova preduzeća nisu fokusirana na nove tehnologije, to ona svojim promotivnim djelovanjem ne povećavaju ni stepen općih društvenih očekivanja od tehnologije. Istovremeno, redovnim praćenjem domaćih medijskih sadržaja, može se uočiti da domaći mediji nisu fokusirani na tehničko-tehnološka dostignuća koja imaju veze sa građevinarstvom. Dakle, ni mediji ne povećavaju stepen općih očekivanja od građevinskih preduzeća u BiH. Sve navedeno ukazuje da situacija u kojoj pretjerano isticanje savremenih tehnologija u korporativnom komuniciranju postaje opasnost za imidž i poslovanje, sa aspekta teorije "The Technology-Image Expectancy Gap", u građevinskom sektoru BH privrede nije bitno prisutna. Međutim pojedina su domaća građevinska preduzeća ipak upala u zamku tehnologije. Pretjerano isticanje tehnologije u izgradnji imidža kod pojedinih BH građevinskih preduzeća dovelo je do kreiranja nerealnih očekivanja te ugrožavanja njihovog poslovanja. U posljednjih nekoliko godina, na BH tržištu je postalo uočljivo nekoliko velikih komunikacijskih i medijskih kampanja vezanih za građevinske projekte. Reklame u novinama, TV i radio emisijama, susreti menadžera sa inostranim i domaćim dužnosnicima, jumbo plakate, intervjui, press konferencije, po prvi put u istoriji BH investicionog tržišta, uspijevaju usmjeriti pažnju društva i medija na građevinska preduzeća i njihove projekte te na nove tehnologije u građevinarstvu. Vrhunac komunikacijskih kampanja najčešće je web prezentacija pomenutih preduzeća. Upravo web stranice sa neumjerenim isticanjem tehnologije često započinju ciklus kreiranja nerealnih očekivanja bitnih javnosti. One su uglavnom profesionalno i moderno dizajnirane, estetski dopadljive, sadržajem bogate, ali pune nerealnih obećanja vezanih za korištenje novih tehnologija u građenju. Već po njima je jasno da se ova preduzeća žele diferencirati upravo tehnologijom. «Društvo i mediji su očarani tehnologijom», kako to formulišu autori teorije "The Technology-Image Expectancy Gap". Iako to nigdje nije eksplicitno rečeno, na osnovu analize komunikacijskih aktivnosti ovih preduzeća čini se da se radi o moćnim savremenim hi-tech građevinskim sistemima koji na BH investiciono tržište uvode najviše tehnološke standarde. Zahvaljujući ovakvoj prezentaciji, građevinska preduzeća sve više generišu prevelika očekivanja svojih javnosti (specifična očekivanja) u pogledu kvaliteta i rokova gradnje, kvaliteta življenja u njihovim objektima, nenarušavanja prirodne sredine tokom i nakon izgradnje objekata i to upravo na način opisan predmetnom teorijom. Prekomjernim isticanjem tehnologije u promociji kreirana su i opća nerealna očekivanja kod svih relevantnih javnosti i u društvu uopće. Vrijeme međutim obično pokaže da građevinska preduzeća koja se agresivno promovišu ističući svoje visoke tehnološke sposobnosti često nemaju stvarne kapacitete da ispoštuju sva obećanja koja daju u pogledu rokova i visokog kvaliteta svojih usluga. Razočaranje javnosti je sve veće i vidljivije što su obećanja veća od očekivanih. Imidž građevinskih preduzeća koje na opisani način komuniciraju sa svojim javnostima biva ugrožen ili potpuno uništen. Poslovanje trpi.

Gdje bi se moglo potražiti rješenje problema narušenog imidža preduzeća koja na opisani način promovišu vlastite projekte sa aspekta teorije "The Technology-Image Expectancy Gap"? Kako je moguće prekinuti opisani ciklus narušavanja imidža? U skladu sa prezentiranom teorijom, rješenje treba tražiti u Grunigovom modelu dvostrane komunikacije. Dakle, da bi se izbjegao rascjep između očekivanja i stvarnosti, građevinska preduzeća prije svega moraju kontinuirano pratiti očekivanja javnosti od njihovog ukupnog poslovanja, projekata koje realizuju i tehnologije koju koriste. Samo na osnovu istraživanja bitnih javnosti moguće je kreirati usmjerene poruke koje bi uspostavile i održale realna te izbjegle pogrešna i nerealno visoka očekivanja. Dalje, komunikacijske strategije moraju reflektovati stvarne tehnološke sposobnosti kompanija bez kreiranja pogrešnih očekivanja. Da bi se izgradio i održao pozitivan imidž preduzeća, njegovi komunikacijski elementi moraju biti usaglašeni sa stvarnim elementima. Isticanje tehnologije koja se koristi u poslovanju mora biti zasnovano na realnosti, a ne na lažnim i praznim obećanjima. Imidž preduzeća tako bi bio sačuvan bez obzira na sve probleme sa kojim se u svom poslovanju i tokom realizacije projekta izvođač radova stvarno susreće.

4. ZAKLJUČCI

1. Navedeni rezultati istraživanja proistekli su iz opsežnih tržišnih istraživanja koje je za potrebe autora ovog teksta tokom 2008. godine putem anketnih upitnika provela istraživačka kuća Puls. Radi se o velikom istraživanju u grupaciji menadžera u oko 6 % svih građevinskih preduzeća registrovanih u BiH. Istraživanje metodom analize sadržaja dokumenata vršeno je i u grupaciji najtiražnijih BH printanih medija. Pored ovog, istraživanje je obuhvatilo grupaciju najznačajnijih investitora pomenute godine. Pri formiranju uzoraka koristila se kombinacija kvotnog i stratificiranog uzorka. Rezultati istraživanja u grupaciji menadžera građevinskih preduzeća ukazuju da je čak njih 87 % prepoznalo važnost korištenja novih tehnologija za ukupan imidž i poslovanje preduzeća. Takođe, 86 % menadžera bi, u situacijama većih finansijskih budžeta, sav novac ulagali u osavremenjivanje vlastitih proizvodnih, uslužnih i komunikacijskih procesa. Međutim, praćenje njihovih komunikacijskih aktivnosti generalno ne ukazuje na isticanje novih tehnologija u promociji na nivou koji bi ugrožavao njihovo poslovanje.

2. Testiranje teorije "The Technology-Image Expectancy Gap" na domaćem investicionom tržištu, ipak je ukazalo na lagano pojavljivanje tendencija u promotivnim aktivnostima domaćih građevinskih preduzeća koje bi mogle dovesti do problema sa njihovim korporativnim imidžom i ukupnim poslovanjem sa aspekta obrađene teorije. Očigledno je da problemi u imidžu i poslovanju bilo kojeg građevinskog preduzeća mogu nastati kao posljedica neumjerenog, pretjeranog isticanja njegovih (stvarnih ili izmišljenih) tehnoloških sposobnosti u promotivnim i drugim komunikacijskim aktivnostima i na toj osnovi stvorenih nerealnih očekivanja. Kako je ovakva očekivanja bitnih javnosti i društva uopće gotovo nemoguće zadovoljiti, imidž preduzeća trpi i neupitno vodi ka opadanju zainteresovanosti za njegove usluge, a time i padu pokazatelja njihove poslovne uspješnosti.

3. Shvatanje imidža kao kozmetičkog sredstva i kategorije koja se može graditi samo komunikacijskim aktivnostima od strane za to formiranih službi i uz pomoć aktivnosti koje ne odražavaju ono što preduzeće zaista jeste, uvijek predstavlja opasnost. Bez podrške stvarnih odnosno onih aktivnosti jednog poslovnog subjekta koji čine njegovu osnovnu djelatnost, bez obzira kako dobro pozicioniran imidž, ne može se dugoročno održati. Korporativni imidž treba posmatrati kao kompleksnu kategoriju sačinjenu od usklađenih stvarnih i komunikacijskih elemenata. I u jednim i u drugim, nove tehnologije igraju veliku ulogu koja često opredjeljuje komparativnu prednost jednog preduzeća nad konkurencijom. Ipak, stalnim ispitivanjem očekivanja bitnih grupacija javnosti, treba kontinuirano spoznavati granice racionalnog korištenja i isticanja tehnologije u vlastitim korporativnim komunikacijama. Samo na taj način, nove tehnologije će kontinuirano doprinositi poboljšanju poslovanja svih pa time i građevinskih preduzeća Bosne i Hercegovine.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

MEHANIZAM NASTAJANJA BIJELOG SLOJA I NJEGOVE KARAKTERISTIKE PRI STRUGANJU OTVRDNUTIH ČELIKA

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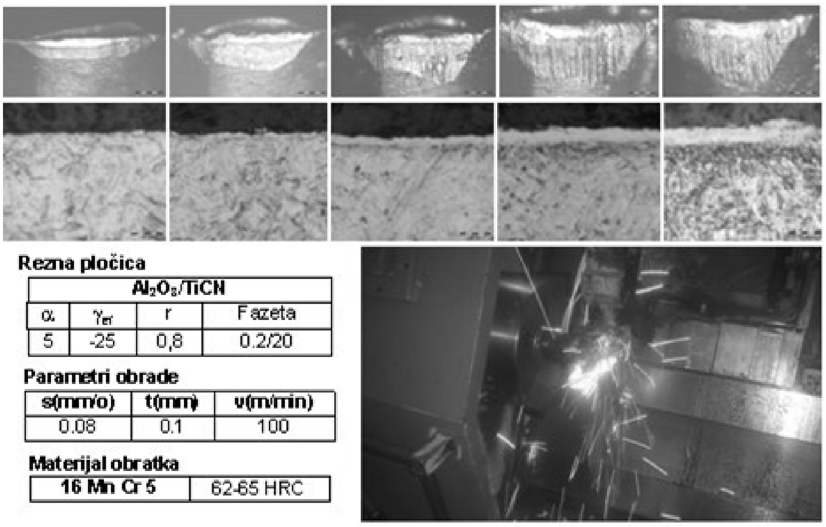
ABSTRAKT
U radu su prezentirani rezultati eksperimentalnih istraživanja autora vezih za nastajanje i karakteristike bijelog sloja pri obradi otvrdnutih čelika. Na osnovu analize eksperimentalnih rezultata dato je viđenje autora u kontekstu objašnjenja mehanizma nastajanja bijelog sloja, te u kontekstu analize karakteristika bijelog sloja ukoliko je isti generisan u toku obrade. Iz grupe uticajnih faktora, akcenat je stavljen na režime obrade te oblik i veličinu leđne istrošenosti alata..
Ključne riječi: bijeli sloj, mehanizam nastajanja bijelog sloja, karakteristike bijelog sloja.

1. UVOD
Naučni pristup prezentiran u ovom radu bavi se izučavanjem nastajanja bijelog sloja (BS-a) u pozitivnom kontekstu, odnosno u kontekstu iskorištenja potencijala sadržanih u njegovim karakteristikama. Ovakav pristup ne negira negativan efekat pojave BS-a na obrađenu površinu kada je on lokalnog karaktera, već propagira njegov pozitivan efekat kada je kontinuiranog karaktera i ravnomjerne debljine. Jednom riječju, ovakav pristup daje mogućnost da se nedostaci koji se javljaju nastajanjem BS-a lokalnog karaktera prevaziđu kroz prelazak lokalnog u kontinuirani karakter, odnosno kroz prelazak negativnog u pozitivan kontekst.

2. ANALIZA UTICAJNIH FAKTORA NA NASTAJANJE I KARAKTERISTIKE BS-A
Pri analizi nastajanja i karakteristika BS-a neophodno je analizirati značajno velik broj uticajnih faktora, između ostalog: material predmeta obrade, material reznog alata, reparacija reznog alata, geometrija reznog alata, primjena sredstava za hlađenje i podmazivanje, veličina leđne istrošenosti alata, primarni mehanizam trošenja alata i u tom kontekstu oblik leđne istrošenosti alata, režime obrade, itd. Iz skupa uticajnih faktora, na nastajnje i karakteristike BS-a, u daljem dijelu rada prezentirani su rezultati eksperimentalnih istraživanja, pri čemu je akcenat stavljen na uticaj oblika i širine leđne istrošenosti alata te režima obrade.

2.1. Uticaj istrošenosti alata na nastajanje BS-a
Ukoliko se govori o stepenu istrošenosti alata, sa aspekta njegovog uticaja na nastajanje i karakteristike BS-a, važno je napomenuti da su uz pojam leđne iztrošenosti alata usko vezani i pojmovi: pojas trošenja na leđnoj površini alata, širina leđne istrošenosti alata, maksimalna širina leđne istrošenosti alata, oblik i veličina leđne istrošenosti (dužina kontakta alata i obradka), karakter dominantnog tipa trošenja koji uzrokuje leđnu istrošenost, itd.
U daljem dijelu istraživanja nastajanje BS-a te njegove karakteristike dovedene su u vezu sa maksimalnom širinom leđne istrošenosti alata. Ovo iz razloga presudnog uticaja pomenutog parametra na pojavu BS-a. Obzirom da se u okviru rada želi analizirati utica režima obrade na

nastajanje i karakteristike BS-a, po metodologiji planiranog eksperiemnta, neophodno je, kroz analizu uticaja širine leđne istrošenosti, odrediti i veličinu širine leđne istrošenosti alata koja će osigurati pojavu BS-a za sve kombinacije parametara režima obrade, naravno unutar posmatranih intervala njihove varijacije.
Granična vrijednost širine leđne istrošenosti alata, odnosno kriterij trošenja alata koji će za sve komabinacije režima obarde osigurati nastajanje BS-a određen je eksperimentalno, pri minimalnim vrijednostima parametara obrade za planirani interval njihove varijacije, za pet nivoa leđne istrošenosti alat. Eksperimentalni testovi trošenja alata vršeni pri obradi otvrdnutog alatnog čelika X155 CrVMo12, iz razloga smanjenja vremena trajanja eksperimentalni testova sa jedne strane, te smanjenja troškova sa druge strane. Izgled pločica istrošenih pri uzdužnom struganju otvrdnutog X155 CrVMo12 čelika, za pet nivoa širine leđne istrošenosti, dat je na sl.1.

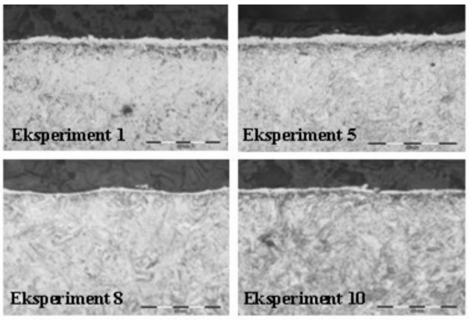


. Uticaj veličine leđne istrošenosti alata na
ıjanje BS-a pri obradi otvrdnutog čelika

Šipke okruglog poprečnog presjeka ϕ80x100 (mm) od 16MnCr5 čelika, nakon bušenja otvora ϕ50 (mm), sječene su na dužinu od 15 (mm). Ovakvim oblikom obradka (prstenasti oblik) pokušala se obezbijediti veća krutost obradnog sistema stezni alat-obradak-rezni alat, te na taj način povećati vjerovatnoća nastajanja bijelog sloja
Za svih pet nivoa leđne istrošenosti alata napravljeni su eksperimentalni testovi uzdužne obrade struganjem otvrdnutog 16MnCr5 čelika. Nakon generisanja obrađenih površina, izvršena je metalografska priprema tako dobijenih uzoraka. Različite vrijednosti debljine generisanih bijelih slojeva, uzrokovane različitim nivoima leđne istrošenosti alata, te njihova direktna proporcionalnost vidljivi su sa mikrosnimaka obrađene površine, sl.1. Treba napomenuti da su nivoi leđne istrošenosti alata 60 (μm), 100 (μm), 165 (μm), 200 (μm) i 240 (μm), posmatrano s lijeva na desno. Saglasno ekpserimentalnim rezultatima (sl.1.) veličina širine leđne istrošenosti alata od 220 (μm) postavljena je kao granična vrijednost koja osigurava generisanje BS-a zadovoljavajuće debljine, te u tom kontekstu omogućava ispitivanje gometrijskih i mehaničkih karakteristika BS-a u narednim fazama istraživanja.

2.2. Uticaj režima obrade na nastajanje BS-a

U 0v0m dijelu istraživanja skupom ulaznih veličina obuhvaćeni su režimi obrade, dok je skupom izlanih veličina, pored srednje debljine bijelog sloja (h_{ar}), obuhvaćeno i srednje aritmetičko odstupanje profila obrađene površine (R_a), kao značajne karakteristike operacija završne obrade kakve uglavnom i jesu operacije obrade otvrdnuti čelika. Eksperimentalni testovi rezanja sastojali su se od spoljašnjeg uzdužnog struganja sa predhodno istrošenim reznim pločicama saglasno postavljenoj graničnoj vrijednosti iste. Karakteristični mikrosnimci obrađenih površina generisanih u toku obrade, rezultati sprovedenih eksperiemntalnih istraživanja saglasno plan matrici prvog reda te intervali varijacije režima obrade, prikazani su na sl.2.



rш. exp.	KODIRANE VRIJEDNOSTI			REZULTATI EKSPERIMENATA			
	x_1	x_2	x_3	h_{sr}	St.Dev.	R_a	h_{sr}/R_a
1.	-1	-1	-1	4,592	0,944	0,70	6,560
2.	+1	+1	+1	4,980	1,330	0,75	6,640
3.	+1	-1	+1	3,627	0,909	1,01	3,591
4.	-1	+1	+1	3,205	0,519	1,17	2,739
5.	-1	-1	+1	4,670	0,687	0,60	7,783
6.	+1	+1	-1	2,725	0,725	0,61	4,467
7.	+1	-1	-1	2,705	0,553	1,00	2,705
8.	-1	+1	-1	2,515	0,670	1,15	2,186
9.	0	0	0	3,308	0,496	0,72	4,594
10.	0	0	0	3,142	0,520	0,70	4,488
11.	0	0	0	3,049	0,517	0,75	4,065

Faktor		Donji nivo	Srednji nivo	Gornji nivo	Interval varijacije
Posmak	s (mm/o)	0.08	0.1	0.12	0.02
	x_1	-1	0	+1	
Dubina rezanja	t (mm)	0.1	0.2	0.3	0.1
	x_2	-1	0	+1	
Brzina rezanja	v (m/min)	100	125	150	25
	x_3	-1	0	+1	

atima

Svaka od veličina iz skupa izlaza dovedena je u korealciju sa režimima obrade, i to za pet različitih oblika regresionih funkcija. Za srednju debljinu bijelog sloja (h_{sr}) kao i njen odnos prema srednjem aritmetičkom odstupanju profila obrađene površine (h_{sr}/R_a), dobivene su praktično upotrebljive regresijske funkcije. Saglasno dobivenim rezultatima, za pouzdanu procjenu h_{sr}, te odnosa h_{sr}/R_a, u posmatranom intervalu varijacije režima obrade, predlažu se izrazi:

$$h_{sr} = \frac{1}{-0{,}7 + 9{,}765 \cdot s + 3{,}43 \cdot t + 0{,}004052 \cdot v - 22{,}2 \cdot s \cdot t - 0{,}0426 \cdot s \cdot v - 0{,}00768 \cdot v \cdot t} \quad ...(1)$$

$$(h_{sr}/R_a) = (5{,}866 + 210{,}5 \cdot s \cdot t - 42{,}1 \cdot s - 22{,}38 \cdot t + 0{,}0056 \cdot v)^2 \quad ...(2)$$

Karakter uticaja brzine rezanja na h_{sr} ogleda se uvijek u direktnoj proporcionalnosti, dok karakteri uticaja posmaka i dubine rezanja ne mogu biti jednoznačno određeni. Ako se pak govori o stepenu uticaja, onda niti za jedan od režima obrade isti ne može biti jednoznačno određen.

Uticaj režima obrade na odnos h_{sr} /R_a vrlo je sličan kako po prirodi, tako i po stepenu njihovog uticaja na h_{sr}. Brzina rezanja je direktno proporcionalna analiziranom odnosu, dok je priroda uticaja posmaka i dubine rezanja promjenjljiva, zavisno od preostala dva parametra obrade, odnosno nije jednoznačna. Stepen uticaja bilo kojeg od parametara režima obrade na analizirani odnos, niti u ovom slučaju, ne može biti jednoznačno određen.

Sprovedena statistička obrada eksperimentalnih rezultata nije rezultirala adekvatnim matemtskim opisom srednjeg aritmetičkog odstupanja profila obrađene površine (R_a) u funkciji parametara obrade, u provom redu zbog nesignifikantnosti većeg broja, a u nekim slučajevima i svih, faktora. Eksperimentalni rezultati ukazuju na različitost karaktera promjene R_a pri rezanju otvrdnutog čelika u odnosu na karakter promjene R_a u uslovima konvencionalnog rezanja.

2.3. Upravljanje nastajanjem i karakteristikama BS-a

U ovom dijelu istraživanja analiziran je uticaj brzine rezanja i širine leđne istrošenosti alata na proces nastajanja BS-a sa aspekta mogućnosti njegovog upravljanja. Analiza uticaja samo brzine rezanja i širine leđne istrošenosti alata proizilazi iz: njihove direktne proporcionalnosti sa debljinom bijelog sloja, dvojakog karaktera parcijalnog uticaja posmaka i dubine rezanja, te ograničenosti po pitanju broja dodatnih eksperimenata.

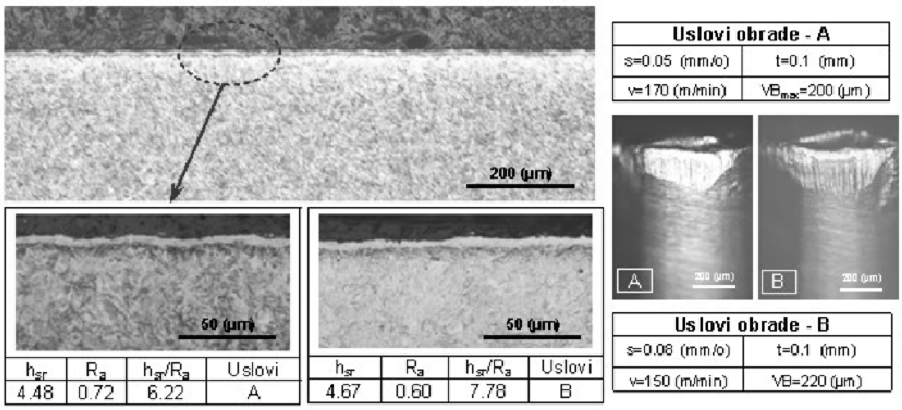
Analizom mikrosnimaka obrađene površine, nakon sprovedenih eksperimentalni testova rezanja [1], došlo se do zaključka da pri minimalnim vrijednostima posmaka i dubine rezanja, brzina rezanja je direktno proporcionalna sa h_{sr} . Uticaj širine leđne istrošenosti alata na h_{sr} istog je karaktera kao i uticaj brzine rezanja. Treba istaći da je stepen uticaja,širine leđne istrošenosti alata na h_{sr}, za manje agresivne uslove obrade manjeg inteziteta u odnosu na stepen uticaja brzine rezanja.

Pri analizi mikrosnimaka obrađene površine za agresivnije uslove obrade [1], primjećena je dominacija uticaja širine leđne istrošenosti alata u odnosu na brzinu rezanja, kako sa aspekta h_{sr} , tako i sa aspekta ravnomjernosti njegove debljine. Povećanje bilo kojeg od analiziranih parametara rezultira generisanjem BS-a praćenog i dodatnom plastičnom deformacijom BS-a. Pomenuti efekat se intenzivira sa porastom širine leđne istrošenosti alata, a isti rezultira smanjenjenjem hrapavosti obrađene površine.
Korištenjem jednačina (1) i (2) moguća je postavka matematskog modela optimizacije, procesa natajanja BS-a pri struganju otvrdnutog 16MnCr5 čelika, datog sljedećom jednačinom:

$$F_c = h_{sr} = h_{sr} = \frac{1}{-0{,}7 + 9{,}765\cdot s + 3{,}43\cdot t + 0{,}004052\cdot v - 22{,}2\cdot s\cdot t - 0{,}0426\cdot s\cdot v - 0{,}00768\cdot v\cdot t}$$

$$x_i \in D = \left\{ \begin{matrix} 0.08 \le s \le 0.12; \quad 0.1 \le t \le 0.3; \quad 100 \le v \le 150 \\ F_s = (h_{sr}/R_a) = (5{,}866 + 210{,}5\cdot s\cdot t - 42{,}1\cdot s - 22{,}38\cdot t + 0{,}0056\cdot v)^2 \end{matrix} \right\} \quad \cdots(3)$$

Jednačina (3) ukazuje na mogućnost upravljanja procesom nastajanja bijelog sloja pri struganju otvrdnutog 16MnCr5 čelika.
Karakteristika većine procesa kojima je moguće upravljati ogleda se u činjenici da se za različite kombinacije ulaznih veličina mogu dobiti približne vrijednosti posmatrane izlazne veličine. S toga su izvedeni dodatni eksperimenti za dvije različite kombinacije uslova obrade (sl.3.)
.



h_{sr}	R_a	h_{sr}/R_a	Uslovi
4.48	0.72	6.22	A
4.67	0.60	7.78	B

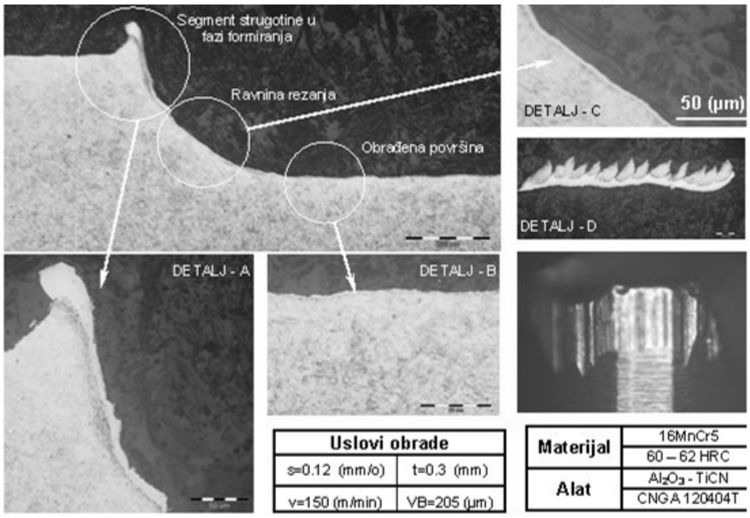
njem i

Naravno da su pri izboru uslova obrade za izvođenje eksperimenata korištena predhodno iznesena saznanja o ovom fenomenu, drugim riječima izbor različitih uslova obrade koji će dati približno isti rezultat na izlazu nije slučajan (sl.3).
Analizom mikrosnimaka obrađenih površina i njima pripadajućih BS-a (sl.3.), dobijena je dodatna potvrda o mogućnosti upravljanja procesom nastajanja BS-a pri struganju otvrdnutog čelika 16MnCr5. Ovakva konstatacija proizilazi iz sličnosti karaktera pojave BS-va (kontinuirani BS-vi u oba slučaja), iz sličnosti karaktera ravnomjernosti njihovih debljina (u oba slučaja BS-vi su prilično ravnomjerne debljine) te iz približnih numeričkih vrijednosti njihovih srednjih debljina (sl.3.).

3. MEHANIZAM NASTAJANJA BS-A

Da bi pri obradi otvrdnutog čelika došlo do generisanja BS-a moraju biti ispunjena dva preduslova. Prvo, generisana količina toplote, koje se javlja kao rezultat odvijanja procesa rezanja, mora se nalaziti na takvom nivou da omogući porast temperature u zoni rezanja iznad temperature austenitizacije materijala obradka. Drugo, nakon dostizanja veličine temeprature rezanja iznad temperature austenitizacije, proces hlađenja mora biti obavljen ekstremno brzo.
Dakle, da bi opis mehanizma nastajanja BS-a bio potpun isti mora sadržavati objašnjenje vezano za fazu ekstremno brzog zagrijavanja kao i njenu povezanost sa ekstremno brzom austenitizacijom, odnosno objašnjenje vezano za fazu ekstremno brzog hlađenje te njegovu povezanosti sa konačnom strukturom bijelog sloja.

Pri struganju otvrdnutih materijala vrijeme kontakta između alata i predmeta obrade, čak i kod poodmakle istrošenosti alata, iznosi najčešće manje od 0.1 (ms). Osim toga prelaz toplote dešava se samo u jednokratnom kontaktu između alata i posmatranog elementa na površini predmeta obrade. Zbog ovako specifičnih graničnih uslova treba imati na umu da izvor visoke temperature i ekstremno brzog zagrijavanja mora ležati u kombinaciji procesa trenja i procesa plastične deformacije (PD). Kroz dejstvo PD, u kratkom vremenu, mogu biti proizvedene velike količine toplote, uzrokujući na taj način brzo zagrijavanje predmeta obrade. U ovom, međutim, ne leži jedini, za struganje otvrdnutih materijala, važan uticaj, jer PD može, takođe, znatno skratiti i vrijeme austenitizacije. Shodno tome, nameće se logičan zaključak da bez PD, pri struganju otvrdnutih materijala, nema nastajanja bijelog sloja. Dokaz uticaja stepena PD na nastajanje i debljinu BS-a u strugotini, ravnini rezanja i na obrađenoj površini vidljiv je sa mikrosnimaka prikazanih na sl.4.

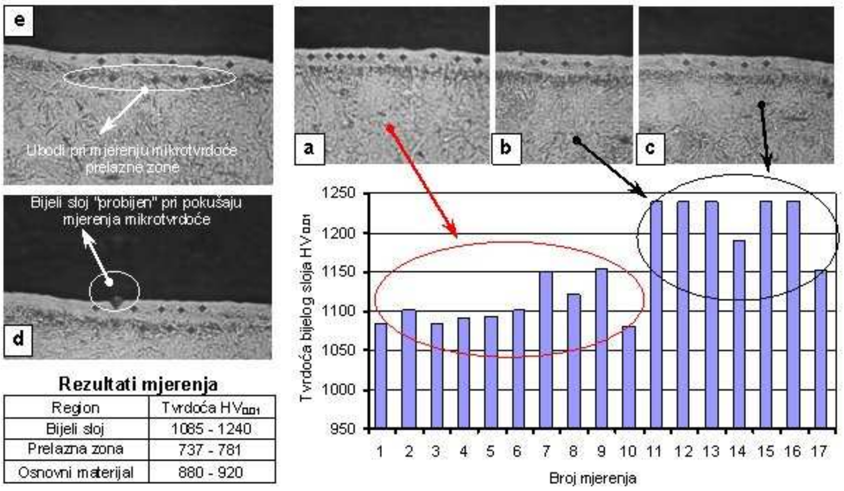


i

Trend smanjenjna debljine bijelog sloja na obrađenoj površini u odnosu na ravninu rezanja, odnosno u strugotinu, potvrđen je kroz sva eksperimentalna istraživanja [1].

4. KARAKTERISTIKE BS-A

Kada se govori o karakteristikama BS-a veoma je važan kontekst u kom se isti posmatra i analizira. Da li će generisani BS imati pozitivan ili negativan efekat, kako na integritet obrađene površine tako i na funkcionalnost dijela, zavisi prije svega od njegovih karakteristika: kontinuiteta ili diskontinuiteta njegovog pojavljivanja, geometrijskog pokazatelja njegovog pojavljivanja, ravnomjernosti geometrijskog pokazatelja njegovog pojavljivanja, mikrotvrdoće kao pokazatelja njegove tribološke superiornosti u odnosu na osnovni materijal, povezanosti sa osnovnim materijalom kao pokazateljem njegove postojanosti. Saglasno predhodnom može se konstatovati da generisani bijeli sloj može biti iskorišten u pozitivnom kontekstu ako ispunjava slijedeće uslove: ima kontinuitet (neprekidan bijeli sloj duž čitave obrađene površine), ima zadovoljavajuću (potrebnu) debljinu, ima približno ravnomjernu debljinu duž obrađene površine, ima veću tvrdoću od tvrdoće osnovnog materijala, i ima dobru vezu sa osnovnim materijalom. Ukoliko generisani bijeli sloj ne ispunjava bilo koji od pomenutih uslova, isti neće moći biti iskorišten u pozitivnom kontekstu, već će kao takav predstavljati defekt obrađene površine.
Potrebne karakteristike BS-a, da bi isti bio iskorišten u pozitivnom kontekstu, evidentne su na mikrosnimcima prikazanim na sl.5. Dobijeni rezultati mjerenja mikrotvdoće pokazuju da se, za slučaj parcijalnih uboda duž obrađene površine na mjernim mjestima sa većom debljinom BS-a, mikrotvrdoća kretala u intervalu 1150 do 1240 $HV_{0.01}$. Izvjesno rasipanje rezultata njerenja je povezano sa izborom mjernog mjesta po debljini BS-a. Za očekivati je da se mikrotvrdoća BS-a mijenja po njegovoj debljini te da je ista "maksimalna" na površini.



Slika 5. BS generisan na obrađenoj površini - ispunjava sve uslove da može biti iskorišten u pozitivnom kontekstu

Strukturne promjene u površinskom sloju predmeta obrade, u toku rezanja otvrdnutih materijala, pored BS-a manifestuju se i prelaznom zonom, tzv. tamni sloj, koja se odlikuje manjom tvrdoćom od tvrdoće osnovnog materijala, sl.5e.

Postojanje navedenih zona ide u prilog mogućeg iskorištenja BS-a u pozitivnom kontekstu, u smislu da tvrdi BS može preuzeti funkciju zaštite obrađene površine od abrazivnog djelovanja, dok omekšana zona (tamni sloj) može preuzeti funkciju veziva BS-a sa osnovnim materijalom

5. ZAKLJUČAK

Na osnovu provedenog eksperiemntalnog istraživanja te analize dobijenih rezultata mogu se donijeti sljedeći zaključci:

1. Ocjenom kvaliteta bijelog sloja mora biti obuhvaćena ravnomjernost debljine duž obrađene površine (h_{sr}), ravnomjernost pojave duž obrađene površine (kontinuiranog ili lokalnog karaktera), te veličina mikrotvrdoće.
2. Na osnovu veličine odnosa h_{sr} /R_a može se izvršiti ocjena ravnomjernosti debljine bijelog sloja te kontinuiteta njegovog nastajanja duž obrađene površine. Po pravilu, veće vrijednosti odnosa h_{sr} /R_a ukazuju na deblji i ravnomjerniji bijeli sloj duž obrađene površine te na obrađenu površinu boljeg kvaliteta.
3. U toku rezanja otvrdnutih materijala, proces nastajanja bijelog sloja na obrađenoj površini može biti praćen i efektom njegove dodatne plastične deformacije, kao rezultat kretanja alata duž ose predmeta obrade, kada veličina mehaničkog opterećenja, koje se javlja u toku procesa rezanja, dostigne potreban nivo. Pomenuti efekat, ukoliko slijedi nakon generisanja bijelog sloja, rezultira smanjenjem hrapavosti obrađene površine u odnosu na očekivanu. Shodno tome, postoji mogućnost identifikovanja bijelog sloja na obrađenoj površini mjerenjem nekog od pokazatelja hrapavosti (R_a, R_{max}) bez matalografske pripreme uzoraka.

6. LITERATURA

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

KORISTI OD UVOĐENJA SISTEMA UPRAVLJANJA KVALITETOM U ORGANIZACIJE

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SAŽETAK
Sve organizacije, bilo da se radi o proizvodnim ili uslužnim, koje žele da se uključe na međunarodno tržište moraju da ispune određene kriterije koji vladaju na tom tržištu. Ako organizacije budu željele da opstanu na tom tržištu i da povećaju svoj udio, moraće da nude jeftine proizvode i usluge vrhunskog kvaliteta. U tome će uspjeti samo one organizacije koje ispunjavaju zahtjeve svih zainteresiranih strana, koje imaju sistemski pristup u svom radu, koje imaju integrirane sisteme koji su im potrebni za uspjeh i koje stalno nadopunjuju i poboljšavaju svoje sisteme.
Ključne riječi: sistem kvaliteta, upravljanje kvalitetom, integralni sistem upravljanja kvalitetom

1. UVOD
U principu, sve organizacije bilo proizvodne ili uslužne, imaju za cilj da se stalno razvijaju i doživljavaju rast. Međutim, to nije moguće za većinu organizacija, jer iste nailaze na mnoge teškoće koje ne mogu da savladaju, pa stagniraju i propadaju. To se posebno odnosi na organizacije koje imaju složenu strukturu u kojoj postoji čitav niz odnosa i relacija koje određuju njihovo ponašanje, poslovanje, upravljanje i razvoj. Upravljanje takvim organizacijama je otežano, jer često imaju veliki broj učesnika različitog profila, motiva i interesa, a poseban problem predstavlja promjenljivost uvjeta u okruženju.

Ovaj rad se upravo temelji na činjenici da je rješenje ovih problema moguće, ako se u organizaciji uspostavi i provodi sistemski pristup. Posebnu snagu u funkcioniranju svakog sistema predstavlja kvalitet, pod kojim pojmom podrazumijevamo i kvalitet proizvoda i/ili usluge, i kvalitet procesa i kvalitet čitavog sistema. To je moguće postići u organizacijama koje su istinski pristupile uvođenju sistema upravljanja kvalitetom po modelu ISO 9001.

Međutim, tu se ne smije stati, već treba prihvatiti novu filozofiju kvaliteta sa tačno utvrđenim mehanizmima i mogućnostima kvaliteta i standardizacije. Treba krenuti ka totalnom upravljanju kvalitetom u organizaciji u cilju dostizanja izvrsnosti cijele organizacije, svakog njenog dijela i svakog zaposlenog kako bi se zadovoljili zahtjevi svih zainteresiranih strana.

Ovaj sistem čini osnovu, a potrebna su stalna poboljšanja cjelokupnog poslovanja organizacije i nadogradnja drugih sistema koji se odnose na samu organizaciju. Ta nadogradnja se ostvaruje kroz integrirani sistem upravljanja. Cilj rada je da pokaže koristi za sve organizacije koje krenu da na ovakav način funkciniraju.

2. ŠTA JE KVALITET I SISTEM KVALITETA

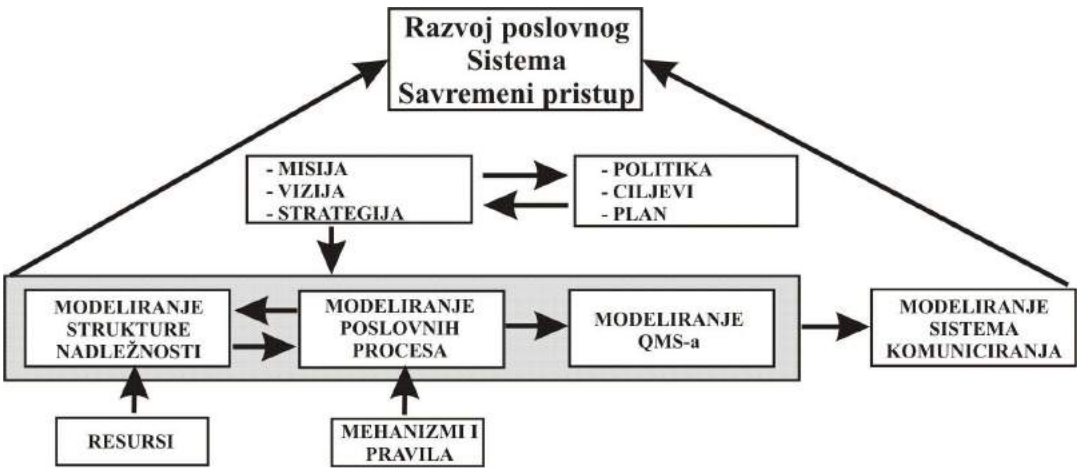
Ima jako mnogo definicija pojma kvalitet, a mi ćemo samo dati opće pokazatelje pojma kvalitet, koji su već u velikoj mjeri prihvaćeni, kao:

- pod kvalitetom podrazumijevamo potpuno ispunjenje želja kupaca, te svih zainteresiranih strana/svih sudionika (zaposlenika, saradnika, vlasnika, društvene zajednice), koje su pismeno utvrđene, usmeno dogovorene ili pak identificirane obradom marketinških podataka

Neka istraživanja pokazuju da 85% svih problema leži u sistemu, a 15% svih problema je u ljudima. Kvalitet se može ostvariti samo kroz sistemski pristup, a svaki sistem sadrži zajedničko, racionalan pristup sa specifičnim ciljem, te logičnu i efikasnu koordinaciju elemenata ili podsistema i tekući tok operacija, koje čine cjelinu i koje su usmjerene ka postizanju cilja. Drugim riječima, sistem kvaliteta predstavlja dio sistema upravljanja poslovanjem organizacije koji uključuje: ustrojstvo organizacije, djelatnosti planiranja, odgovornosti, praksu, procedure, procese i druge potrebne resurse za primjenu, postizanje, ocjenu, održavanje i mijenjanje (poboljšanje) politike kvaliteta. Sistem upravljanja kvalitetom teži da ujedini sve elemente koji utiči na kvalitet proizvoda ili usluge organizacije.

Ko želi da uđe u proces integracija u Evropi, mora se otvoriti u tom smislu, restruktuirati svoje poslovanje, prihvatiti vrijednosti, pravila i standarde koji tamo vrijede. Vanjski načini funkcioniranja i vanjske tehnologije prisiljavaju nas da učimo i usvajamo novo, da se prilagođavamo i mijenjamo vlastiti mentalni sklop i prije svega svoje znanje i način rada.

U svemu ovome ključnu ulogu ima menadžment organizacije, a ona se ogleda u primjeni savremenog pristupa u organiziranju i rukovođenju organizacijom, što se može i grafički predstaviti.



Slika 1. Savremen pristup u razvoju poslovnog sistema

Najkraći i najefikasniji put za ispravno i sistemsko ustrojstvo neke organizacije je uvođenje sistema upravljanja kvalitetom po seriji standarda ISO 9000, koju sačinjavaju četiri temeljna standarda:

ISO 9000 – Osnove i riječnik
ISO 9001 – Zahtjevi
ISO 9004 – Smjernice za poboljšanje performansi
ISO 19011 – Provjere/auditi

Prva verzija standarda serije ISO 9000, koji su prvi standardi netehničke prirode, izdata je 1987. godine. Uslijedila je prva velika revizija ovih standarda 1994. godine, a zatim druga velika revizija 2000. godine. Zadnja revizija ove serije standarda bila je 2008. godine.

Standardi su našli veliku primjenu u čitavom svijetu, jer se njihovom primjenom otklanjaju barijere u međunarodnoj saradnji i prometu roba, usluga i informacija, a Evropska unija ih je prihvatila kao harmonizirane standarde, koji važe za sve njene članice.

3. PREGLED NEKIH SPECIFIČNIH STANDARDA ZA POJEDINE OBLASTI

Pored standarda serije ISO 9000, u sve široj primjeni su i standardi za pojedine oblasti, kao što su:

■ ISO 14001 – Sistem upravljanja zaštitom okoline – Ovaj sistem uz poštivanje zakonskih propisa spada među ključna pitanja djelatnosti i razvoja savremenih kompanija jer uspostavlja „ECO - BALANCE" – balans između ekonomije i ekologije.

■ ISO 18001 – Sistem upravljanja zašitom zdravlja i sigurnosti na radu – Ovaj standard od općeg je interesa za sve zainteresirane strane: poslodavce, društvenu zajednicu, te posebno zaposlenike i njihove porodice. U većini zemalja ovo područje je uređeno Zakonom o zaštiti na radu i raznim podzakonskim i tehničkim propisima, a u Evropskoj uniji ovo područje je uređeno direktivom i plus brojnim specifičnim direktivama za pojedinu tehničku opremu ili tehnološki proces.

■ ISO 22000 – Sigurnost hrane – Daju smjernice koji zahtjevi treba da se ispoštuju da bi hrana bila ispravna za upotrebu.

■ HACCP – Hazard Analizis and Critical Control Point/Analiza rizika i kontrola kritičnih tačaka u proizvodnji hrane. HACCP je sistematičan pristup identifikaciji opasnosti i rizika u postupanju sa namirnicama, a koji pruža jasne metode utvrđivanja načina kontrole tih rizika.

■ ISO/TS 16949 – Posebni zahtjevi za primjenu ISO 9001 u proizvodnji automobila i odgovarajućim servisnim organizacijama.

■ ISO 17000 – Sistem upravljanja kvalitetom u laboratorijama. Laboratorije su jedan od presudnih faktora za postizanje kvaliteta, a u ovom standardu su navedeni uslovi koje moraju zadovoljiti laboratorije da bi valjano uradile svoj posao.

■ CE znak – Strateški značaj ocjenjivanja usklađenosti proizvoda sa zahtjevima Evropske unije. Oznaka CE (Conformite Europeene) predstavlja administrativnu efektivnu etiketu („pasoš"), i njome se označava usklađenost sa ključnim uslovima iz direktiva. CE znak je obavezan i mora se nalaziti na svakom proizvodu prije isticanja proizvoda na tržište i stavljanja u pogon.

4. INTEGRIRANI SISTEM UPRAVLJANJA

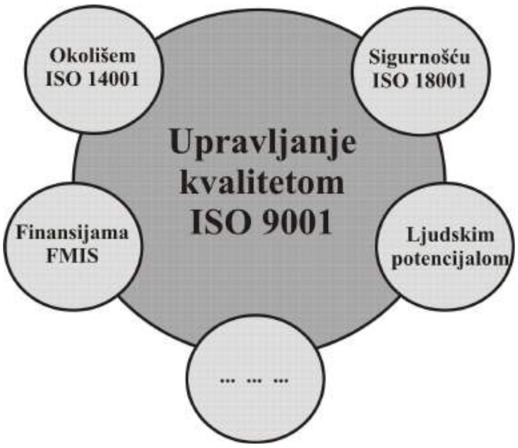
Ući i održati se na globalnom i liberaliziranom tržištu mogu samo subjekti koji zadovoljavaju zahtjeve prvenstveno s tri bitna aspekta:

- kvaliteta,
- cijene,
- rokova isporuke.

Pri tome se, pod pojmom kvalitet ne podrazumijeva samo kvalitet proizvoda i usluge, već mnogo šire – kvalitet integriranog (cjelokupnog) poslovanja organizacije, što uključuje i zaštitu okoliša, mjere zaštite zdravlja i sigurnosti ljudi, te brojne ostale parcijalne sisteme upravljanja, itd.

U tom konteksu preporučljivo je kreirati i implementirati integrirani sistem za potpuno i kvalitetno upravljanje poslovanjem cijele organizacije (u svijetu poznat kao Integrated Management System –

IMS), što znači da naprijed nabrojane sisteme i druge sisteme i uslove koji se odnose na dotičnu organizaciju, treba integrirati u jednu cjelinu.



Slika 2. Integrirani sistem upravljanja

Kako se vidi sa gornje slike, osnovu za uspješnu integraciju svih sistema, odnosno cjekokupnog poslovanja organizacije čini sistem upravljanja kvalitetom po seriji standarda ISO 9000. Da je moguće napraviti i implementirati integrirani sistem upravljanja, dokazuje i činjenica da svi ISO standardi za sistem upravljanja imaju i zajedničke ključne elemente.

5. UČINCI DOBROG UPRAVLJANJA KVALITETOM

Da bismo ušli u proces osavremenjavanja organizacije, ovim, već provjerenim putem, navedimo i slijedeće argumente za QM-sistem:

- PRODAJA
  - prijem u listu dobavljača
  - javni tenderi
  - povjerenje kupca

- IZVOZ
  - ukidanje trgovačkih barijera
  - CE znak

- TROŠKOVI
  - minimiziranje troškova grešaka i ispitivanja

- GARANCIJA
  - optimiranje rizika
  - minimiziranje odgovornosti vezano za proizvod
  - minimiziranje odgovornosti vezano za organizaciju

- MOTIVACIJA
  - unapređivanje razmišljanja o preduzeću
  - unapređenje timskog razmišljanja
  - transparentni tokovi.

Uspostavljanjem **IMS** – Integriranog sistema upravljanja, organizacija teži ka balansu zadovoljenja svih zainteresiranih, što je prikazano na slijedećoj slici.

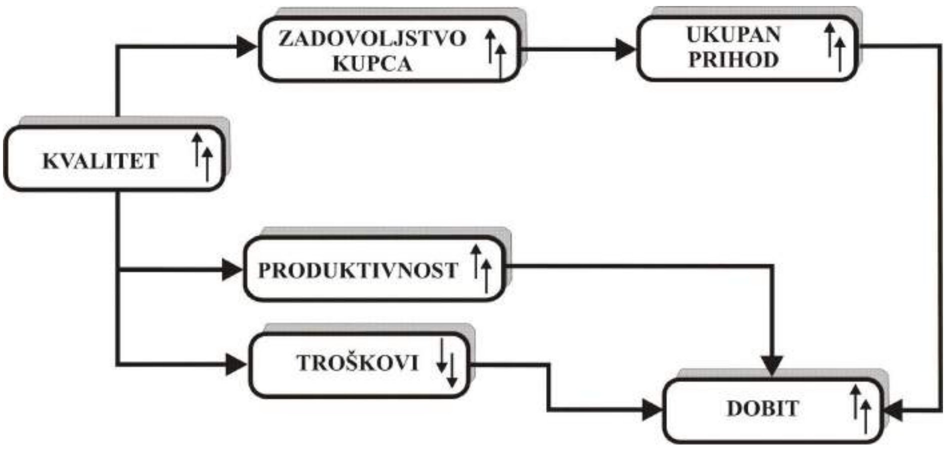
Slika 3. Zainteresirane strane

Od nositelja vlasničkih prava se zahtijeva i očekuje da dio profita ulažu u održivi razvoj kroz upravljački sistem životne sredine, zdravlja i sigurnoszi zaposlenika, i druge projekte od šireg značaja.

Organizacije koje su uspostavile sistem upravljanja kvalitetom imaju niz prednosti koje se ogledaju u slijedećem:

^ Svakome su jasne politika kvaliteta i ciljevi kvaliteta
^ Zaposleni su svjesni i kompetentni prema kvalitetu
^ Nadležnosti i odgovornosti rukovoditelja su strogo određene
^ Ovlasti su distribuirane prema shemi rukovođenja
^ Ustroj i zadaci su maksimalno transparentni
^ Prakticira se timski rad
^ Poznate su želje i potrebe kupaca
^ Kvalitet se planira od početka-od zamisli
^ Razvoj proizvoda okrenut je prema tržištu
^ Potpuna je dokumentiranost svih aktivnosti
^ Proizvod/usluga odgovara specifikaciji i standardu
^ Specifikacija odgovara očekivanjima kupaca
^ Proizvod se stvara u potpuno ovladanom procesu
^ Statistički se obrađuju uzroci koji dovode do nekvaliteta
^ Teži se stalnim poboljšanjima kvaliteta proizvoda, procesa i čitavog sistema

Učinke dobrog upravljanja kvalitetom možemo predstaviti ključnim parametrima koji su uobičajeni u ocjeni poslovanja svake organizacije.



Slika 4.Učinci dobrog upravljanja kvalitetom

6. ZAKLJUČAK

Samo objektivnim sagledavanjem trenutnog stanja svoje nesavršenosti, proučavanjem razvojnih trendova u svijetu u svim sferama koje su od interesa za predmetnu organizaciju, stručnim analizama i primjenom pravih rješenja na vrijeme i u dovoljnjoj mjeri, organizacija može da računa na uključenje u zahtjevna svjetska tržišta i da opstane na tim tržištima. Ove aktivnosti moraju da budu permanentne, da se stalno uči, da se timski radi, i posebno da se razvija kultura kvaliteta, jer je ona najutjecajniji faktor u svim aktivnostima.

Sve ovo je moguće primjenom savremenih sistema upravljanja kvalitetom i njihovom integracijom u jednu cjelinu, te stalnim poboljšanjem svih faktora koji imaju utjecaj na poslovanje organizacije. Ako bi se u nekoj organizaciji istinski uvela ovakva praksa, bez sumnje, to bi dalo višestruke koristi toj organizaciji, a te koristi su upravo razmatrane u ovom radu.

Integrirani sistem upravljanja, praktično predstavlja proširenje koncepta sistema upravljanja kvalitetom na sve druge navedene parcijalne sisteme upravljanja u organizaciji (standardizirane i nestandardizirane) i njihovo integriranje. To je danas opće prihvaćen model upravljanja kompanijama u poslovnom sistemu.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

UTICAJ REŽIMA TERMIČKE OBRADE NA SILU IZVLAČENJA SA REDUKCIJOM DEBLJINE ZIDA

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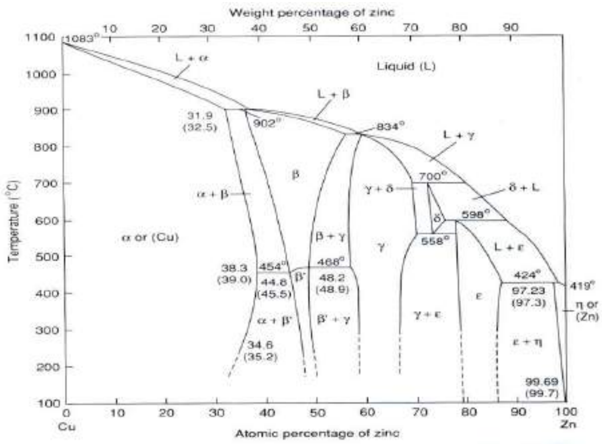
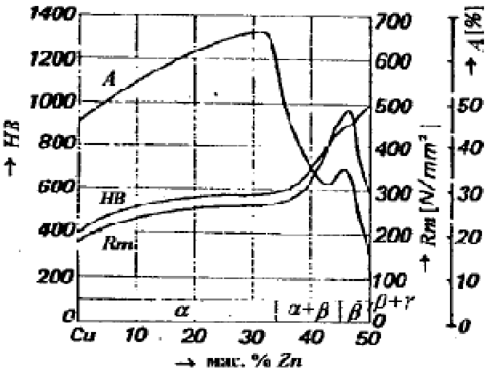
ABSTRACT
Pri projektovanju procesa dubokog izvlačenja sa redukcijom debljine zida posebnu pažnju treba posvetiti izboru režima termičke obrade, kako bi se sila izvlačenja održavala u propisanim granicama.
Različiti režimi termičke obrade rezultiraju različitim tvrdoćama i veličinama zrna radnog predmeta, a sa rastom izlazne tvrdoće raste i sila izvlačenja, što može negativno uticati na stabilnost procesa zbog povećanog trošenja i zastoja uslijed izmjene alata.
Keywords: duboko izvlačenje sa redukcijom debljine zida, režimi termičke obrade

1. UVOD
Dubokim izvlačenjem sa redukcijom debljine zida uglavnom se proizvode čaure za sve vrste streljiva. Propisani zahtjevi vezani za svojstva, koje čaura mora da ima ostvaruju se: konstrukcijom, izborom pogodnog materijala i odgovarajućom tehnologijom izrade.Zbog specifičnosti eksploatacije čaura, kod većine tehnoloških postupaka izrade istih, propisana je izlazna tvrdoća gotovih proizvoda. Od pripremaka do gotovog proizvoda potrebno je nekoliko operacija izvlačenja, a u svakoj operaciji dolazi do promjene plastičnih osobina materijala (promjena tvrdoće i veličine zrna). Izborom odgovarajućeg režima termičke obrade u prvoj operaciji izvlačenja i međuoperacijskim žarenjima pokušava se propisana tvrdoća i veličina zrna gotovog proizvoda držati u dozvoljenim granicama. Povećana izlazna tvrdoća direktno utiče na povećanje sile izvlačenja, što za posljedicu ima ugrožavanje stabilnosti procesa izvlačenja, tj. povećanje trošenja alata i broja zastoja zbog njegove izmjene.

2. REŽIMI TERMIČKE OBRADE I NJIHOV UTICAJ NA SILU IZVLAČENJA ZA CuZn28
Legure bakra sa cinkom kod kojih je sadržaj bakra veći od 50% (ostatak je Zn) su poznate pod imenom *mesinzi*. Za proizvodnju čaura koristi se mesing CuZn 28 zbog izraženih plastičnih svojstava. Dijagram stanja legura bakar–cink je prikazan je na Slici 1.
Jednofazne oblasti na dijagramu stanja odgovaraju područjima stabilnosti različitih čvrstih rastvora (α, β, γ, ε, η). Između jednofaznih postoje i dvofazne oblasti koje se dobijaju različitim kombinacijama u čvrstom stanju i reakcijama iz tečnog stanja. Svaka od ovih strukturnih oblasti se odlikuje čitavim nizom osobina koje se međusobno značajno razlikuju. Sa porastom sadržaja Zn do ~50% čvrstoća raste, a zatim naglo opada što je karakteristika svojstava plastičnosti, čiji se pad javlja već poslije sadržaja Zn od ~30%, dok tvrdoća pokazuje stalnu tendenciju porasta (Slika 2.). Najtvrđa je γ-faza koja ima tvrdoću iznad HB=3000N/mm^2.

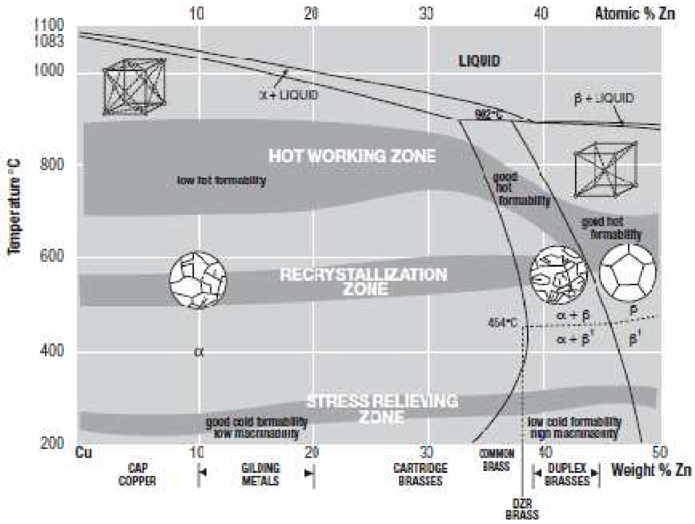


Slika 1. Dijagram stanja legura Cu-Zn



Slika 2. Promjena mehaničkih osobina legura Cu-Zn

Ovakva promjena osobina, ali i odgovarajuća tehnološka svojstva, uslovila su i primjenu. Najviše se koriste legure do 50% Zn, Slika 3.



Slika 3. Cu-Zn parcijalni fazni dijagram

Mesinzi sa sadržajem Zn koji odgovara području stabilnosti α označeni su i kao α–mesinzi, a po istom pravilu, postoje i (α+β)–mesinzi i β–mesinzi. α–mesinzi se dobro plastično prerađuju u hladnom stanju, a slabije na višim temperaturama. Za razliku od njih, β–mesinzi se dobro prerađuju u toplom stanju, dok su na nižim temperaturama relativno krti.

Mesing CuZn28 je najvažnija legura u grupi mesinga, zbog svoje veoma velike duktilnosti u α oblasti.
Pored cinka na kvalitet mesinga znatno utiču neizbježne primjese kao:
-olovo (Pb) koje u količini od 0,03% snižava plastičnost;
-željezo (Fe) koje u količini većoj od 0,05% takođe snižava plastičnost i izaziva krtost;
-sumpor (S), izaziva mjehure pri livenju već u količini većoj od 0,002%;
-bizmut (Bi) u količini većoj od 0,002% izaziva krtost mesinga i u hladnom i u toplom stanju.
Dozvoljava se da ukupan sadržaj primjesa iznosi najviše 0,15%. Sem redovnih primjesa koje prate mesing, radi povećanja korozijske stabilnosti, mesingu se katkad dodaju razni dodaci, kao na primjer aluminijum, silicijum i dr.

Topljenje mesinga se vrši u indukcionim pećima. Temperatura topljenja mesinga je oko 960°C, a livenja 1120 – 1140 °C. Livenje mesinga vrši se u metalne kokile, čiji se zidovi hlade protočnom

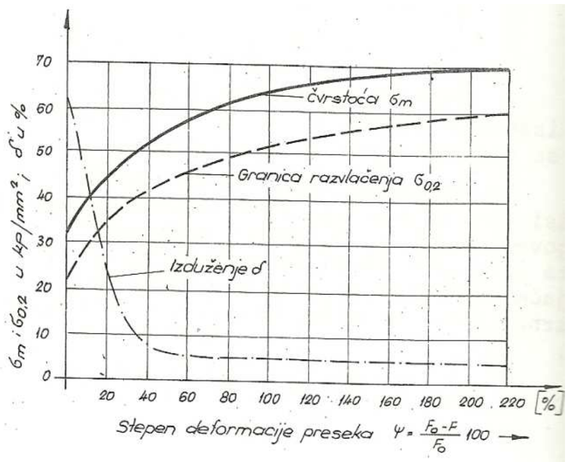
vodom. Ohlađen mesing se površinski čisti, a zatim zagrije na temperaturu 840 – 860 °C i podvrgava toplom valjanju u trake određenih dimenzija. Mesingane trake se po valjanju odgrjevaju do pune rekristalizacije, a zatim se vrši nagrizanje i pranje. Poslije toga se vrši hladno valjanje traka radi poboljšanja tehnoloških osobina i kalibriranje na debljinu koju moraju imati rondele.
Stepen redukcije debljine mesinganih traka pri hladnom valjanju treba da je oko 30%, tj.

$$\varepsilon_h = \frac{h_o - h}{h_0} 100 \approx 30\% \qquad ...(1)$$

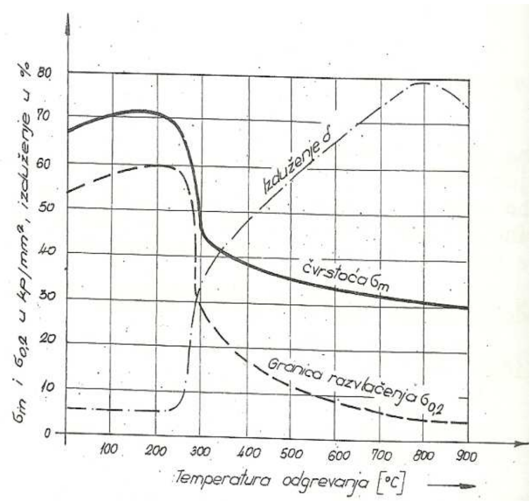
gdje je:
h_0 (mm) – debljina trake prije valjanja
h (mm) – debljina trake poslije valjanja
Najrasprostranjenija mana livenja, koja se primjećuje pri isijecanju rondele, je mjehur koji se pojavljuje u vidu rascjepa, ako se poklapa s linijom isijecanja.
Upotrebljivost mesinga ne zavisi samo od sastava i mehaničkih osobina mesinga, nego i od njegove strukture. Struktura treba da je sitnozrnasta. Krupnozrnasta struktura pri izvlačenju daje hrapavu površinu, naročito pri većem stepenu deformacije.

3. UTICAJ STEPENA DEFORMACIJE I TEMPERATURE ŽARENJA NA MEHANIČKE OSOBINE CuZn28

Mesing CuZn28 se prerađuje u hladnom stanju. Posljedica hladne obrade je otvrdnjavanje mesinga i povećanje njegove čvrstoće. Sa povećanom deformacijom, otpornost materijala prema daljnoj deformaciji se stalno povećava, a duktilnost mu istovremeno opada, tj. smanjuju mu se plastična svojstva. Kod određenog stepena deformacije, plastična svojstva materijala se mogu toliko smanjiti da izazovu lom deformisanog materijala.
Promjene mehaničkih osobina mesinga CuZn28 u zavisnosti od stepena deformacije prikazane su na Slici 4. [2].
Materijalu koji je plastičnom deformacijom izgubio plastična svojstva, ista se mogu povratiti zagrijavanjem do određene temperature, pri čemu prvo dolazi do pojave oporavljanja, a zatim do procesa rekristalizacije, koju prati rast zrna. Kod procesa oporavljanja se ne opažaju promjene u mikrostrukturi, ali se poboljšavaju plastična svojstva materijala i oslobađaju unutrašnja naprezanja.
Na Slici 5. [2] prikazane su promjene mehaničkih osobina CuZn28 u zavisnosti od temperature zagrijavanja (žarenja) prethodno deformisanog materijala (materijal je prethodno pretrpio deformaciju ψ =125%)



Slika 4. Dijagram zavisnosti mehaničkih osobina CuZn28 u funkciji od stepena deformacije



Slika 5. Dijagram zavisnosti mehaničkih osobina CuZn28 u funkciji od temperature (materijal je prethodno pretrpio deformaciju ψ =125%)

Iz dijagrama na Slici 5. vidi se da zagrijavanje do 250 °C ne izaziva promjene mehaničkih osobina mesinga.
Od 250° – 300°C povećava se izduženje za oko 30%, dok se čvrstoća na kidanje i granica razvlačenja naglo smanjuju. Izduženje zatim ravnomjerno raste do oko 800°C kad počinje da opada, dok su čvrstoća i granica razvlačenja u stalnom laganom opadanju. Poslije 800°C nastaje zona pregrijeva. Interval od 275° – 350 °C naziva se zonom oslabljenja. U ovom temperaturnom području svojstva mesinga su nestabilna i u toj zoni se nalazi najniža granica rekristalizacije. U zoni 350° – 750 °C vrši se ravnomjerna promjena mehaničkih osobina praćena porastom zrna.
Sa dijagrama (Slika 5.) zaključuje se da se gornja granica rekristalizacije nalazi u području od 600° – 750°C. Mesing ne stari ali je osjetljiv na koroziju pod dejstvom unutrašnjeg naprezanja. Unutrašnja naprezanja pod uplivom hemijskih produkata iz atmosfere, izazivaju u izvučenom mesingu prskanje.

4. REKRISTALIZACIONO ŽARENJE CuZn28

Rekristalizacija je proces formiranja novih nenapregnutih zrna, približno sfernog oblika, sa relativno malom gustinom dislokacija, dakle stanje koje karakteriše materijal prije plastične deformacije. Nova zrna se formiraju oko nukleusa i rastu dok se prvobitna struktura ne transformiše u potpunosti u novu sitnozrnastu strukturu. Da bi se odigrao ovaj proces potrebno je prisustvo procesa difuzije na malim rastojanjima.

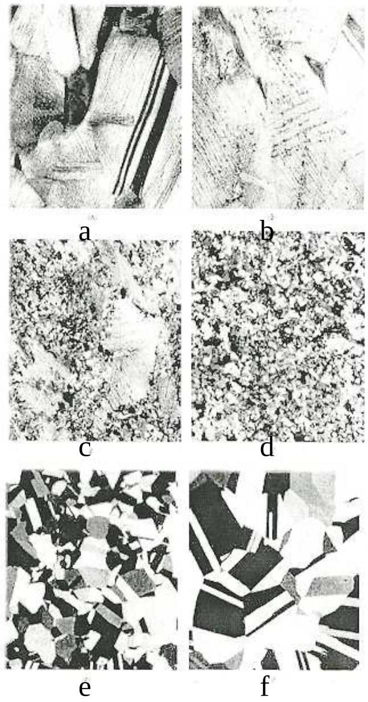
U toku procesa rekristalizacije, kao i kod procesa kristalizacije, zapaža se etapa stvaranja centara kristalizacije. Centri kristalizacije se stvaraju na nižoj temperaturi, ako je materijal u procesu *hladne obrade deformacijom* više deformisan. Kao centri kristalizacije služe oni dijelovi deformisanog kristala, gdje je naprezanje bilo najveće, jer se u procesu oporavljanja najprije tu sredilo stanje i isčezla svaka deformacija rešetke. Ovi dijelovi imaju pravilnu kristalnu rešetku koja služi kao centar kristalizacije i raste na račun deformisane okoline.U procesu rekristalizacije mehanička svojstva koja su se promijenila kao rezultat *hladnog rada* se vraćaju u prvobitno stanje: materijal postaje mekši, slabiji i duktilniji.

Rekristalizacija je proces čiji stepen zavisi od dužine trajanja (vremena) i temperature. Temperatura pri kojoj počinje proces rekristalizacije se naziva temperaturom rekristalizacije. S obzirom da je visina temperature topljenja izvjesna mjera za energiju koja se mora unijeti da bi se kristalna veza atoma razrušila, to je i temepratura rekristalizacije funkcija temperature topljenja. U praksi se kao rekristalizaciona temperatura nekog materijala definiše ona temperatura, pri kojoj se hladnom deformacijom jako deformisana struktura potpuno rekristališe približno za jedan sat.

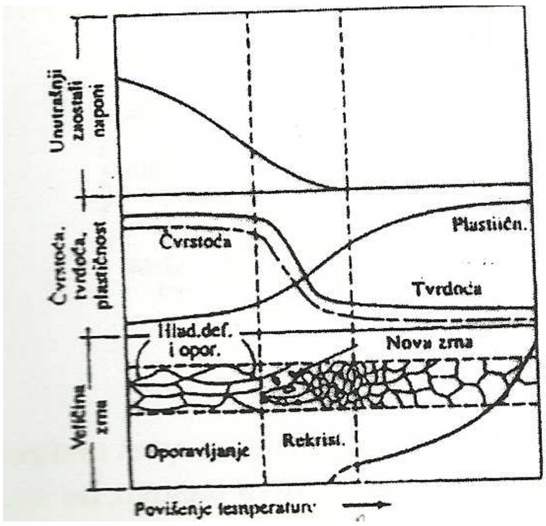
4.1 Uticaj vremena

Stepen (ili količina) rekristalizovanih zrna raste sa vremenom, kao što je prikazano na Slici 6. a-f.

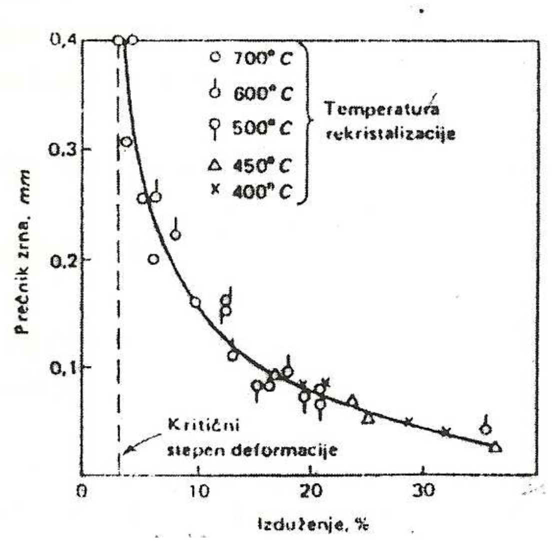
Rekristalizacija počinje nakon određenog vremena, koje se naziva inkubacioni period, u toku koga se aktiviraju prve klice. Brzina rekristalizacije dQ/dt je u početku mala. Međutim, brzina se povećava sa vremenom, dostiže neku maksimalnu vrijednost, a zatim se opet smanjuje na kraju procesa. Kriva rekristalizacije ima karakterističan S oblik tipičan za procese koji se odvijaju stvaranjem klica i rastom novih kristala (Slika 7.).
Brzina stvaranja klica mijenja se sa vremenom na sličan način kao i ukupna brzina rekristalizacije, dok je brzina rasta kristala najčešće konstantna.



Slika 6. Snimak koji pokazuje nekoliko etapa u procesu rekristalizacije i rasta zrna mesinga (a) Struktura zrna nakon rada na hladno (33%) (b)Početak procesa rekristalizacije nakon zagrijavanja od 3s na 580°C; veoma mala zrna su ona koja su rekristalizovana (c) Djelimična zamjena zrna formiranih u procesu rada na hladno sa rekristalizovanim (4s na 580°C). (d) Kompletna rekristalizacija (8s na 580°C). (e) Rast zrna nakon 15 min na 580°C. (f) Rast zrna nakon 10 min na 700°C.



Slika 7. Uticaj zagrijavanja na strukturu i svojstva hladno deformisanog materijala



Slika 8. Zavisnost veličine rekristalisanih zrna mesinga od procenta deformacije

4.2 Uticaj temperature i deformacije

Izotermalne krive rekristalizacije pokazuju da je vrijeme za potpunu rekristalizaciju toliko kraće ukoliko je temperatura veća.

Inkubacioni period i vrijeme potrebno za potpunu rekristalizaciju su utoliko kraći ukoliko je stepen deformacije veći, tj. temperatura rekristalizacije je utoliko niža ukoliko je prethodni stepen deformacije veći.

4.3 Veličina rekristalizacionog zrna

Svi faktori koji utiču na količinu energije koja se akumulira pri deformacij (ε, t, brzina deformacije, oblik naprezanja, veličina zrna), utiču i na veličinu rekristalizacionog zrna.

Stepen deformacije je najvažniji faktor koji utiče na veličinu rekristalisanih zrna. Veličina zrna se brzo smanjuje sa porastom deformacije.

Granica popuštanja se povećava sa smanjenjem veličine zrna, dok se sposobnost limova da se oblikuju razvlačenjem povećava sa povećanjem veličine zrna.

Neki rezultati pokazuju da temperatura rekristalizacije ne utiče na veličinu rekristalizacionog zrna u α-mesingu.

Prvobitna, odnosno početna veličina zrna, znatno utiče na brzinu rekristalizacije i to prvenstveno na brzinu stvaranja klica. Sa smanjenjem prvobitne veličine zrna povećava se brzina stvaranja klica i smanjuje veličina rekristalisanih zrna (Slika 8.).

4.4 Uticaj veličine zrna na mehaničke osobine

U jednofaznim sistemima kao što je CuZn28, najvažnija karakteristika strukture je veličina zrna i njihova homogenost, jer sve mehaničke osobine prvenstveno zavise od veličine zrna.Veličina zrna, pa samim tim i mehaničke osobine, u najvećoj mjeri zavise od: hemijskog sastava, temperature i vremena žarenja, režima tople i hladne prerade.
Eksperimentalno je utvrđeno da se granica popuštanja povećava sa smanjenjem veličine zrna prema Hall-Petchovoj jednačini:

$$\sigma_{0,2} = \sigma_t + Kd^{-1/2} \qquad ...(2)$$

gdje je:
d – prečnik zrna; K – empirijska konstanta; σ_t -napon savladavanja trenja rešetke.
Tvrdoća pokazuje analognu zavisnost kao i granica popuštanja:

$$(HB) = (HB)_0 + K_1 d^{-1/2} \qquad ...(3)$$

gdje je:
$(HB)_0$ – tvrdoća; d – prečnik zrna; K_1 – empirijska konstanta.
U žarenom stanju vrijednosti tvrdoće se nalaze u dosta uskom intervalu od 50 – 70 jedinica po Brinelu. Uticaj veličine zrna na izduženje je takvo da se ono povećava sa smanjenjem granice popuštanja, odnosno sa povećanjem veličine zrna.

5. ZAKLJUČAK

Teoretska istraživanja, prezentirana u ovom radu, imala su za cilj dobijanje stvarne slike uticaja režima termičke obrade na silu izvlačenja sa redukcijom debljine zida. Rezultati istraživanja dokazuju da izbor režima termičke obrade za izradu elemenata izvlačenjem sa redukcijom debljine zida, bitno utiče na stabilnost procesa izvlačenja, kvalitet obrađene površine i silu izvlačenja.
Postavljene teoretske podloge su poslužile za eksperimentalna istraživanja uticaja različitih režima termičke obrade na rast sile izvlačenja i uspostavljanje veze između sile izvlačenja, tvrdoće pripremka i tvrdoće radnog predmeta. Rezultati eksperimentalnih istraživanja biće objavljeni u narednom radu.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

ANALYSIS OF CHARACTERISTIC PARAMETERS FOR TORQUE CONVERTER

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ABSTRACT

In this paper are analyzed characteristic parameters of torque converter: transmission ratio, efficiency and factor of sliding depending on the engine effective power and the number of rotations of the engine. Analysis of these parameters is realized through mathematical model, and the results obtained are presented through diagrams. Curves obtained clarify the operation of hydrodynamics transmission in general and especially torque converter depending on the effective power and number of rotations of engine, including the start time.

Keywords: Torque converter, transmission ratio, factor of sliding, efficiency.

1. TORQUE CONVERTER

Torque converter consists of two main parts: circuit of pump- entrance, which is related to the shaft of the driving machine and the circuit of turbine- exit, which is related to the shaft of working machine. Torque converter effort transformation of rotation number the circuit of pump for constant torque of the circuit of turbine. Two working circuits (the pump and turbine) are placed in front of each other and has same number of vanes, which stand at normal plane in the axis of rotation. In general we distinguish three characteristic cases of the torque converter and driving machine:

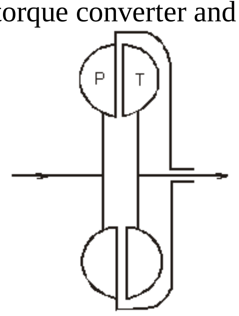

Figure 1. Constructive form of torque converter

- if the circuit of pump and turbine rotates with the same number of rotations, with the opposite direction;
- for normal loads, circuit of turbine rotates slowly circuit of pump;
- circuit of the pump rotates with the same number of rotations while the circuit turbine is fixed, this case provides maximum energy transfer which is necessary for the issuance of the driving to work when the resistance are maximal.

Advantages of the torque converter are:
- greater flexibility of the torque converter between driving and working machine,
- driving machine starts without any load,
- driving machine is protected from unexpected overload and dynamic shocks,
- effectively put out the vibration,

- high level of efficiency $\eta = 0.97...0.98$.

2. CHARACTERISTICS QUANTITY AND BASIC EQUATIONS OF TORQUE CONVERTER

Transmission ratio of the torque converter intend ratio of rotations number of turbine to the rotation number of the pump:

$$i = \frac{n_T}{n_P} \qquad ...(2.1)$$

For the case when it is $n_P = n_1$ and $n_T = n_2$ reciprocal value of the factor sliding (s) corresponds to the definition of the transmission ratio (equation 2.1), which is in accordance with standard DIN 3960 for gear transmission.

From this, the expression for sliding factor of the torque converter, takes this form:

$$s = \frac{n_1 - n_2}{n_1} = 1 - \eta \qquad ...(2.2)$$

Efficiency of the torque converter represents the ratio of output and input power or the ratio of output and input of rotations number:

$$\eta = \frac{P_2}{P_1} = \frac{n_2}{n_1} = i \qquad ...(2.3)$$

3. ANALYSIS OF PARAMETERS OF TORQUE CONVERTER

Determination of the main parameters of torque converter: the transmission ratio, factor of sliding and efficiency, during of process of connection it is done based on expressions (2.1) (2.2) and (2.3), while the angular velocities of the torque converter are gained during the simulation by MATLAB software. In figure 3.1 is given scheme for analysis of the torque converter based on the MATLAB software.

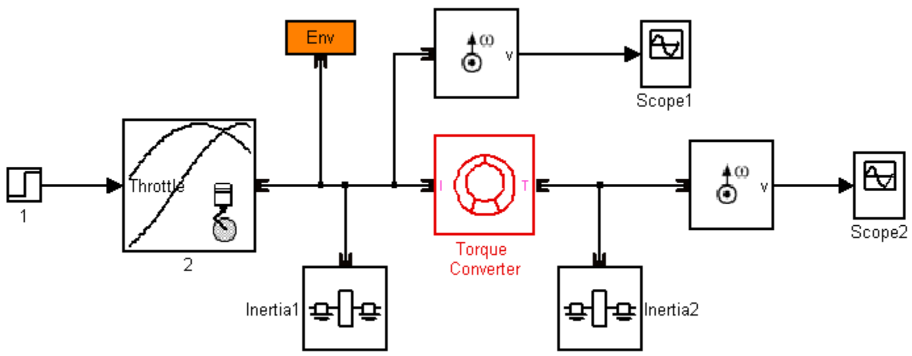

Figure 2. Scheme for analysis of the torque converter

3.1. The influence of power on the parameters of the torque converter

Obtained results through simulation in MATLAB are presented in the following diagram. In figure 3 are presented the curves of the transmission ratio of the torque converter during process of connection of torque converter for the three characteristic values of engine power (Pe=110 kW, Pe=140 kW, Pe=165 kW), depending on the time **t**.

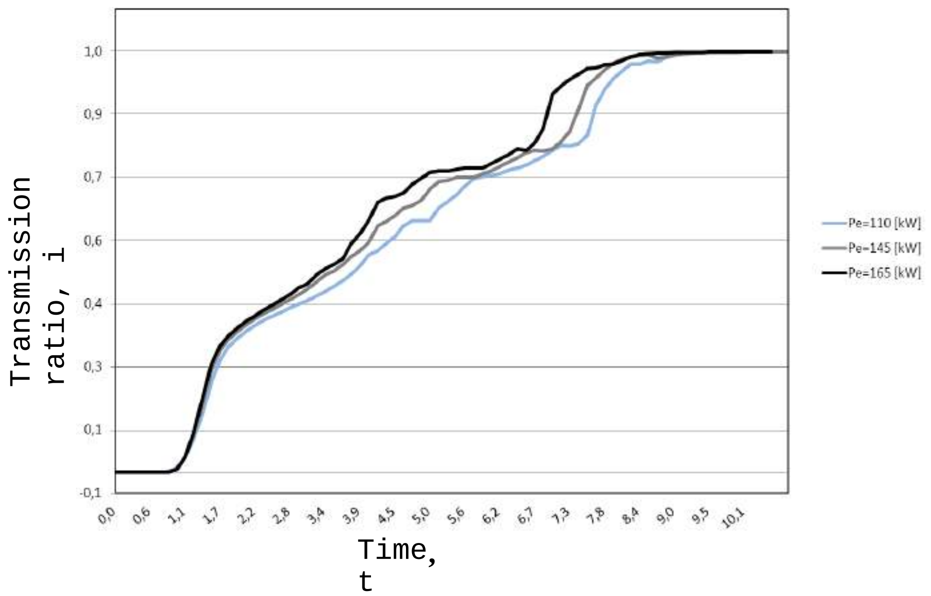

Figure 3. Transmission ratio on dependency of time

Taking into account expression (2.1), first transmission ratio is zero, because the angular speed of the circuit of turbine is not rotating, angular speed turbine circuit is zero, but during the time begins to grow to a value one, when angular speed of torque converter circuits is equal. This enables synchronization of angular speed between the crankshaft and main shaft of transmission during gear changing. Also in the diagram, in figure 3, it is seen the influence of engine power at the time of reaching the maximum value of transmission ratio.

In figure 4 are given the curves of factor of sliding of torque converter during the process of torque converter connection.

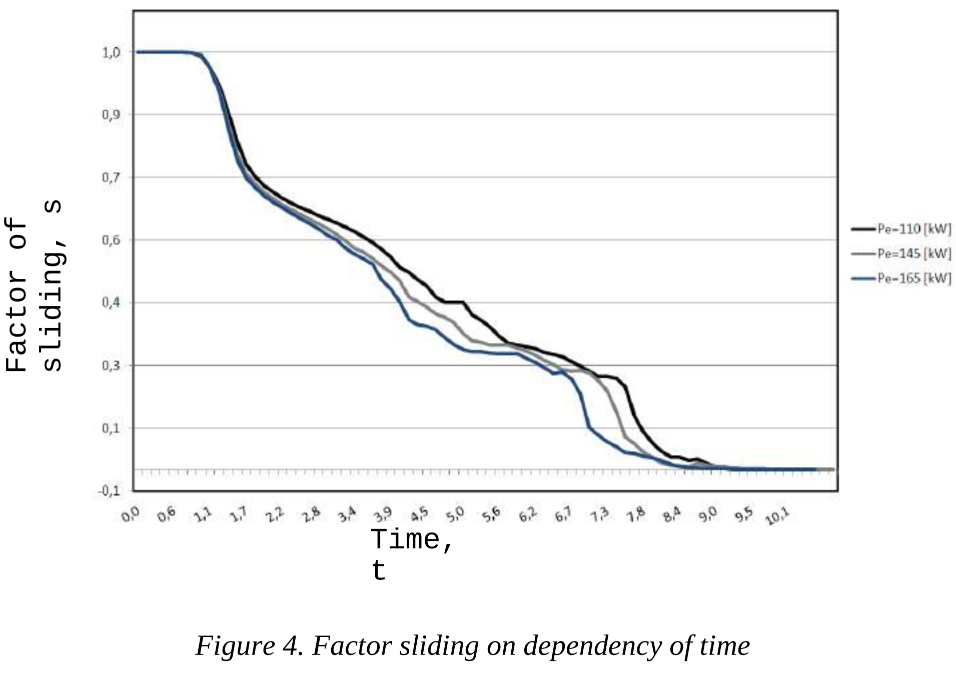

Figure 4. Factor sliding on dependency of time

From Figure 4 shown that initially factor sliding has its maximum value, because all the power that is transmitted to the pump circuit is transferred to put into motion the oil (mechanical energy of pump circuit turns into kinetic energy of fluid), but this happen in short time while the rotating numbers of torque converter circuits are equal, also from curve it can be seen influence of engine power at the factor of sliding.

In the figure 5 are given curves of torque converter efficiency during process of connection.

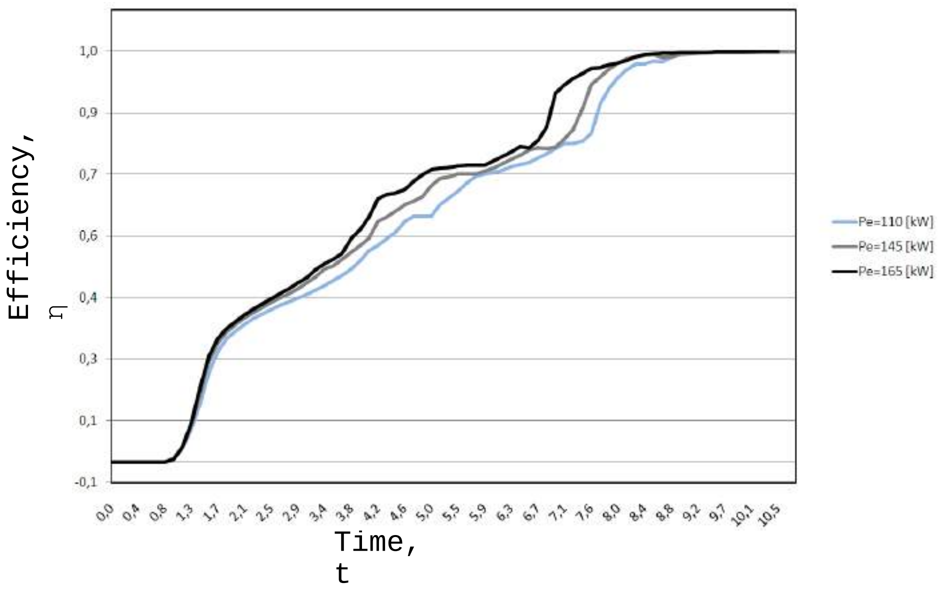

Figure 5. Efficiency on dependence of time

Analyzing the diagram it can be seen that efficiency increases proportionally while decreases factor of sliding.

3.2. Influence of rotations number into torque converter parameters

Through three values of the rotation number of crankshaft engine are analyzed main parameters torque converters.

In figure 6 are shown curves of transmission ratio for different of rotations numbers (n_e=4200 min^{-1}, n_e=5400 min^{-1}, n_e=5700 min^{-1}).

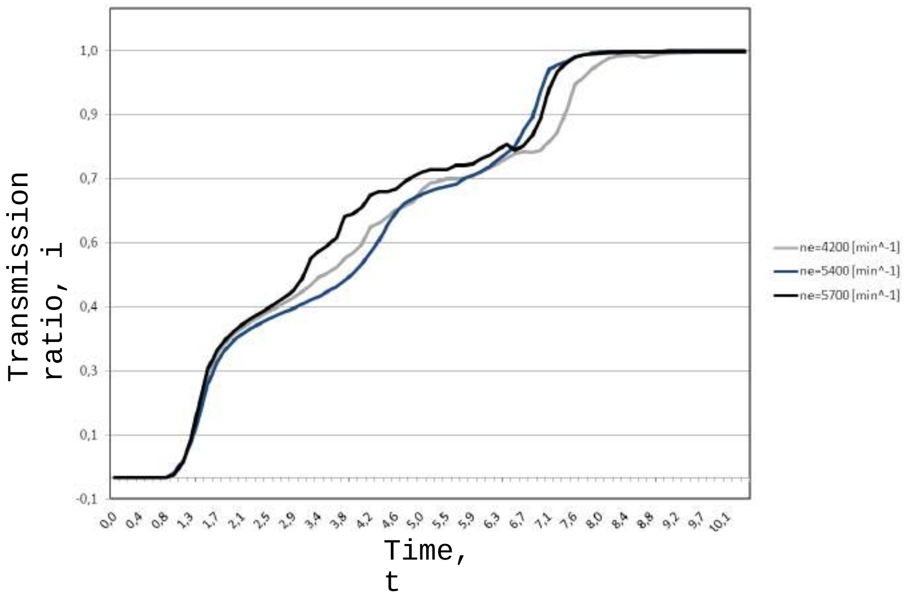

Figure 6. Transmission ratio on dependency of time

From diagram it can be seen the influence of rotations number during process of torque converter connection. With increasing of rotations number increases transmission ratio, while the maximum value of transmission ratio is reached faster.

In figure 7 are shown curves for factor sliding on dependency of time during process of connections and rotations numbers, for the case when engine power is constant.

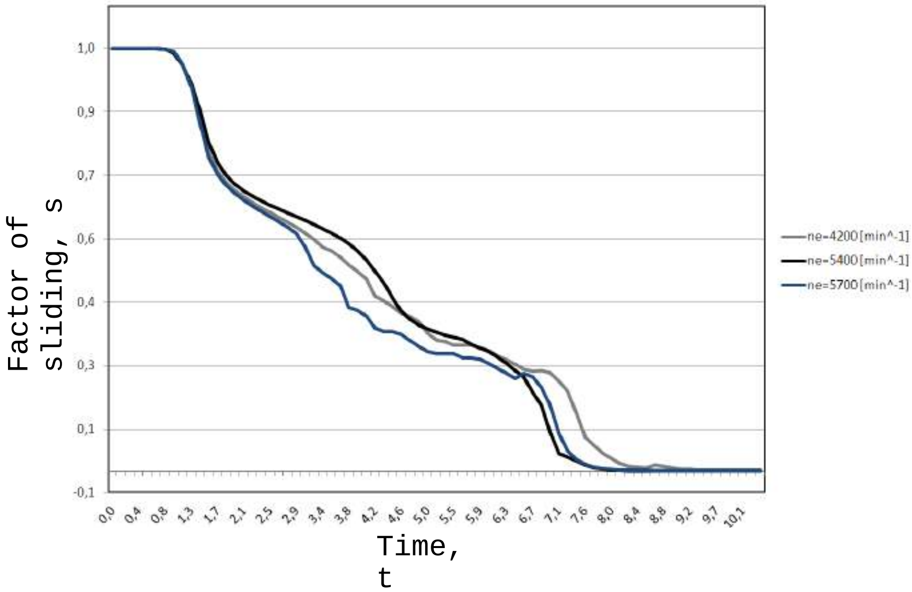

Figure 7. Factor sliding on dependence of time

From figure 7 it can be seen that initially factor sliding has its maximum value, because all the power that is transmitted to the pump circuit is transferred to put into motion the oil, but this happen in short time while the rotating numbers of torque converter circuits are equal, also from curve it can be seen influence of rotations number of engine crankshaft into factor of sliding.
In figure 8 are given curves of efficiency of torque converter during process of connection.

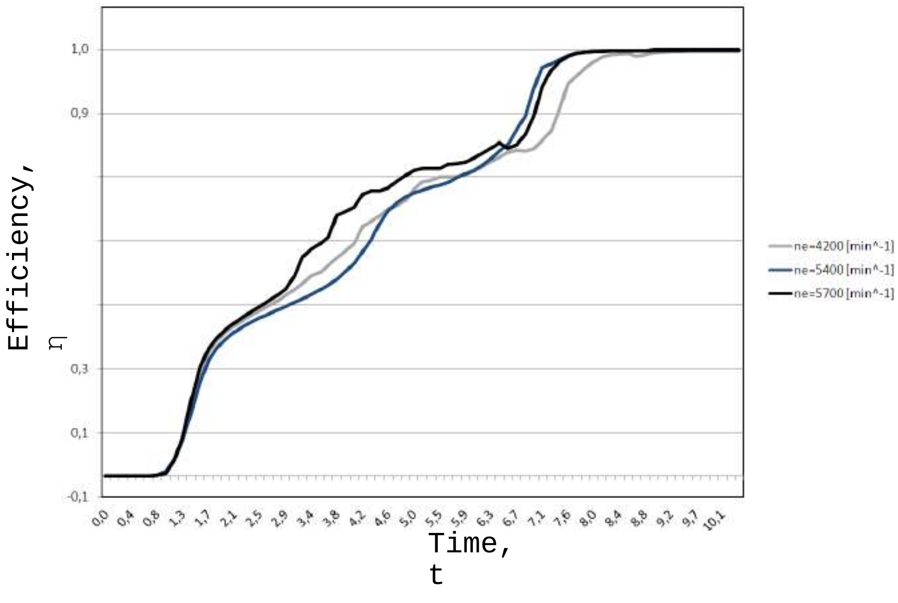

Figure 8. Efficiency on dependency of time

From figure 8 it can be seen that curves of efficiency, for different rotations number, efficiency increases proportionally while factor sliding decreases, so we can say that with the increasing of rotations number, torque converter increases its effectiveness, what reduce power losses.

4. CONCLUSION

According to the paper for torque converter we can concluded that:

- torque converter enables the transfer of power with small losses and convenient arrangement;
- from the presented curves, figure 3 and 6 for transmission ratio can be seen the influence of engine effective power and rotations number. With the increased of power or rotations number it can be reached faster maximum value of transmission ratio;
- large influence on the factor sliding have power and rotations number, with increasing power and rotations number decreases factor sliding,
- the influence of power and rotations number on efficiency can be seen through figures 5 and 8, where its value increases proportionally while factor of sliding decreases.
- in this case we can conclude that two main parameters of engine, power and rotations number have enough large influence of torque converter.

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1st International Scientific Conference on Engineering
”Manufacturing and Advanced Technologies”
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

ANALYSIS OF GEOMETRIC PARAMETERS OF THE ROAD DURING MOVEMENT OF VEHICLE THROUGH ROAD WITH CURVES AND LONGITUDINAL STEEP

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ABSTRACT
In this paper are analyzed geometric parameters of the road during movement of vehicle through road with curves and longitudinal steep. In particular is analyzed the influence of curve radius and longitudinal steep in the movement velocity and vehicle stability. The analysis of these parameters is achieved through PC Crash software, while obtained results are presented through diagrams.Curves obtained through simulation clarify the impact of different velocity of vehicle movement including stability of vehicle.
Keywords: geometric parameters of the road, curve radius, longitudinal steep.

1. INTRODUCTION
During the traffic flow on the road, all of motor vehicles, specially transport vehicles, show their crucial influence on the capacity and level of service, while moving in one way roads. Transport vehicles, looking at the static and dynamic aspect, have a significant difference from passenger vehicles, although the number of these vehicles is much smaller than the number of passenger vehicles, approximately 25%, but their influence directly indicates the general terms of road traffic flow.
On the roads with the slope over 8%, this effect is several times greater because the different velocities and movement between transport vehicles and passenger vehicles are very significant. For this reason, it is necessary to build a separate lane on the way with either straight or curved. Requirement to build special lane for the road traffic flow is determined based on gear-transport vehicles on the road with slope, while the speed of movement of vehicles at the beginning and in the end are determined based on the characteristic curve of the change of gears while driving the road with slope. The driver in practicality does not press the acceleration pedal to the end, even when acceleration is possible, in which case the average peripheral forces usually is 74% [4], which is in accordance with experiences in EU countries.

Table 1. Technical characteristics of the transport vehicles Mercedes Actros 1831

Technical characteristics	
Overall Weight	*180000 [N]*
Characteristic ratio of gearbox transmission i_n	i_1=14.93, i_7=3.39, i_8=2.65, i_9=2.05, i_{10}=1.6, i_{11}=1.28, i_{12}=1
The ration of transmission in differential i_0	i_0=2.533
Maximum velocity, v_{max}	*160 [km/h]*
RPM, n_{max}	*1800*
Maximum power, P_{emax}	*230 [kW]*
Engine torque, T_{emax}	*1800 [min^{-1}]*
Engine torque, T_{emax}	*1530 [N·m]*
The number of rations for maximum moment	*1080 n^{-1}]*

2. TRACTION FORCE

The vehicle traction force is determined through this equation:

$$F_t = \frac{T_e \cdot 30 \cdot i_n \cdot i_o \cdot \eta_p}{r_d} \qquad ...(1)$$

Figure 1 shows the traction forces (F_t) and the ideal forces (F_{id}) depending on the velocity of vehicle.

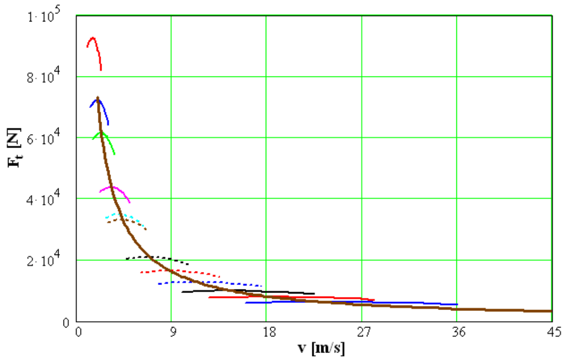

Figure 1.Shows two traction and ideal forces of the vehicle for different radios of the transmission dependent on velocity of vehicle

Ideal force curve was obtained as a result of the estimated use rate of the gas pedal 74% [4]

3. DYNAMIC CHARACTERISTICS

The dynamic characteristic of the vehicle is determined by the equation:

$$D = \frac{F_t - K \cdot A \cdot v^3}{G_p} \qquad ...(2)$$

Dynamic characteristics present the level of the vehicle carrying capability usefulness through equation (2), presented graphically in figure 2.

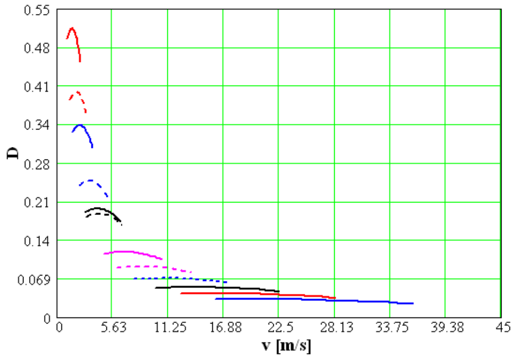

Figure 2. Dynamic characteristics

4. THE SPEED OF MOVEMENT

The speed of movement of vehicle is very important parameter for determining the performance of vehicle, road capacity and level of service. Analysis of the vehicle speed of movement determines road capacity and level of service.

Vehicle speed of movement is determined by the equation:

$$v = v_0 + a \cdot t \qquad ...(3)$$

The travelled way (displacement of vehicle) is given by the expression:

$$s = s_0 + v \cdot t + \frac{1}{2} \cdot a \cdot t^2 \qquad ...(4)$$

The vehicle acceleration is given by the expression:

$$a = D - \psi \qquad ...(6)$$

Where ψ- general coefficient of road

$$\psi = f \cdot \cos\alpha - \sin\alpha \qquad ...(7)$$

Figure 3, present speed curves of vehicle movement for the road with longitudinal steepness u=3%, for two characteristic cases, straight road and curved road R= 100 (m), for transportation vehicles Mercedes 18.31 and 26.40.

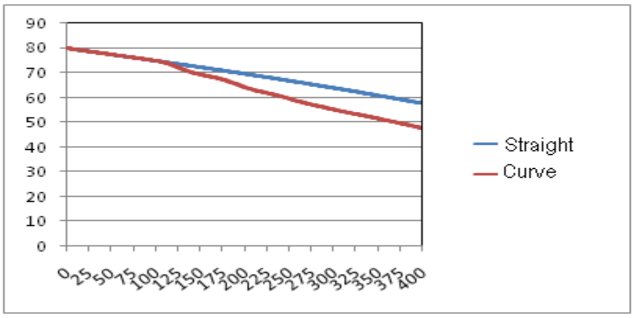

Figure. 3. Change of speed from travelled way

Figure 3, present the variation of speed of vehicle movement for the road, for two cases mentioned above, for the travelled distance. This change comes as a result of the impact of longitudinal steepness, and direct from sloping resistance. Furthermore, in other velocity curves, which were obtain as a result of the movement of vehicles on the road with except longitudinal steepness, has also curve, and the change of speed of movement is even more emphatic for the fact, that the influence of centrifugal force and the adaption of movement to road conditions has influenced this change be so great.

In Figure.4 are presented speed curves of vehicle movement for the travelled way with longitudinal steepness u=5%, for two characteristic cases, straight road and curve road R= 100 (m) for transportation vehicles Mercedes 18.31.

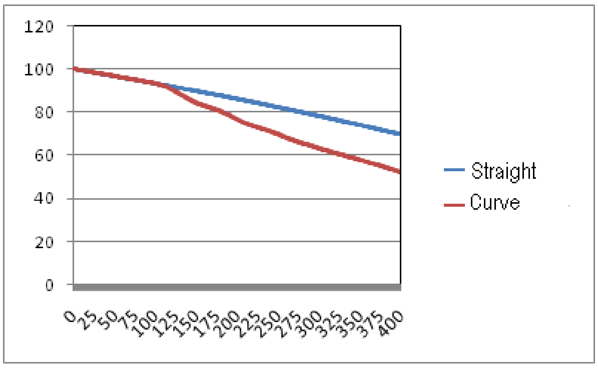

Figure. 4. Changes in speed for the travelled distance

Also, as shown in Figure 4, even with the increase road longitudinal slope, the speed of movement of the vehicle is changing, although the initial speed of movement of the vehicle is v=100 [km/h]. If the curve is initially analyzed, the values do not change, because the first part of the road is straight, but in case when curved of road starts, then the difference is more significant.

In Figure 5 are presented speed curves of vehicle movement in the length of the curve road with radius R=100 [m] and for two different values of longitudinal slope with initial speed of v=80 [km/h].

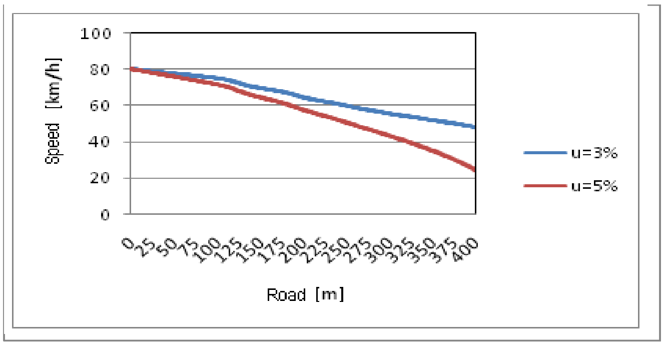

Figure. 5. Changes in speed for the travelled distance

Figure 6 show the curves of the speed of the vehicles in the road with radius of curvature R=100 [m] and that for two values of the longitudinal slope of the road with initial speed of v=100 [km/h].

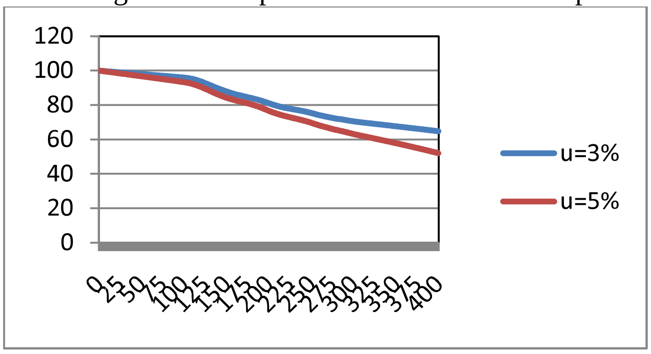

Figure 6. Changes in speed for the travelled distance

By analyzing the diagram curves, shown on Figures 5 and 6, we can conclude that: during the movement the vehicle through the curved road and sloped road, the difference of the velocity is greater. Moving the vehicles through curved and sloped road, is a specific concern, because the engine changes on its working regime. In that case the influence of the driver is very important factor during movement on those conditions.

5. CONCLUSION

By analyzing, Figures 5 and 6, the influence of the initial velocity is shown in the case when initial velocity is greater and the difference is smaller. Based on the analyzed values, when the initial velocity is 80 km/h, the difference is greater than in case when the initial velocity is 100 km/h. Based on this we can note that moving on road with slope (in the beginning of the slope) with higher moving velocity it directly and positively influences the flow conditions, but we need to take in consideration also the safety.

The difference of the velocity depending from distance past through that road, can't be analyzed only by the dynamic characteristics of the vehicles, because on those conditions the influence of the driver is the main factor.

Important factor which influence in the difference of velocity between two cases is the weight of the vehicle.

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1st International Scientific Conference on Engineering
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MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

DETERMINATION OF ADJUSTING CONTROL FORMULA OF GRINDING DEVICE OF HELICAL SURFACES

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ABSTRACT:
The paper presents the functioning principle of a device for grinding helical face surfaces of cutting tools, adaptable for surface grinding machines, as well as the adjustment formula for the device.
Keywords: helical movement, adjustment formula.

The helical movement is a composed movement consisting in a rotation around the fixed axis V, simultaneously with a translation movement, parallel with this axis. We have the helical movement (V, ω, p). We take V on axis Oz, of a Cartesian coordinates system (Fig.1). The rotation angle φ and the travel h, can be seen in figure 1, defining the helical movement of point M, with the following relations

$$\frac{d\varphi}{dt} = \omega; \qquad ...(1)$$

$$\frac{dh}{dt} = u, \qquad ...(2)$$

where, ω represents the angular speed, respectively, u, the travelling speed, of point M, in the helical movement (Fig.1).
We define the helical parameter by the ratio:

$$p = \frac{u}{\omega} = const. \qquad ...(3)$$

If point M, in its helical movement makes a complete rotation, then we have the relation:

$$H_f = 2 \cdot \pi \cdot p, \qquad ...(4)$$

where, H_f is the pitch of the helical movement.

The helical movement is named right-helical movement, if the directions of $\bar{\omega}$ and $\bar{u}$ are the same and left-helical, if the directions of $\bar{\omega}$ and $\bar{u}$ are opposed.

Radius vector $\bar{r}$ of point $M(x, y, z)$, in its helical movement, is defined as follows (Fig. 1)

$$\left.\begin{aligned} \overline{OP} &= a\bar{e}(\varphi), \\ \overline{PM} &= h\bar{k} \\ \bar{r} &= a\bar{e}(\varphi) + h\bar{k} \end{aligned}\right\} \quad ...(5)$$

where versors, $\bar{e}$ and $\bar{k}$, are represented in figure 1.

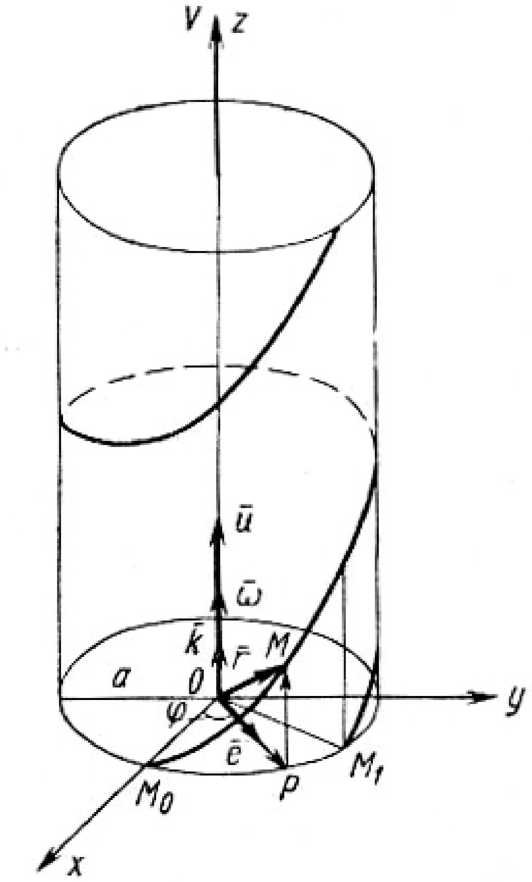


Fig. 1 Illustration of the helical movement of point M

In the simplest case $h = u \cdot t,\ u = p \cdot \omega,$ the vector equation of the normal helical line has the form:

$$\left.\begin{aligned} \bar{r} &= a \cdot \bar{e}(\omega \cdot t) + u \cdot t \cdot \bar{k} \\ &\textit{sau} \\ \bar{r} &= a \cdot \bar{e}(\varphi) + p \cdot \varphi \cdot \bar{k} \\ &\textit{sau} \\ \bar{r} &= \bar{i} \cdot a \cdot \cos\varphi + \bar{j} \cdot a \cdot \sin\varphi + \bar{k} \cdot p \cdot \varphi \end{aligned}\right\} \quad ...(6)$$

The parametric equations of the helical line have the form:

$$x = a\cos\varphi;$$
$$y = a\sin\varphi; \quad ...(7)$$

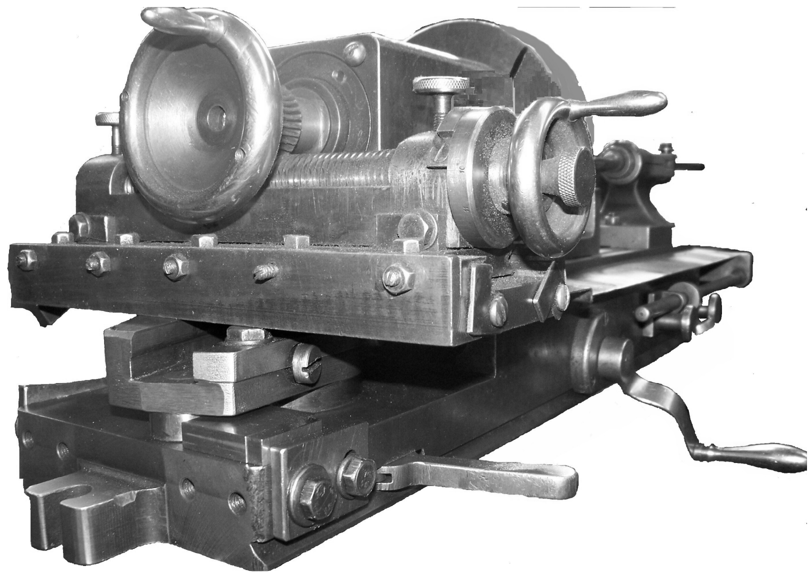
$$z = p\varphi$$

Generating this movement is necessary for grinding the helical surfaces when sharpening the cutting tools. The proper sharpening of cutting tools determines their performance and operating life. Companies specialized in the field manufacture cutting tools for which the face surface pitch is indicated with a precision of two decimals. This can be seen in figure 2, where tools produced by the English company Clarkson are shown.

Fig. 2 Several milling tools, produced by the English company Clarkson, where the pitches of the face surfaces (sharpening) with a precision of two decimals are engraved.

These tools are used for operations carried out on CNC machines. In order to reset the initial geometrical parameters, the worn-out tools will be re-sharpened. For this purpose, special sharpening devices have been created, adaptable for surface grinding machines. Sharpening machines have been conceived: conventional or CNC, by some renowned companies. We continue by presenting a device for grinding helical surfaces, made at S.C. Uzina Mecanică Cugir S.A.- Romania, which exists in the Tool Making Department (Fig.3).

According to the cinematic diagram [Fig. 3,(b)], the tool, (5), which is about to be sharpened, is assembled between the points, (2). Through the crank (1), the longitudinal slide (15), of the device is driven in a movement of translation, moving also the bar slide guide, (3), adjusted at angle γ_w. The bar slide, (16), interdependent with the transverse slide, due to the longitudinal travel of the bar slide guide, (3), will move the transverse slide, (11), and at the same time the worm (17), which gears to the worm gear (18). As a consequence the worm (17), will rotate the worm gear, (18), and at the same time the tool (5), and thus the movements of travelling and rotation combine, resulting in the helical movement. With the plate, (14) we can make the divisions so as to sharpen all the tool's teeth.



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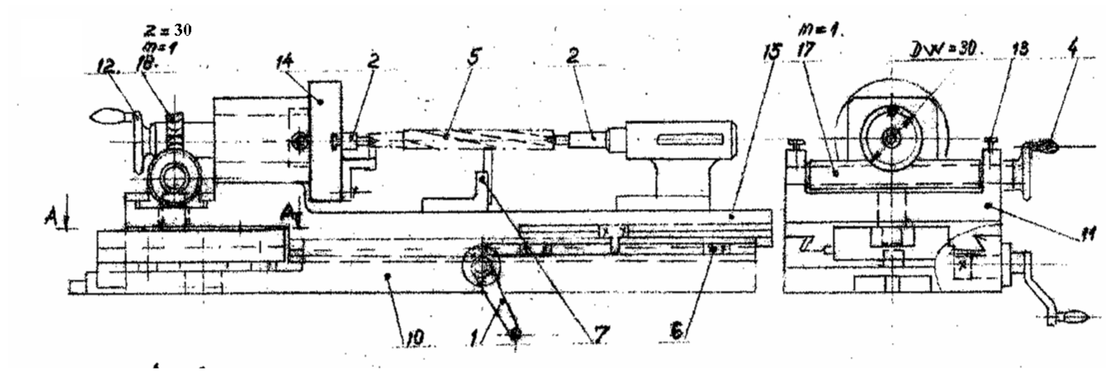
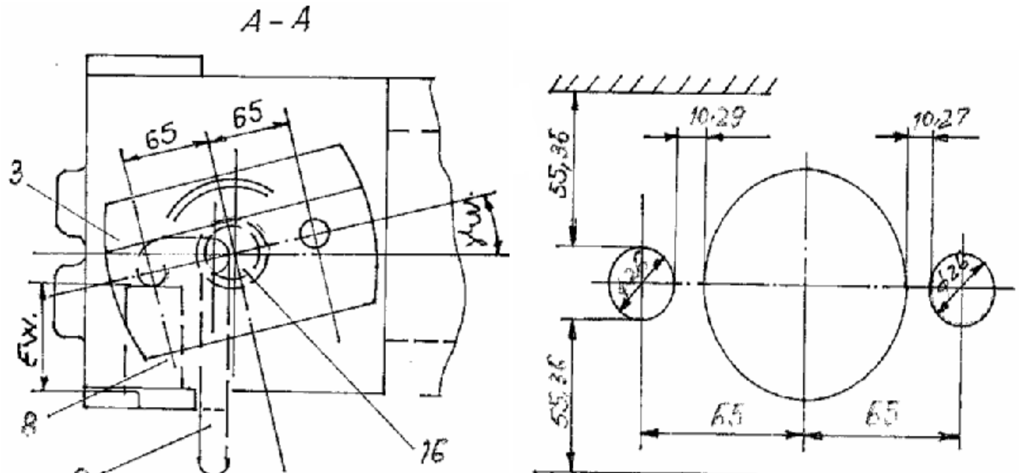


b



c

Fig.3: Device for grinding helical surfaces: (a) overview; (b) cinematic diagram; (c) adjustment of the helical pitch with the principle of the sinus rule:1-crank; 2-points; 3-bar slide guide; 4- handwheel with graduated drum; 5-the tool to be sharpened; 6-back stop;7-tool support; 9-blocking crank of the bar slide guide;10-bed; 11-transverse slide; 12-handwheel with graduated drum; 13-screw for blocking the worm; 14-plate with division system;15-longitudinal slide; 16-bar slide; 17-worm; 18-worm gear

Through the handwheel, (4), having a graduated drum, we can adjust the cutting depth when the tool is sharpened.
The pitch of the helical surface of the tool to be sharpened, H_f, is made through adjusting the cutting angle, γ_w, of the bar slide guide, (3). The worm, (17), has the axial module $m = 1 \quad mm$, and the worm gear, that gears to the worm, has the number of teeth $z = 30$. As a consequence the roll diameter of the worm gear is

$$d_w = m \cdot z = 1 \cdot 30 = 30 \quad mm. \qquad ...(8)$$

The worm, (17), gears to the worm gear (18), similarly to a rack and pinion, thus ensuring the rotation component of the helical movement. Obviously, the translation component of the helical movement will result from the longitudinal movement of the slide, (15).
The relation between the pitch of the helical surface, H_f, and the cutting angle of the bar slide guide, (3), is as follows:

$$ctg\gamma_w = \frac{H_f}{\pi \cdot d_w}. \qquad ...(9)$$

The adjustment angle, γ_w, of the bar slide guide (3), [Fig.3 (b)], is adjusted using the sinus rule principle, by taking into account the device construction [Fig.3 (c)], resulting the following adjustment formula

$$E_w = 55,36 + 65,6 \cdot \sin\gamma_w. \qquad ...(10)$$

Through the adjustment formula (10) the calculated Jo-blocks package, E_w, ensures the carrying out of the pitch, H_f, of the helical surface to be generated with the device presented.
We continue by presenting a case study regarding the adjustment of the device with the purpose of sharpening the face surface of a cylindrical front mill presented in figure 2 (bottom of the figure)
As we can notice the pitch of the helical front surface has its value engraved on the part where the tool is gripped, i.e.:

$$H_f = 77,72 \quad mm.$$

We use formula (9) to calculate the adjustment angle of the bar slide guide, (3), as follows:

$$\gamma_w = arcctg\left(\frac{77,72}{\pi \cdot 30}\right) = 50^0 29' 23,4''$$

The bar slide guide, (3), will incline based on the sinus rule principle at the angle $\gamma_w = 50^0 29' 23,4''$.
For this purpose we will use the adjustment formula (10) i.e.:

$$E_w = 55,36 + 65,6 \cdot \sin 50^0 29' 23,4'' = 105,9711678 \quad mm..$$

We will make a Jo-Blocks package with the value:

$$E_w = 105,971 \quad mm,$$

which will be installed as we can notice in figure 3 (c), in the place marked E_w.
To conclude,

- the device described in the paper can be adapted to surface grinding machines, with the purpose of sharpening cutting tools ;

- the construction of the device allows the accurate sharpening of tools meant to be used on CNC machines;
- the adjustment of the sharpening helical surface pitch through sinus rule, using a Jo-Blocks package, ensures high precision without operator's special effort;
- the device described in the paper can be used to control the helical surfaces with the purpose of determining the pitch H_f

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

VALUE STREAM MAPPING CONCEPT AND AN APPLICATION IN IRON AND STEEL PLANT

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ABSTRACT
The main aim of the companies are perpetuating their existence and obtaining profit. To do this, companies need to respond the customer needs, provide high quality products in fewer prices to adapt themselves to both the domestic and global competitive environment. Lean manufacturing helps forming the work flow by determining the waste and provide advantage in the global competitive environment. Decreasing the costs by reducing the wastes helps increasing the profits. By this general aim, lean production approach which is first implemented by Japan automotive corporation Toyota Motor Company has also recognized by the American automotive corporations and the other companies till today. The value on the chosen product's work flow helps determining the waste which is the basic of lean manufacturing. If product is added value by a factor, that factor is defined "value"; otherwise it is "waste". Value Stream Mapping which is one of the Lean Manufacturing techniques determine the product's process, determine the factors associated with process, analyze the process and factors, determine the waste and source of the waste.
In this paper, Lean Manufacturing is researched on; Value Stream Mapping concept and executing of Value Stream Mapping are explained. In the implementation section, Coil Value Stream Mapping is formed, the information of the flow is analyzed and suggested improvements are presented.
Key Words: Value Stream Mapping, Value, Lean Manufacturing.

1. INTRODUCTION
Lean manufacturing characterize all the things which do not add value to product as "waste" and try to eliminate it. All the things which do not modify production physically are accepted as waste [1]**.** According to Ohno (1988), there are 7 fatal wastes in the production systems [4]. They are; overproduction, waiting, transportation, unnecessary operations, unnecessary storage, unnecessary movements and defective production. Lean Manufacturing provides some tools and techniques to remove the mentioned wastes. The first stage to enter Lean Manufacturing system in a company is analysing the value stream which is comprised of values and wastes. Then the activities which do not add value must be eliminated [7].

Value Stream Mapping comes first in the techniques which help modeling the value streams. Value Stream Mapping is a mapping technique which is used modeling the material and information streams in the supply chain [6]. The main purpose of the Value Stram Mapping is determining the wastes in the value stream and setting the stages to eliminate these wastes. Value Stram Mapping is a technique which provide to set Lean Methods will be used in which part of the value stream.

Value Stream Mapping is a technique whic uses standard sembols. Value Stream Mapping provides the benefits below seperated from the other mapping techniques;

- Generates a base for Lean Applications,
- Associates the supply chain,
- Displays both material and information streams,
- Establishes a connection between production planning, production scheduling and shop controling.

The main purpose of this paper is mapping the value stream in the supply chain in a company by using Value Stream Mapping; determining the wastes and generating a plan to eliminate the wastes.

2. LEAN PRODUCTION

Lean Manufacturing is a production system which is better, faster, and cheaper and needs less area, less design and labor hour; which gets rid of the waste implementations [3].

2.1. Value Stream Mapping

Value Stream Mapping is a method to see value, wastes and waste sources, and to revive consideration of more than a single process. Value Stream Mapping requires working at not only a single process, on the larger image, and requires improving the totality [6]. The main rationale of Value Stream Mapping is reducing the operational subjects to some products level which is understood by managers [2]. Value Stream Mapping can be a planning tool, an education tool and the process of change tool.Value Stream Mapping is started by selecting of the product family. Current case map is drawn. It provides informations to design future case map. Changings in the current and future cases interact each other. The last step is preparing implementation plan and apply it [6].

3. VALUE STREAM MAPPING IN AN INTEGRATED IRON-STEEL COMPANY

Community facilities where producing is carried out in multiple facilities which complete each other are called as “Integrated Facilities”. Integrated Facility where the implementation was done in is a large-scale copmany which produces iron and steel products. The stream of coil is shown in figure 1 which is made by block;

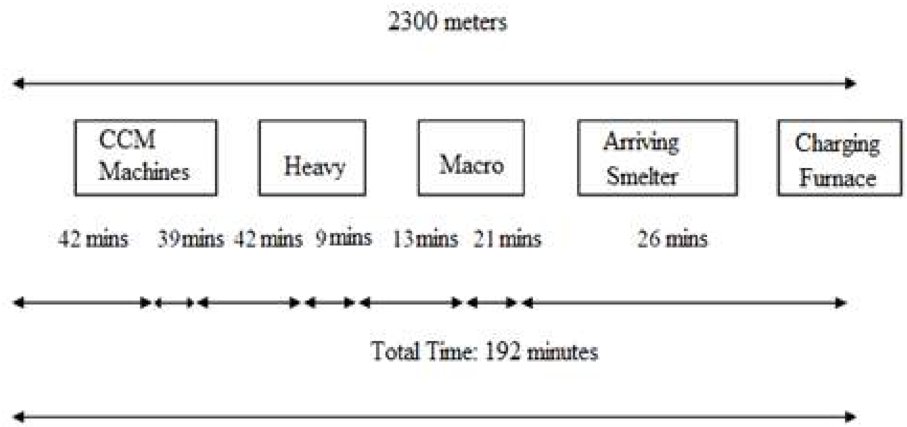

Figure 1. The way of the coil along the process

3.1. Analysing Current State

In this case, Current State of the company will be analysed and only coil product family will be considered. In this stage, the symbols and the steps below are applied [5].

Step 1. The icons which symbolize customer, supplier and produce management are drawn.

Step 2. It is required that an info box is drawn below the icon of customer and demands of customer are written in that box in this step. So that required informations about companies work system were collected and necessary calculations were made;

Working Time: There are 20 workdays in a month. Production continues 24 hours and 3 shifts. Each shifts continue 8 hours and there are two 10 minutes and an hour lunch break.

- Minutes/Day=24x60=1440 minutes
- Breaks=(3x60)+(3x2x10)=240 minutes
- Net Production Time(Net operating time)=1440-240=1200 minutes

Customer Demands: Avarage daily demands; 208 ton/day via railway, 597 ton/day via seaway and 605 ton/day via roadway.

- Daily Demand= 208+597+605=1807 ton/day
- Tact Time = Daily net operating time / Daily Net Demand = (1200x60)/1807 = 39,8 s / ton

Step 3. Shipping and purchasing informations were written on current state map. Truck, ship and train symbols are drawn upper shipping symbols which were drawn from supplier to factory and from factory to customer. And shipping frequencies are written upper of these symbols. Shipping from suppliers has different frequencies but company generally has daily shipping.

Step 4. Production processes are drawn downside of the paper as first process is on left and last process is on right. Info boxes for processes are drawn under process box and there must be spaces between process boxes to write inventory information.

Step 5. Info boxes under process boxes are filled with process information. Information in the info boxes are summarized in table 1. **Production Processes:** Company's processes for coil are sintering, obtaining liquid iron (blast furnaces), sulfur removal, converters, ladle metallurgy, file dump and producing coil.

Table 1. Data relating to the manufacturing process

Process Parameters	Sintering	Blast Furnaces	Sulfur Removal	Converters	Ladle Metallurgy	File Dump	Coil Rolling
Net Operating Time (s/day)	72000	72000	72000	72000	72000	72000	72000
Cycle Time(s/ton)	5,6	8,1	4,3	4,6	3,9	10	38,3
Preparing Time (min)	0	0	0	0	0	240	239
Operating Time (%)	100	100	100	100	100	80	80
Employee(piece)	234	235	48	102	83	130	98
Shift	3	3	3	3	3	3	3
Storage (ton)	2928	2826,1	300	300	450	300	249,1

Step 6. Production Management's information streams between supplier, customer and processes are shown on the map. Forecest and demand frequences are written upper information streams. Production Management makes deals with suppliers, demands for years are sent to suppliers and monthly certain demands are ordered. Because of the variation of the company's customer, company is demanded frequently. So that production management prepares sale forecasts and prepares the daily production plans.

Step 7. There are inventories between the processes so that inventory symbols are drawn between process boxes. Inventory amounts are written under inventory symbols.

Step 8. Pushing System is proceeded in the company and this stream system is shown in the figure 2.

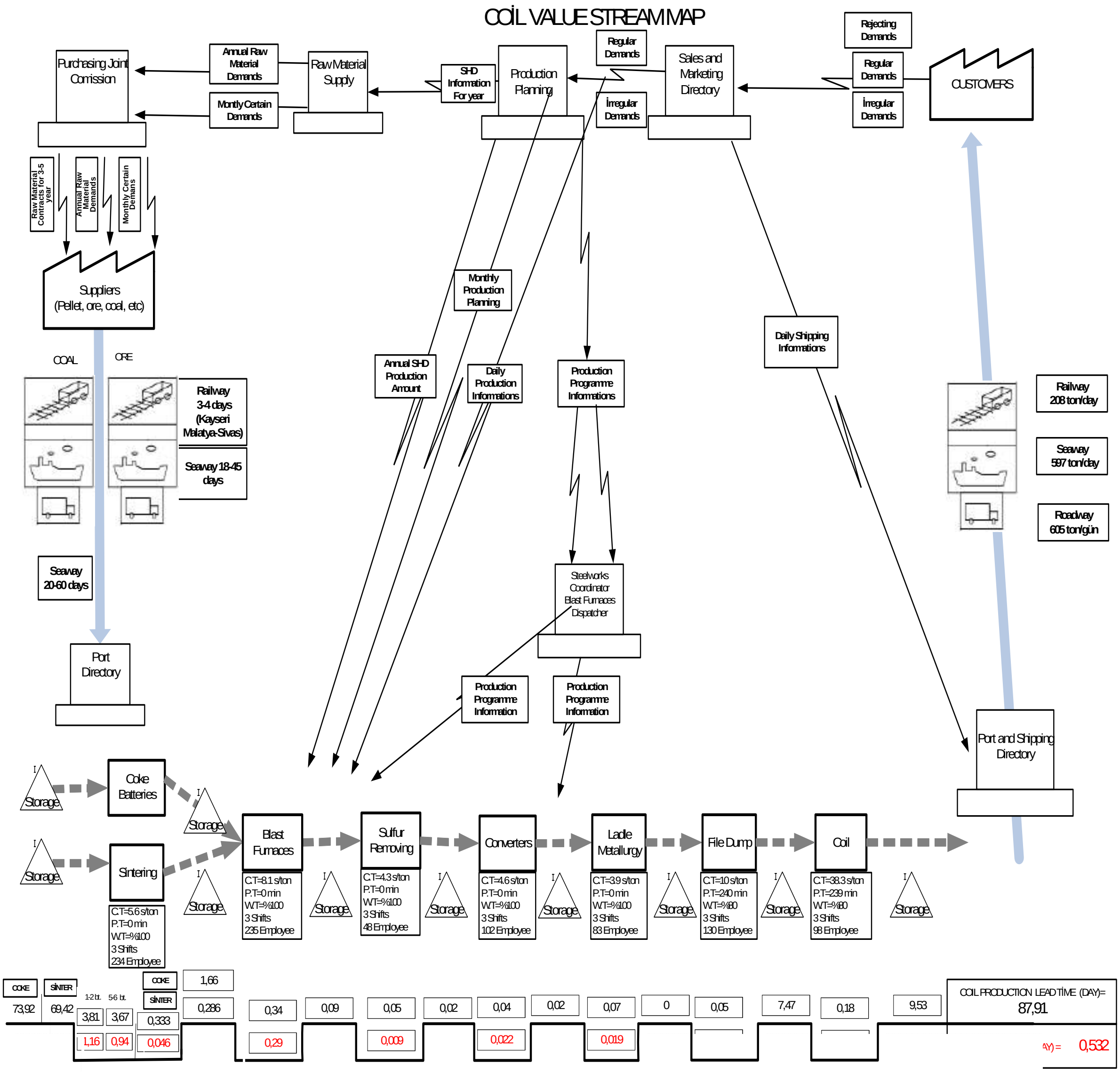

Figure 2. Coil Current State Value Stream

3.2. Future State Mapping Reviews

To speculate about the Future State, examining the Current State is required. When we look the coil production process, we see that operations which coil has are done in different, big factories. The large scale of the implementation must be considered when designing the future state.

When Current State Map is examined, it is seen that the value added time in the process is 0,532 day and the lead time is 87,91 days. So that the %99,3 of the operations are formed from the nonvalue added operations, wastes. Future State Map must be done to eliminate these waste operations. Reviews below were down by examining the Current State;

- Cause of the storages between the manufacturing processes is the large scaled transfering part of batch size.
- According to company's plan of existing settlement, transporting distances between manufacturing processes are long and it makes large batch sizes.
- Providing the stream between manufacturing processes will help eliminating the storages waiting between processes.
- In the Current State, shipping from the suppliers are 18-45 days and 20-60 days via seaway, railway and roadway. Causes of the long shipping times, storages are large and this generates nonvalue added times. Storage times so that nonvalue added times can be reduced by increasing the frequency of shipping and etc.
- Via same idea above, storages between processes and factories can be reduced and nonvalue added times can be reduced.

When we look at the Current State, cycle times, production lead times and nonvalue added times in the factories are different. The reasons of it are processing the production steps in different factories and and failing to handle processes one by one because of the very large scale of the company. Large scale of the company blocked us about examinig the factories one by one and mapping the current state. What to do about this subject, generating the current state maps of the factories one by one and examine them to analyse the problems in the factories of company.

Examining the factories of company was not done because of the disadvantages which were mentioned above, and Future State Map was not drawn because of superfacial assessments about the Current State.

But improvements are carried out to eliminate wastes and nonvalue added operations by doing kaizen and using the proposal system in the company. There is a Kaizen implemantation to eliminate wastes below. This and similar implementations will help to generate the Future State Map of the company.

3.3. A Focused Kaizen Example

Step 1: Topic Selection; Improvement of the sofa warehous of Automation and Electricity Management.

Step 2: Determining the Target; %15 reduction about unregistered materials (extra, scrap, sale pending)

Step 3: Establishing the Team

Step 4: Understanding of the Present Situation

Step 5: Generating Project Plan

Step 6: Analysing; Causes of the wastes and unnecessary storages are analysed.

Step 7: Implementations; Realization implementations of improvements. Platinium scrap from the warehouse;

- Can be used by Quality Metallurgy Management. 4000 gr of that scrap was delivered.
- Rest of the scrap was sold.
- Redundant materials are returned to the central warehouse.
- Unregistered and temporary materials will not be accepted to the sofa warehouse anymore.
- Warehouse software will be done by Software Management for sofa warehouse.

Step 8: Realization and Gains

- Electronic Scraps: 26 600 Kg x 0.78= 20 748 TL=13 832 $
- Platin Scrap Using: 4000 gr = 80 000 TL=53 333 $
- Platin Scrap Selling: 4808 gr = 96 000 TL=64 000 $
- Total Gains: 196.748 TL=131 165 $
- Scrap Selling: 70 m²,
- Returning unregistered and redundant materials: 80 m²
- Total Gains: 150 m²

Step 9: Standardization; Implemented methods and works are standardizated.

Step 10: Dissemination; Methods which were used in this department will be used in the other departments of the company.

4. CONCLUSION

Value Stream Mapping is a mapping technique which is used modeling the material and information streams in the supply chain. The main purpose of the Value Stram Mapping is determining the wastes in the value stream and setting the stages to eliminate these wastes. Value Stram Mapping is a technique which provide to set Lean Methods will be used in which part of the value stream. In the last part Value Stream Mapping method was implemented in an integrated iron-steel company. These suggestions are offered by examining the current state;

Cause of the storages between the manufacturing processes is the large scaled transfering part of batch size. According to company's plan of existing settlement, transporting distances between manufacturing processes are long and it makes large batch sizes. Providing the stream between manufacturing processes will help eliminating the storages waiting between processes. In the Current State, shipping from the suppliers are 18-45 days and 20-60 days via seaway, railway and roadway. Causes of the long shipping times, storages are large and this generates nonvalue added times. Storage times so that nonvalue added times can be reduced by increasing the frequency of shipping.

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1st International Scientific Conference on Engineering
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MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

LOCATION FOR SETTLEMENT OF CENTRAL PLATFORM FOR ROTOR EXCAVATOR REPAIR SRs-1300, SRs-650

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ABSTRACT

Considering that the Republic of Kosovo has a small surface of its territory by the economical aspect, however there are concentrated energetically resources of the Balkan and European row.
Surface exploitation of useful minerals without any doubt represents an easy way of the exploitation with a lower cost in report to the underground exploitation, but very often during the exercise of mineral activity appear problems for intervention and repair of rotor excavators in mines.
According to the requirements of the company are done additional researches inside the mine as in the aspect geological-engineering basing lit logical description of the drilling, and getting of samples for laboratorial analyses which will be done with equipments of the most sophisticated technology with two tests, beginning from the tri axial test and direct shearing considering even statistical processing for obtaining more real parameters in the location wherein the excavators will be placed for their repair from the technological and geotechnical aspect.
In this context this work has to do with problems of this field which are occurred as a sequence of deformation (the damage of bearings, change of engines, lubrication against corrosion etc.).
Keywords: repair, rotor excavator, central platform, deformation.

1. INTRODUCTION

The territory of Kosovo is quite rich with natural resources that have a great strategically importance for the development of various industrial fields and economy of the country, to exploit the coal in the most rational way, anyhow it was necessary to intervene in technological equipments in order to operate more than 30 years in this mine. For their rehabilitation it is located the site as in fig 2 in order to substitute the bearings, lines , metallic spare parts, which is the purpose of this work.
In order to achieve the determined goal it was necessary to be done nine drillings in a depth of up to 15 m with symbol (G_{-1}-G_{-9})with drilling coordinates (table.1) location wherein is done the research is shown nearby the surface mine in Bardhe and Mirash in(figure. 1) whereas in (figure 2), [1,9]. Software program surfer 8 By analyzing a number of samples for analysis of physical-mechanical properties according to the various depths that are shown in tables (2). The purpose and importance of the study in this work is the obtaining of physical-mechanical parameters for repair of excavators, (table.4).

2. METHOD AND RESULTS

Laboratorial analysis, determination of physical-mechanical parameters for rotor excavators repairing SRs-1300, in the location wherein are done geological- geo mechanical drillings, and are taken

Figure.1 Geographical position of the location for excavators repair.

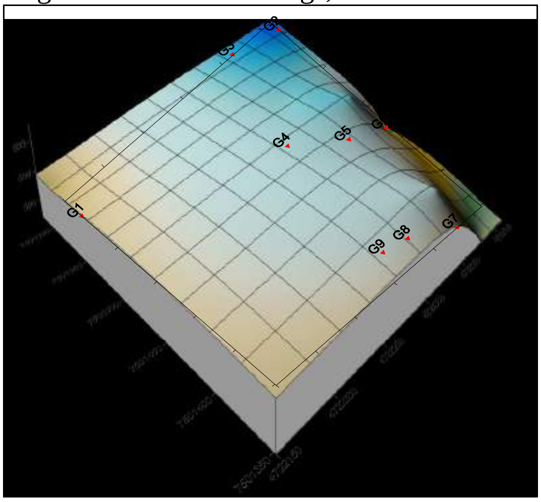

Figure. 2. Location for excavators repairing

Figure 3. Photo, the settlement of excavator for repairing

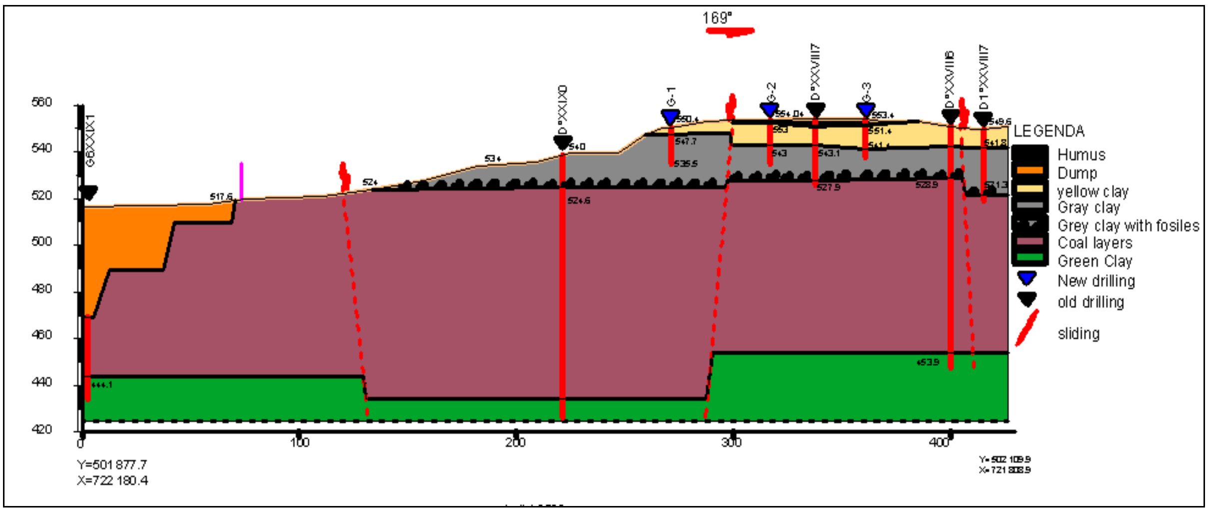

Figure 4. Longitudinal profile

the samples for physical-mechanical features analyze, [3,6,7] and are determined the following parameters :

- Natural humidity W[%]
- Volume weight γ [kN/m^3]
- Specific weight γ_s [kN/m^3].
- Granule metric content
- Atterberg' s borders in consistence W_r, Wp, Ip, Ic and I_r.
- porosity (n) and porosity coefficient (e)
- Internal friction angle (φ) and cohesion (C)
- Tri axial test
- Direct shear test
- Module of elasticity E_N [kN/m^2]

Table. 1. Drilling coordinates

Drilling	Coordinates X	Y	Z
G-1	4722149.9	7501594.9	595.6
G-2	4722411.4	7501606.15	599.1
G-3	4722363.8	7501617.2	598.5
G-4	4722332.1	7501515.23	597.9
G-5	4722376	7501481.05	598.1
G-6	4722408.3	7501465.9	595.2
G-7	4722380.5	7501348.3	592.7
G-8	4722341	7501371.23	597
G-9	4722314.9	7501376.7	597.2

2.1. Natural humidity

The specification of the humidity content in natural state is done according to this formula.1.

$$W = \frac{G_1 - G_2}{G_2 - G} 100\% \qquad \dots(1)$$

The obtained values are in these limits;
Yellow clay W=25.1-43.77 %
Grey clay W=33.45-40.90%

2.2. Volume weight

Volume weight is calculated according to formula 2:

$$\gamma = \frac{G}{V}, [\frac{kN}{m^3}] \qquad ...(2)$$

In the same way by drying the sample is specified volume weight of the earth in dried state according to the formula 3:

$$\gamma_t = \frac{G_t}{V}, [\frac{kN}{m^3}] \qquad \dots(3)$$

The obtained values are in these limits;

Yellow clay γ=16.32-18.73 [kN/m^3],
γ_t=19.69-14.82 [kN/m^3],
Grey clay γ=17.13-18.36 [kN/m^3],
γ_t=12.16-13.61 [kN/m^3],

Results for each analyzed sample are shown in (table .2).

Table 2. Obtained results for humidity and volume weight

Ordinal. nr	**Sample**	**Weight of humidity sample W [gr]**	**Dry sample weight Ws [gr]**	**Weight of water [gr]**	**Volume of the cylinder V [cm3]**	**Volume weight of humidity sample γ=W/V [kN/m3]**	**Volume weight of dried sample γt=Ws/V[kN/m3**	**Water content Ww/Ws*100(%)**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	**G-1** 2.00-3.00	787.9	574.8	210.1	444	17.68	112.95	39.55
2	7.00-8.00	799	583.1	215.9	444	18.00	13.13	37.03
3	13.00-14.00	778.5	571.5	207	444	17.53	12.87	36.22
4	**G-2** 2.00-3.00	772.5	545.3	227.2	444	17.40	12.28	41.67
5	7.00-8.00	779.7	549.5	230.2	444	17.56	12.38	41.89
6	13.00-14.00	792	570.2	221.8	444	17.84	12.38	41.67
7	**G-3** 3.00-4.00	784.9	575.4	209.3	444	17.68	12.96	36.41
8	7.00-8.00	785.4	572.2	213.2	444	17.69	12.89	37.26
9	13.00-14.00	815	604.5	210.5	444	18.36	13.61	34.82
10	**G-4** 2.00-3.00	784	560	224.5	444	17.67	12.61	40.09
11	7.00-8.00	780	554.3	225.7	444	17.67	12.48	40.72
12	13.00-14.00	776	580.1	195.9	444	17.48	13.07	33.72
13	**G-5** 2.00-3.00	797.5	581.1	216.4	444	17.96	13.09	37.24
14	7.00-8.00	776.7	576.4	200.3	444	17.49	12.98	34.75
15	13.00-14.00	783.7	585.3	198.4	444	17.65	13.18	33.90
16	17.00-18.00	782.8	586.9	196.2	444	17.63	13.21	33.45
17	**G-6** 2.00-3.00	779.6	549.2	230.4	444	17.56	12.37	41.95
18	7.00-8.00	767.9	534.1	233.8	444	17.30	12.03	43.77
19	13.00-14.00	760.7	539.9	220.8	444	17.13	12.16	40.90
20	**G-7** 2.00-3.00	758.4	547.6	210.8	444	17.08	12.33	38.50
21	8.00-9.00	831.8	635.8	196	444	18.73	14.32	30.83
22	**G-8** 2.00-3.00	724.4	519.1	205.3	444	16.32	11.69	39.55
23	7.00-8.00	810	616.2	193.8	444	18.24	13.88	31.45
24	13.00-14.00	823.2	657.9	165.3	444	18.54	14.82	25.13
25	**G-9** 2.00-3.00	782.7	555.1	227.6	444	17.63	12.50	41.00
26	7.00-8.00	836.3	650.3	186	444	18.84	14.65	28.60
27	14.00-15.00	812.8	617.2	195.6	444	18.32	13.90	31.69

2.3. Specific weight

Specific weight is calculated according to formula 4

$$\gamma_s = \frac{g}{(g_2 + g) - g_1}, [\frac{kN}{m^3}] \quad \ldots (4)$$

The obtained values are in these limits;

Yellow clay γ_s=25.91-26.81 [kN/m^3],

Grey clay γ_s=25.86-26.85 [kN/m^3].

3. GRANULE METRIC CONTENT

This method is based in physics laws, wherein the granules with different sizes but with the same volume weight, they have different speed in water sinking . The speed of sinking in water as the function of granules diameter is given by Stocks , according to the expression 5:

$$v = \frac{2(\gamma_s - \gamma_w)}{9 \cdot \rho} \left(\frac{D}{2}\right)^2 \left[\frac{cm}{\sec}\right] \quad \ldots(5)$$

4. ATTERBERG' S BORDERS IN CONSISTENCE

In the engineering practice there are used two the most famous limits of plasticity as the top limit (or liquid limit) and bottom limit (or of plasticity),according to formula 6,7,8 Bozo L, (2007)

Plasticity index $I_p = W_L - W_p$ …(6)

Limit index $I_L = (W - W_p)/I_p$ …(7)

Consistency index $Ic = (W_L - W)/ I_p$ …(8)

5. POROSITI (n) AND POROSITY COEFFICIENT(e)

The specification of these parameters is done according to the obtained results in laboratorial analysis, where is specified the volume weight of the sample in dried state and specific weight.

Porosity (n) is specified according to formulas (9,10,11):

$$n = \frac{Vp}{V} = \frac{V - Vt}{V} = \left[1 - \frac{Wt}{\gamma_s V}\right] \quad \ldots(9)$$

$$\frac{W_t}{V} = \gamma_t \; n = \left(1 - \frac{\gamma_t}{\gamma_s}\right) \quad \ldots (10)$$

Porosity coefficient (e):

$$e = \frac{\gamma_s (W - Wt)}{\gamma_w Wt} \quad \ldots(11)$$

According to the calculations the porosity is in these limits:

n=44.17-55.04 [%]

e =0.791-1.27

6. MODULE OF ELASTICITY

Module value of elasticity is specified according to the expression 12:

$$E_N = \frac{\Delta\sigma}{\Delta \frac{\Delta h}{h}}, \left[\frac{kN}{m^2}\right] \quad \ldots(12)$$

σ -relative loading [kN/m^2]; $\Delta_{h'/h}$- relative compression

Figure 5. Modules of Elasticity

Table 3. Obtained results from elasticity Module

for yellow clay	σ =100 [kN/m^2]	E_N= 1424.40 – 6225.00 [kN/m^2]
	σ =200 [kN/m^2]	E_N = 2439.00 – 7142.86 [kN/m^2]
	σ =400 [kN/m^2]	E_N = 2985.00 – 9523.81 [kN/m^2]
grey clay	σ =100 [kN/m^2]	E_N= 2325.60 – 6451.61 [kN/m^2]
	σ =200 [kN/m^2]	E_N = 4347.80 – 8333.33 [kN/m^2]
	σ =400 [kN/m^2]	E_N = 7843.14 – 12500.00 [kN/m^2]

$$C_{pergj} = \frac{C_{pd}^N \times npd + C_t^N \times ntr}{n_{pd} + n_{trer}}, \left[\frac{kN}{m^2}\right] \quad ...(13) \qquad \varphi_{pergj} = \frac{\varphi_{pd}^N \times n_{pd} + \varphi_t^N \times n_{trer}}{n_{pd} + n_{trer}}, \left[{}^0\right] \quad ...(14)$$

n_{pd}-number of samples with shearing test
n_{ter}-number of samples with tri axial test

Table 4. Obtained results with Direct shear test end Tr iaxial test[3,5,6]

yellow clay	Grey clay	coal
φ= 13.1 [°]	φ= 14.12 [°]	φ= 35 [°]
C= 9.0 [kN/m²]	C= 10.9 [kN/m²]	C= 50 [kN/m²]
γ= 18.22 [kN/m³]	γ= 19.82 [kN/m³]	γ= 12 [kN/m³]

7. CONCLUSION

In the location specified for emplacement of excavator are done 9 drillings and taken 20 samples of them to analyze physic- mechanical particularities, during tests analyzing it is noted a slight difference between two tests. In order to obtain the average of it, it is used the formula 13,14.

In order to be the square (zone) stable for excavators repairing should be undertaken these measures:

Digging of canals for removing water the zone should be compressed well with cylinder.

To be laid gravel according to the need and to be done the compression up to the time when is achieved the capability of the allowed keeping.

After compression should be measured the module of compression with circular plate.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

DETERMINING OF EFFICIENCY OF THE CINEMATIC COUPLE TYPE ROLL – CYLINDER

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ABSTRACT
In this work is make an analyze regarding the mechanical efficiency by experimental research using a device for helicoidally movement simulation. The precision of helicoidally generation is determinate in relation between normal force and acting torque. For a high accurate determination of the measurements is made by electronic transducers for displacement and rotation.
Key words: cinematically couple, helicoidally motion, displacement and rotating transducer.

The helical motion is generate by a rotation motion and a translation realized simultaneous.
To determine the parameters of helicoidally motion is using a device like one from figure 1, based on a cinematically couple type roll – cylinder. The adjusting of the pitch is making by the positioning of the roll axis relative to the shaft axis. Depending on the angle adjustment can generate the following motions:

1. If the roll axis is parallel to the shaft axis, this it will generate an rotation motion;
2. If the roll axis is perpendicularly on the shaft axis, the last one he will generate a translational motion;
3. If the axis of roller make an angle between 0° and 90° with the axis of cylinder, the cylinder will accomplish an left-hand helical motion;
4. If the axis of roller makes an angle between 90° and 180° with the axis of cylinder, the cylinder will design a right-hand helicoidally motion.

The components of the device are, schematically represented in figure 1a, and these are:

1 – handle
2 – central shaft
3 – support
4 – mechanism for adjustment of roller position
5 – roller
6 – disk
7 – marker
8 – barrel

9 – test weight
10 – top assembly
11 – supporting element of top assembly
12 - test weight for pressure contact

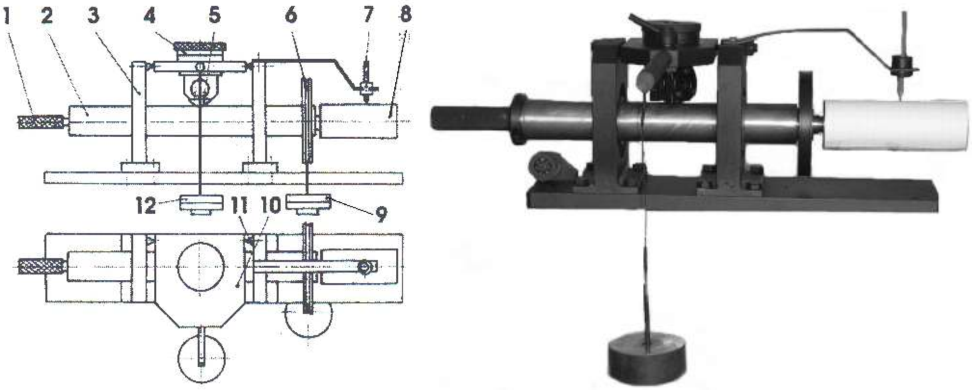

Figure 1. Device for generation of helicoidally motion

The value of the pitch is determined by the value of the angle between roller and shaft axis.

$$p = \pi \cdot D_0 \cdot tg\theta \qquad ...(1)$$

where:
p − propeller pitch generated;
D_0 − diameter of the shaft;
θ − the angle between axis roll and the axis shaft.

In figure 2, is presented a device described above and which are mounted several of necessary elements to study of mechanical efficiency at the cinematically couple type roll – cylinder.
The device generate the helicoidally motion through rotating of the shaft by a mass m_2, which acts through a drive cable mounted on the shaft.

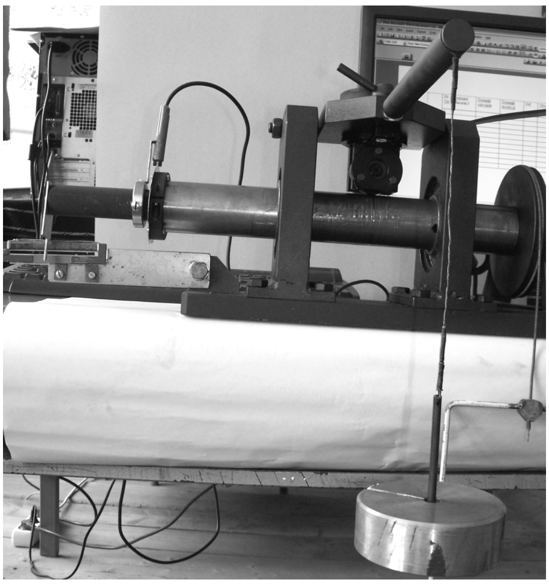

Fig. 2 Device for generating of helicoidally motion equipped with the necessary elements for establishing of the relation between the adjusting angle of the roll and the maxim couple at the cinematically couple type roll – cylinder

The mass m_2 gravitational fall free and rotate the disk same time with the shaft. Depending by the adjusting of the roll it is generate a certain value of pitch, according with relation 1.

To determine the mechanical efficiency is used a measure system which put in evidence the forces and the displacements of components.

The calculus of the mechanical work is making by take in consideration components of the device.

The source of actuating is given by the test etalon 9. By moving of this into a gravitational field it is producing the engine mechanical work.

$$L_m = G \cdot d = m_2 \cdot g \cdot d \qquad ...(2)$$

where:

m_2 − the test weight, in kg;

g − gravitational acceleration, in m/s^2;

d − the distance route by the test weight, in m.

The resistant mechanical work is achieved by displacement of the friction force on the propeller length.

$$L_r = G \cdot \mu \cdot l = (m_1 \cdot \alpha \cdot g) \cdot \mu \cdot l \qquad ...(3)$$

where:

G − represent the weight of the mass m_1;

α - device constant (α =7)

μ − friction coefficient;

l − the length route by on generated propeller.

$$l = k \cdot \pi \cdot D_0 \cdot tg\theta \qquad ...(4)$$

where

k − is proportionality coefficient.

The mechanical work is:

$$\eta = \frac{L_r}{L_m} \qquad ...(5)$$

The measuring transducer gives a voltage proportional with the distance route by the mobile element at the rotation of the device's shaft with a given angle, chose in advance depending by the adjustment of pitch. This voltage is measured by a digital multimeter only during the optical sensor is actuate through a disk with slots. For a single rotation with a given angle γ of shaft. The value in volts (V) of the measured voltage is calibrated through direct reading in centimeters of axial displacement of shaft.

At an adjusted pitch it is calculated for a chosen angle at the rotating sensor the corresponding displacement of the shaft.

With friction without loss this value must to be equal with the corresponding value of the voltage indicated by the multimeter.

To evaluate the functioning of this device it is used a mass $m_1 = 4\ kg$, and to obtain the rotating moment is used an turntable with masses $m_2 = 0{,}5\ kg$.

Figure 3 shows a schematic diagram of the measured part.

The components are:

1 – rotary power sensor; 2 – adjusting circuit of transducer;
3 – gate circuit; 4 – multimeter; 5 – PC audio card; 6 – computer (PC); 7 – monitor.

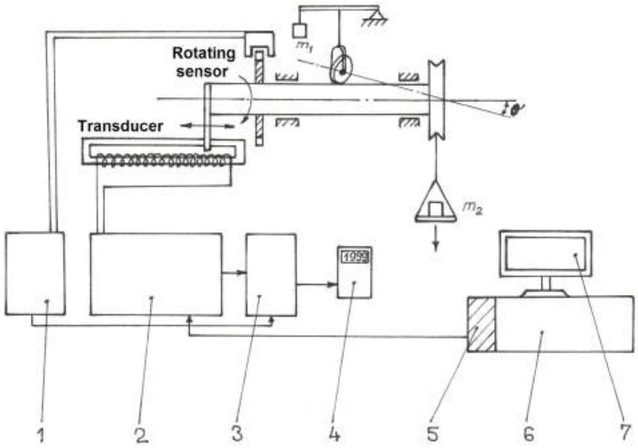

Fig. 3 The schematic diagram of measured part of device for generating of helicoidally motion

CASE STUDY
In experimental measurements regarding the device, were established as optimal values for a propping functioning, the following values:

Mass $m_1 = 6\ kg$ Mass $m_2 = 0{,}5\ kg$

Angle $\theta = 58^o$ Angle $\gamma = 90^o$

In these circumstances are determinate the following movement parameters:

- The pitch $p = \pi \cdot D_0 \cdot tg\theta = \pi \cdot 0{,}05 \cdot 1{,}8 = 0{,}25\ m$
- At the measured angle $\gamma = 90^o$

The displacement movement on the pitch it will be $l = 0{,}0625m$. For this displacement is corresponding a fall $0{,}0082\ m$.

The mechanical motor work: $L_m = G \cdot d = m_2 \cdot g \cdot d = 0{,}5 \cdot 9{,}81 \cdot 0{,}082 = 0{,}402\ N \cdot m$

The resistive mechanical work:

$$L_r = (m_1 \cdot \alpha \cdot g) \cdot \mu_r \cdot l = (6 \cdot 7 \cdot 9{,}81) \cdot 0{,}018 \cdot 0{,}0625 = 0{,}283\ N \cdot m$$

The efficiency in this case: $$\eta = \frac{L_r}{L_m} = \frac{0{,}283}{0{,}402} = 0{,}705$$

CONCLUSIONS
In determining operations it was considered the operating system of the material in a elastic domain, and the rolling friction coefficient, $\mu = 0{,}011$ for dimensions of device's parts and domain of vitese in which is acting the device.

The measurements have counting by the adjusting possibilities of the device depending by the constructive dimensions of that.

The computer is used like a integrated part component of the measuring system and also to process and to manage the dates.
The presented diagram assures the necessary accuracy to determine the kinematics parameters.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

UTICAJ STEPENA DEFORMACIJE PRI HLADNOM VUČENJU NA ČVRSTOĆNE I DUKTILNE OSOBINE VATROOTPORNOG AUSTENITNOG ČELIKA AISI 310

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REZIME
Osim što omogućava proizvodnju žice i šipki unutar veoma uskih tolerancija sa čistim i glatkim površinama, hladno vučenje omogućava značajno povećanje čvrstoćnih osobina vučenog materijala. Naravno, porast čvrstoćnih osobina je praćen odgovarajućim padom duktilnih osobina. Porast čvrstoće i pad duktilnih osobina sa porastom stepena hladne plastične deformacije tokom procesa vučenja (deformaciono ojačanje) u najvećoj mjeri zavisi od sadržaja legirajućih elemenata u nekom čeliku. U ovom radu je razmatran uticaj stepena hladne plastične deformacije na čvrstoćne i duktilne osobine visokolegiranog vatrootpornog austenitnog čelika (25% Cr i 20% Ni) AISI 310 koji se karakteriše visokom vrijednošću deformacionog ojačavanja.
Ključne riječi: hladno vučenje, deformaciono ojačavanje, austenitni čelici

1. UVOD

Za razliku od vruće i tople plastične deformacije, odnosno odgovarajućih tehnoloških postupaka prerade, čija primjena podrazumijeva prethodno zagrijavanje deformiranog komada na dovoljno visoku temperaturu, što uzrokuje pojavu tankog oksidnog filma na njegovoj površini uslijed visokotemperaturne oksidacije, hladna plastična deformacija, u okviru tehnoloških postupaka prerade kao što su hladno vučenje ili hladno valjanje, uglavnom se provodi na sobnim temperaturama i na komadima bez prisutnog oksidnog filma, jer bi inače dolazilo do utiskivanja tvrdih oksida u površinske slojeve deformiranog komada, a time i slabljenja kvaliteta površine, uz brzo trošenje alata. Druga značajna razlika između hladne, tople i vruće deformacije odnosi se na pojavu različite dislokacione strukture. Naime, jedna od posljedica plastične deformacije je povećanje gustine dislokacija. Međutim, u slučaju vruće deformacije, budući da se odvija na dovoljno visokim temperaturama, deformirana struktura se zamjenjuje rekristalisanom strukturom, što uzrokuje vraćanje gustine dislokacija na nivo prije izvođenja deformacije. U slučaju tople deformacije, koja se odvija na nešto nižim temperaturama od temperature rekristalizacije, dolazi do formiranja ćelijske dislokacione substrukture uz fragmentiranje deformisanih zrna na subzrna. S druge strane, u slučaju hladne deformacije, osim pri izuzetno visokim stepenima deformacije, formira se struktura sa haotičnim rasporedom dislokacija [1]. Budući da je deformaciono ojačavanje direktno vezano za povećanje gustine dislokacija, najveće ojačanje se može postići hladnom deformacijom, nešto manje toplom deformacijom, zbog djelomičnog poništenja dislokacija i njhovog raspoređivanja po granicama subzrna, dok kod vruće deformacije ne dolazi do deformacionog ojačavanja zbog odvijanja rekristalizacionih procesa. Porast čvrstoćnih osobina (napon tečenja, zatezna čvrstoća) uzrokovan deformacionim ojačavanjem praćen je sniženjem duktilnih osobina (izduženje, kontrakcija). Navedeno je izraženije, što je primjenjeni iznos hladne deformacije veći. Pri tome, intenzitet ojačavanja je veći što je viši sadržaj legirajućih elementa. Takav slučaj je upravo prisutan kod austenitnih čelika, odnosno čelika koji na sobnim temperaturama posjeduju austenitnu strukturu. Navedena struktura se postiže legiranjem čelika sa dovoljnom količinom austenitno stabilizirajućih elemenata od kojih su najvažniji nikl, ugljik, mangan i dušik. Ukoliko se radi o austenitnim nehrđajućim i vatrootpornim čelicima sadržaj legirajućih elemenata se dodatno povećava, jer se čeliku dodaje i odgovarajuća količina elemenata koji osiguravaju potrebnu korozionu otpornost, kao što su krom i silicij, koji su inače jaki stabilizatori ferita. Sadržaj austenitno i feritno stabilizirajućih elementa određuju stabilnost austenita pri hladnoj plastičnoj deformaciji. Tako u slučaju metastabilnih austenitnih čelika pri hladnoj deformaciji može doći do djelomične transformacije austenita u martenzit, a time i intenzivnijeg ojačavanja [2]. Sa druge strane, odnos austenitno i feritno stabilizirajućih elementa određuje i mogućnost izdvajanja δ ferita čije se prisustvo negativo odražava na deformabilnost čelika kako u vrućem tako i u hladnom stanju [3]. U ovom radu razmatran je uticaj stepena hladne plastične deformacije u procesu vučenja na čvrstoćne i duktilne osobine visokolegiranog vatrootpornog austenitno stabilnog čelika AISI 310 u kome je odnos elemenata koji stabiliziraju austenit i ferit takav da ne dolazi do izdvajanja δ ferita. Eksperimentalni dio rada je urađen u Metalurškom institutu »Kemal Kapetanović« Zenica.

2. REZULTATI EKSPERIMENTALNIH ISTRAŽIVANJA

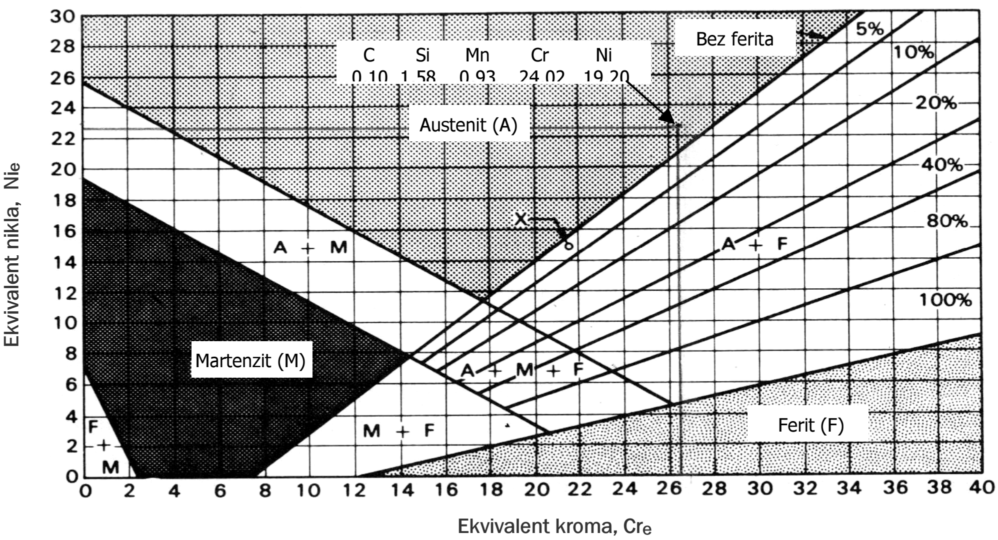
Vruće valjana šipka nominalnog promjera 14 mm korištena je kao polazni profil u okviru eksperimentalnog istraživanja. Hemijski sastav šipke dat je u tabeli 1. Sadržaj svih elemenata se nalazi unutar dozvoljenih granica propisanih standardima ASTM A 167 i ASTM A 480/A 480M za čelik S31000, odnosno AISI 310. Sadržaj austentno stabilizirajućih elemenata, koji se uzima u obzir kroz ekvivalent nikla, i sadržaj feritno stabilizirajućih elemenata, koji se uzima kroz ekvivalent kroma, je takav da je struktura čelika austenitna bez prisutnog δ ferita (Slika 1.). Ekvivalent kroma i nikla, za konkretnu leguru, izračunat je unošenjem sadržaja pojedinih legirajućih elemenata u odgovarajuće formule [2] kako slijedi:

Tabela 1. Hemijski sastav materijala vučene šipke

Sadržaj elementa u (%)						
C	Si	Mn	P	S	Cr	Ni
0,10	1,58	0,93	0,019	0,005	24,02	19,20

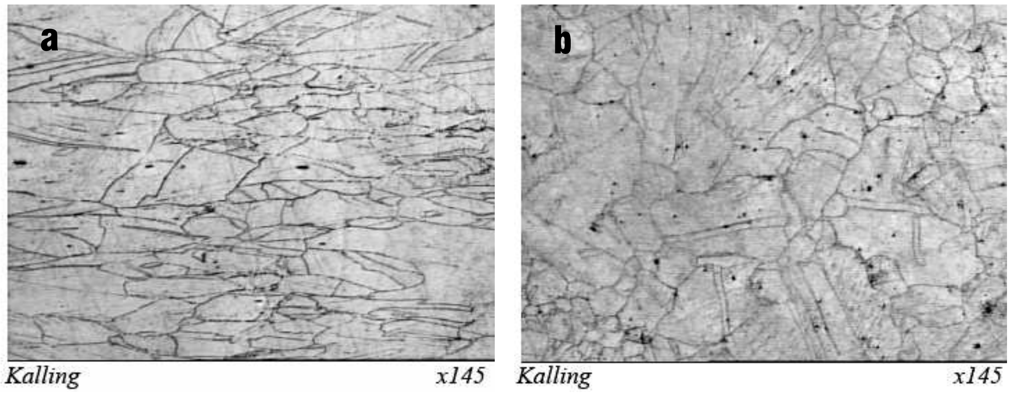
$$Cr_e = \%Cr + 1,5x(\%Si) = 26,39$$

$$Ni_e = \%Ni + 30x(\%C) + 0,5x(\%Mn) = 22,66$$



Slika 1. Položaj tačke koja karakteriše mikrostrukturni sastav vučene šipke u Schaeffler -ovom [2] srukturnom dijagramu za Cr-Ni čelike

Odsustvo δ ferita u strukturi vučene šipke potvrđeno je i metalografskim ispitivanjima (Slika 2.)



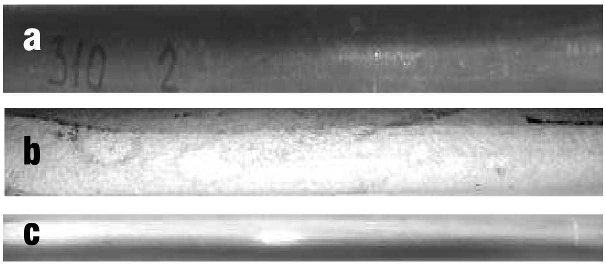
Slika 2. Mikrostruktura vučene šipke (51,6% hladne def.); a) uzdužno, b) poprečno

Također, u strukturi vučene šipke (Slika 2.) nije primjećeno prisustvo deformacionog martenzita tako da je ojačavanje razmatrane legure isključivo posljedica deformacionog ojačavanja samog austenita. Navedeno je rezultat činjenice da su temperature M_s (temperatura početka transformacije austenita u martenzit) i M_{d30} (temperatura kod koje 30% hladne deformacije u strukturi obrazuje 50% deformacionog martenzita) jako niske. Vrijednosti M_s i M_{d30} temperature izračunate su korištenjem empirijskih formula [4] koje ukazuju da se sa povećanjem sadržaja legirajućih elemenata mogućnost za transformaciju austenita u martenzit tokom hladne deformacije sve više smanjuje.

$$M_s = 502 - 810x(\%C) - 13x(\%Mn) - 30x(\%Ni) - 12x(\%Cr) = -455^oC$$

$$M_{d30} = 497 - 462x(\%C) - 9{,}2x(\%Si) - 8{,}1x(\%Mn) - 13{,}7x(\%Cr) - 20x(\%Ni) = -284^oC$$

Vruće valjane šipke ϕ14mm su nakon uklanjanja površinskog oksidnog filma vučene na ϕ12,5mm, u cilju pripreme profila za naknadno kontrolisano vučenje, zbog nesavršenosti presjeka vruće valjane šipke. Nakon pripremnog vučenja izvršeno je rekristalizaciono žarenje šipki na 1150^{o}C u trajanju od 5 minuta sa naknadnim gašenjem u vodi. Na ovaj način postignuta je tvrdoća šipki od 170 HV10 [5].



Slika 3. Izgled površine šipki nakon: a) vrućeg valjanja, b) luženja, c) hladnog vučenja

Uklanjanje oksidnog filma poslije vrućeg valjanja šipki ϕ14mm, odnosno rektistalizacijskog žarenja vučenih šipki ϕ12,5mm izvršeno je njihovim potapanjem u smjesu: 2 litra 19% HCl, 200 ml koncentrovane H_2SO_4, 200 ml HNO_3 i 1 litar vode. Nakon uklanjanja oksidnog filma šipke su ispirane u vrućoj vodi. Na slici 3. dat je izgled površine šipki nakon vrućeg valjanja, nakon uklanjanja oksidnog filma i nakon vučenja na konačnu dimenziju ϕ8,7mm. Vučenje je obavljeno na vučnoj klupi uz korištenje mokrog podmazivanja. Kao sredstvo za podmazivanje korišteno je mazivo namijenjeno za vučenje visokolegiranih čelika. Oksalna kiselina (10%), kao nosač maziva, korištena je samo prije posljednje provlake. U slučaju ostalih provlaka priprema šipki pred vučenje sastojala se u nagrizanju njihovih površina u istoj kiselini u kojoj je vršeno skidanje oksidnog filma, s tim da su šipke prije potapanja u kiselinu odmašćivane. Reduciranje presjeka šipki od promjera 12,5 mm do finalnog promjera 8,7 mm obavljeno je vučenjem na 7 matrica na kojima su postizani različiti pojedinačni stepeni deformacije (Tabela 2.). Samo vučenje je

Tabela 2. Pojedinačne i ukupne deformacije po matricama

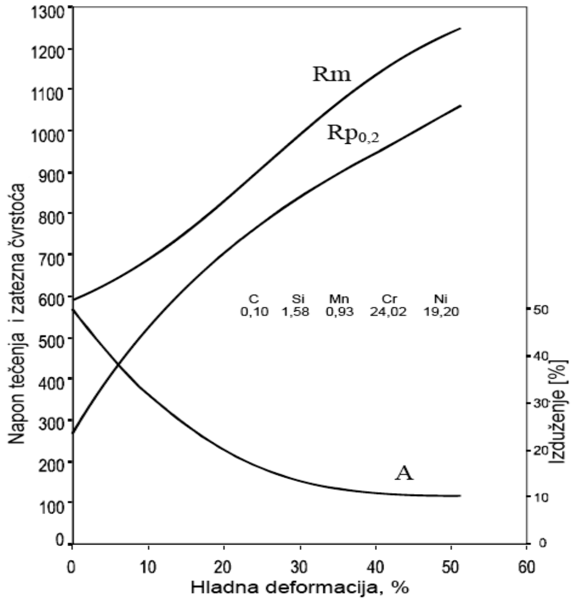
Promjer matrice (mm)	Pojedinačna deformacija (%)	Ukupna Deformacija (%)
12,0	7,8	7,8
11,5	8,2	15,4
11,2	5,2	19,7
10,5	12,1	29,4
9,7	14,6	39,8
9,5	4,1	42,2
8,7	16,1	51,6

obavljeno bez većih problema. Primjena oksalne kiseline na zadnjoj provlaci (najveća pojedinačna deformacija, 16,1%) pokazalo je da se radi o efikasnom nosaču maziva.

Nakon svake provlake (matrice) odsječen je dio šipke dužine dovoljne za izradu epruvete za ispitivanje zatezanjem. Ispitivanje je provedeno na mašinski obrađenim epruvetama nominalnog promjera 8 mm i početne mjerne dužine 40 mm. Rezultati ispitivanja zatezanjem su prikazani u tabeli 3. Uticaj stepena deformacije pri hladnom vučenju na čvrstoćne (napon tečenja $Rp_{0,2,}$ zatezna čvrstoća Rm) i duktilne osobine (izduženje A) čelika AISI 310 sumarno je prikazan na slici 4. Sa porastom stepena hladne deformacije čvrstoćne osobine postepeno rastu dok izduženje relativno brzo pada do oko 10%, gdje se nakon toga održava.

Tabela 3. Rezultati ispitivanja zatezanjem na +20°C žarene (proba br. 1) i vučenih šipki (probe od 2 do 8)

Proba br.	Ukupna deform. (%)	$Rp_{0,2}$ (MPa)	Rm (MPa)	A (%)
1	0	269	594	48,0
2	7,8	462	649	36,0
3	15,4	666	777	23,0
4	19,7	676	807	16,5
5	29,4	840	1025	11,5
6	39,8	936	1123	9,0
7	42,2	970	1150	10,8
8	51,6	1061	1257	11,0



Slika 4. Uticaj stepena deformacije pri hladnom

3. ZAKLJUČAK

Vatrootporni čelik AISI 310 zbog prisustva dovoljne količine legirajućih elemenata karakteriše se stabilnom austenitnom strukturom zbog čega je njegovo ojačavanje hladnom deformacijom isključivo rezultat deformacionog ojačavanja samog austenita, međutim i pored toga moguće ga je značajno ojačati. Razmatrani čelik moguće je plastično obrađivati primjenom postupka hladnog vučenja, međutim, zbog intenzivnog ojačavanja, a time i značajnog povećanja otpora deformaciji, pripremi za vučenje potrebno je posvetiti posebnu pažnju. Navedeno se posebno odnosi na pripremu površine. Dejstvom kiselina formirane neravnine na površinama vučenih šipki trebaju da osiguraju unošenje dovoljne količine sredstva za podmazivanje u deformacionu zonu matrice kako bi se spriječio metalni kontakt vučenog materijala sa stijenkom matrice, a time i nedopustivo trenje koje onemogućava normalno vučenje. Primjena oksalne kiseline omogućava formiranje efikasnog nosača maziva u procesu hladnog vučenja čelika AISI 310, kao i u slučaju drugih sličnih austenitnih čelika.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

EXPERIMENTAL DETERMINATION OF FRICTION COEFFICIENT IN TUBE HYDROFORMING

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ABSTRACT
Process of tube hydroforming enables manufacturing of various thin walled hollow components of complex shapes in very efficient way. In this process one of the most significant parameter is friction which takes place between the tube and the die. Impact of friction is unfavorable: it increases needed force and non-uniformity of tube deformation. For the modeling of the tube hydroforming as well as for qualitative and quantitative analysis of the process knowledge of coefficient of friction is indispensable. Current paper describes two experimental methods to determine coefficient of friction in elastic and plastic zone of the tube during hydroforming process.
Keywords: tube hydroforming, friction, experiment.

1. INTRODUCTION

Tube hydroforming process makes possible to produce thin-walled hollow components with favorable weight to stiffness ratio. This feature is essential in many branches of mechanical engineering, specially in automotive industry. This process is also applied in production of components for supply industry, sanitary installation industry, pipe and pipe components etc .
Single steps in tube hydroformin are shown in Fig.1. Tooling consists of two die halves, bottom and upper die. Tube is inserted into the die and two horizontal punches act in axial direction at the tube ends. In the same time tube is pressurized by inner hydraulic pressure. Due these two simultaneous actions , mechanical and hydraulic, tube is expanded and pressed (deformed) against the die wall. Proper combination between axial force and inner pressure in every particular case is crucial for the final result.
At the end of the process die is opened and workpiece is taken out of the die.
Beside straight tubes, pre-bent tubes can also be subjected to hydroforming which enables production of even more complex components.
One of the main process parameter in the process is friction which occurs as a result of relative movement between tube and die wall. Impact of friction is negative as it increases needed force and causes non-uniformity of the deformation. Only if problem of friction is treated and solved in proper way error-free component can be produced.
Current paper is bound to the problem of friction in the process of tube hydroforming. Particular focus is placed on the experimental possibilities to determine coefficient of friction (COF).

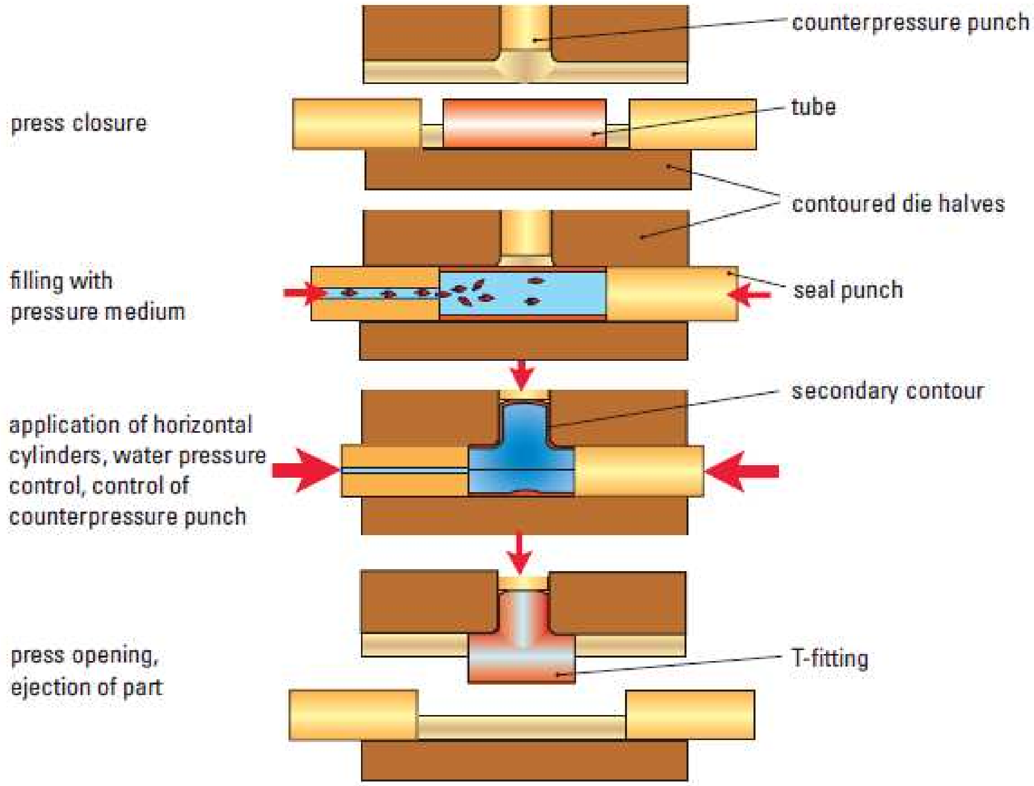

Fig.1. Phases in tube hydroforming /5/

2. EXPERIMENTAL DETERMINATION OF COEFFICIENT OF FRICTION (COF)

In the process of tube hydroforming, basically, two different zones exists (Fig.2): a.) feed zone in which deformation is elastic and b.) forming zone where three-dimensional plastic strain state occurs. Consequently, friction conditions in those two zones are different. Therefore, methods to determine COF also differ.

In feed zone COF can be determined by various experimental methods, but most of them are based upon so called "push through test" *[1]* , *[2]* In this test tube is pushed through the die which causes friction at the die wall. The friction force can be measured and COF is obtained as:

$$\mu = Ft/Fn = (Fu - Fb) / (A \times p)$$

Fu – axial force at the upper punch
Fb – axial force at the bottom punch
A – contact surface between the tool and tube
p – contact pressure

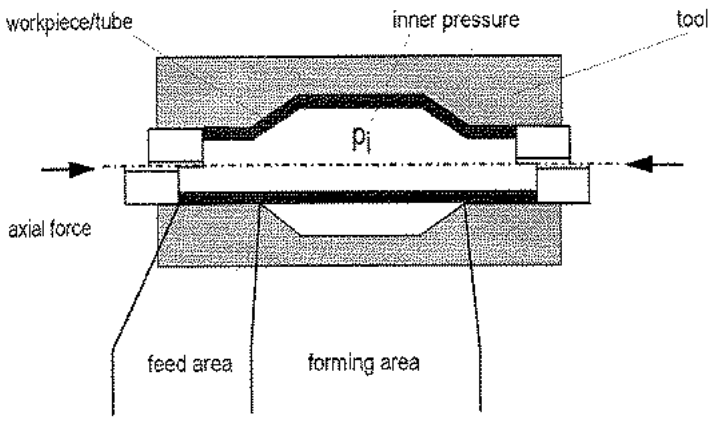

Fig.2. Different zones in tube hydroforming

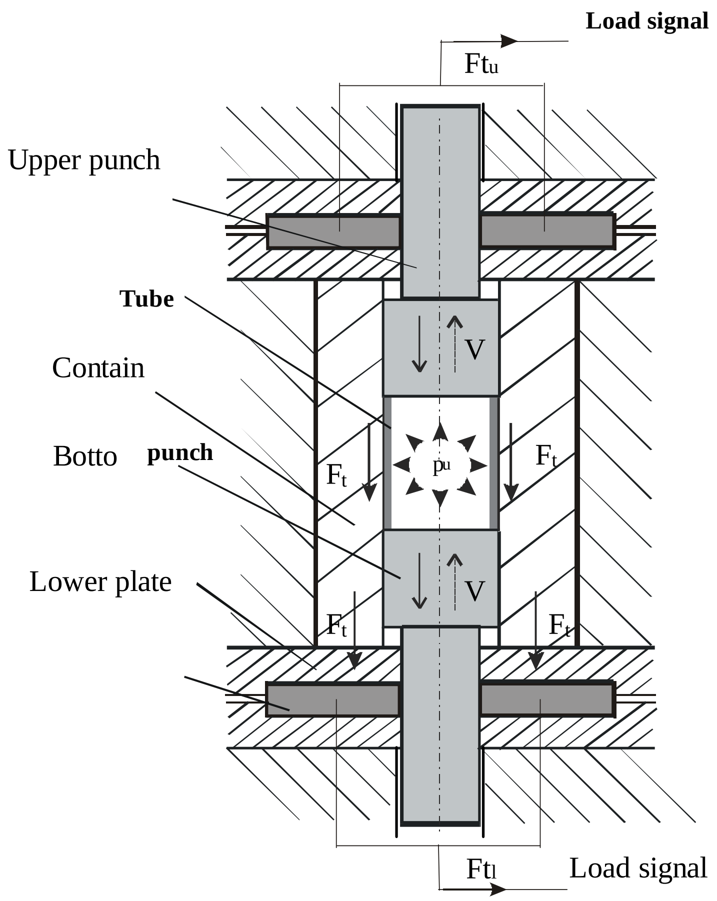

Fig.3. Toolinf for measurement of COF /2/

In Fig.3. tooling for measuring friction force is shown. This force is obtained as a difference of the punch forces (bottom and upper punch).
Experimental tooling in two different positions is shown in Fig.4.

Fig.4. Experimental tooling

For the determination of COF in plastic (forming) zone analytical solution has been proposed *[1]* .This solution enables calculation of COF in tube hydroforming on the basis of geometrical data obtained by measuring of tube before and after deformation and on the basis of material data and inner pressure.

Following consideration is the base for the proposed analytical solution: when the tube , closed in the die and subjected to the inner pressure, is loaded by the axial force, two kinds of deformation can occur. In friction free conditions die wall deforms uniformly (Fig.5b). If there is a friction between

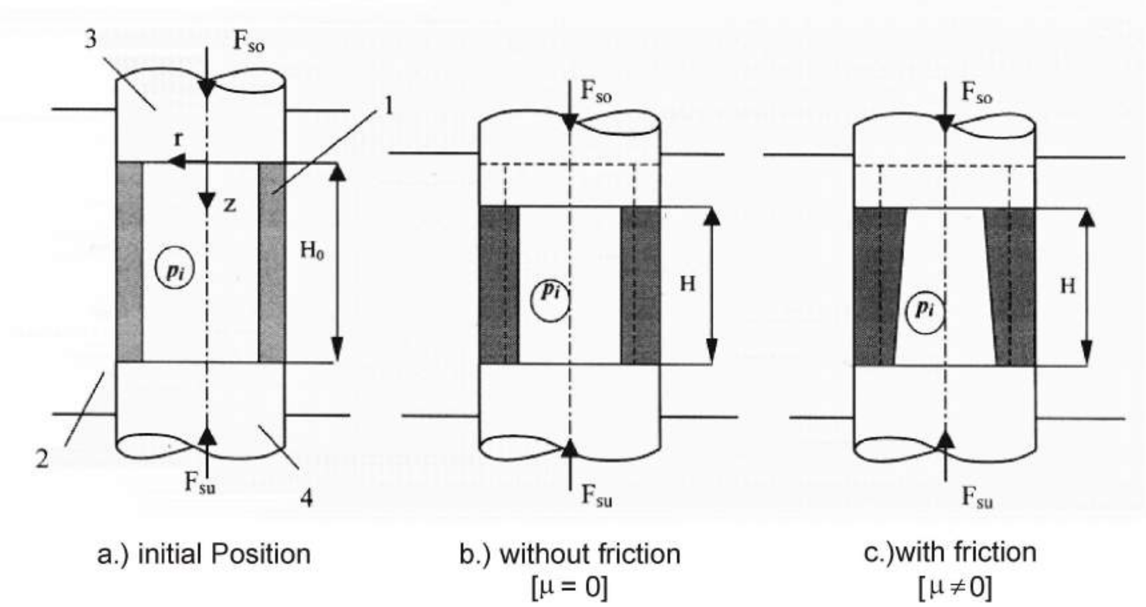

Fig.5. Different possibilities of tube hydroforming *[1]*

the die and the tube (real case) wall thickness along the tube is not constant (Fig.5c). Biggest wall thickness is at the side of movable punch and lowest at the side of fixed punch. Analytical method which details can be seen elsewhere *[1]* gives following expression for the calculation of COF in plastic region:

$$\mu = \frac{\beta \cdot C \cdot (A_1 \cdot \varphi_1^n - A_2 \cdot \varphi_2^n) + p_i \cdot (A_1 - A_2)}{p_i \cdot d_a \cdot \pi \cdot h} =$$

$$= \frac{1{,}15 \cdot C \cdot \left\{ \left(d_a^2 - d_{i_1}^2\right) \cdot \left[\ln \frac{s_1 (d_a - s_1)}{s_0 (d_a - s_0)} \right]^n - \left(d_a^2 - d_{i_2}^2\right) \cdot \left[\ln \frac{s_2 (d_a - s_2)}{s_0 (d_a - s_0)} \right]^n \right\} + p_i \cdot (d_{i2}^2 - d_{i1}^2)}{4 \cdot p_i \cdot d_a \cdot h}$$

In abowe expression are:

C, n – material properties
s – thickness of the tube wall
p – inner pressure
d – tube diameters
h – tube height

3. RESULTS AND CONCLUDING REMARKS

Results of the COF measurement in elastic region (feed area) are given in Fig.6 where COF is

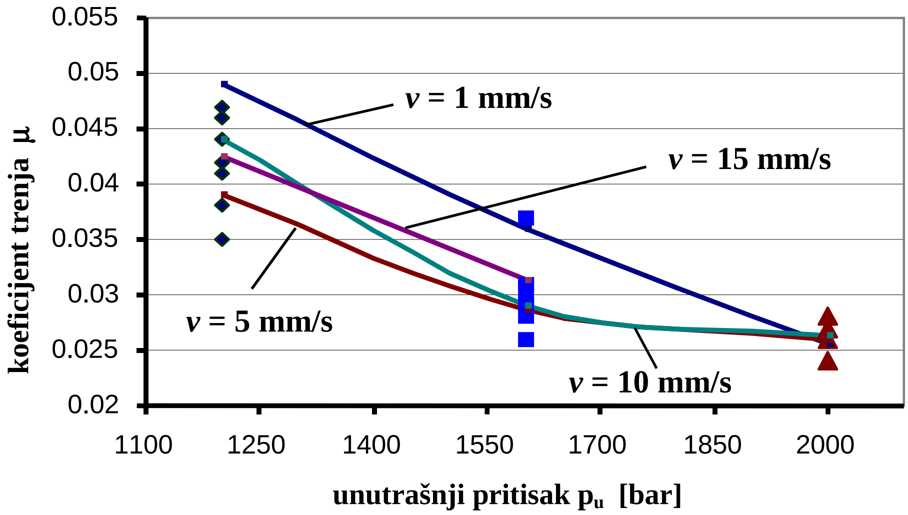

Fig.6. COF in elastic region as a function of inner pressure and velocity

shown as a function of inner pressure and relative velocity between tube and die wall. As it can be seen, decrease of velocity and increase of inner pressure causes reduction of COF and vice versa. In plastic region COF is also dependent on inner pressure (Fig.7).

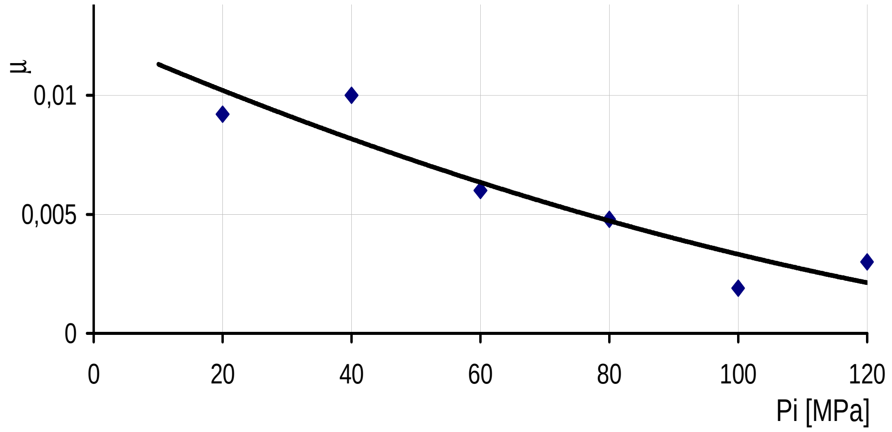

Fig.7. COF in plastic region as a function of inner pressure

Higher inner pressure gives lower COF and vice versa, which indicates that with increasing inner pressure contact stress increases steeper than the tangential stress at the contact surface between tube and die.

Based upon presented experimental investigations following conclusions can be drawn:

- in tube hydroforming two different zones exist: elastic zone (feed zone) and plastic zone.
- among a number of methods for determination of COF in feed zone (elastic region) push through test has been most frequently applied.
- original analytical methodology has been developed to calculate COF in plastic region. It makes possible to determine COF based upon experimentally obtained geometrical data, material and process data.
- obtained COF values in plastic zone are lower than those in elastic zone.
- higher inner pressure results in lower COF
- for the same value of COF milder materials exhibit higher degree of wall thickness inhomogeneity than it is the case at stronger materials.

Acknowledgement: This paper is the results of mutual research within Ceepus Project C II - HR - 108.

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CONTRIBUTION TO THE DIMENSIONAL ACCURACY ANALYSIS OF METHYL METHACRYLATE PATTERNS CREATED BY RTV CASTING

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ABSTRACT
Technological process of RTV casting has evolved with the development of new materials and the rapid prototyping processes. The prototype made by any RP process can be used as a model for making the RTV silicone rubber moulds. The functional components are obtained with casting the plastics in such mold. The literature states that this process has limited accuracy. So, it applies for plastic parts with less precision. Dimensional accuracy measurements of more castings were made in this research to determine how the dimensions differ from the computer's 3D solid model. The specimens are obtained with casting in the RTV silicone rubber molds. The measuring of specimens is performed using the instrument micrometer caliper.
Keywords: RTV casting, Dimensional accuracy, Methyl methacrylate

1. INTRODUCTION
Rapid prototyping is a model making from 3D CAD data. It is possible to use different materials like wood, polymers, metals, ceramics and composites in various forms (liquids, powders, thin plates, etc.) [1]. Models are often made in order to estimate the shape and size, determine the functionality, making the samples for the customer, product photography for marketing purposes, testing in the wind tunnels, etc. Rapid tooling includes a number of techniques that are used for the rapid development of complex tools, moulds and shapes, which are then used to produce final parts. These procedures are commonly used in the case of small series of products and for tools when the usual procedure was very expensive. Rapid manufacturing is the rapid prototyping technology applied to the production of final parts that go into the sales. The rapid tooling is divided in the rapid tooling of soft and hard tools in relation to the lifetime of produced tools. In terms of the way of making the rapid tooling is divided into direct and indirect tooling. The technological process of RTV casting is kind of the indirect soft tooling.

2. RTV CASTING
The silicone rubber Room Temperature Vulcanizing – RTV casting has application mainly in the manufacture of plastic prototypes in a small series. The size of the series is a few parts up to several

hundred. It depends on the reactive nature of the polymer, the geometric complexity of parts and the damage of the mould when removing the parts.

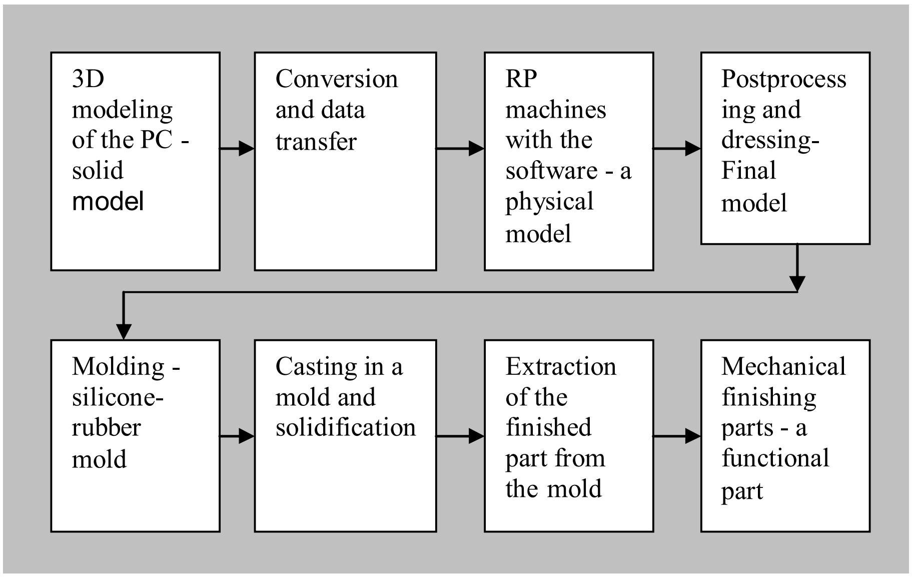

Figure 1. The phases of RTV casting

The RTV process has many phases (Figure 1.). First, it is necessary to make 3D model of the part using some software for 3D solid modelling with a PC (Figure 2.). Then this data is converted to the format used by RP machines (e.g. STL format).

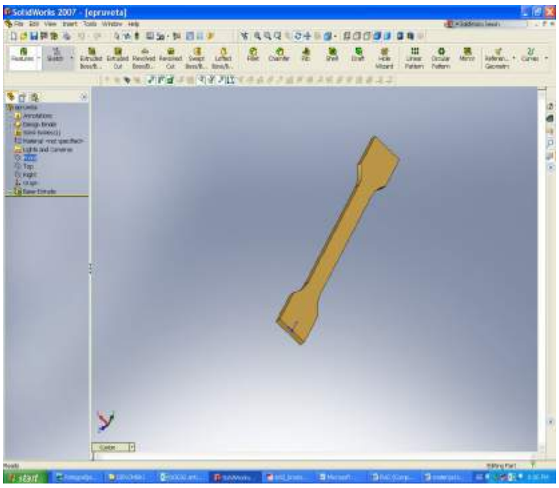

Figure 2. 3D solid model

Figure 3. The physical models in the cardboard boxes

RP machine makes a physical model based on that. Then the model is post-processed. It’s drying on a specific temperature, infiltration for reinforcement and so on. The post-processing depends on the used RP process. The next phase is making the silicone rubber moulds (Figure 3.). Two-component mixtures are commonly used for mould material, such as Tekasil [9]. When the components are mixed in a certain ratio, the mass is poured from a height in a thin stream to the model (Figure 4.). This allows the silicone fill all the holes and squeeze out air, which ensures that the mass be vulcanized without air bubbles. The model can be separated from the mould after 24 hours, but it is necessary to wait 48 hours, and even more to reach the final mechanical properties of the vulcanized silicon.

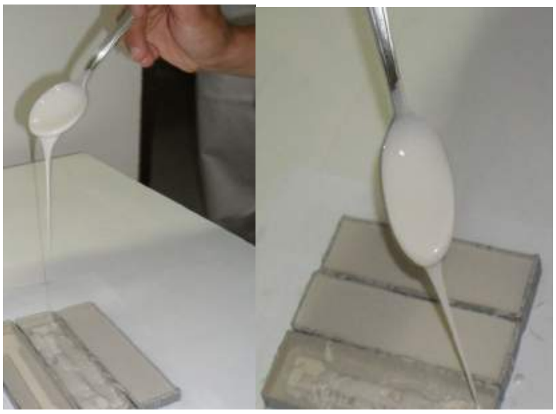

Figure 4. The silicone is poured from a height in a thin stream to the model

Figure 5. Pouring the polymer into a mold.

The next stage is the merging of polymers into the mould (Figure 5.). The most commonly used materials for casting are polyurethane, polyester, epoxy, lead-tin alloy (200 [° C]), pewter (230 [° C]) and zinc alloys. It is necessary to ensure that the deformation of mould is as small as possible, because the mould is flexible. After solidification the moulded part is removed (Figure 6.) and eventually finished (removing a excess, grinding, ...). That way we get a part ready for use.

Figure 6. Removing the part from the mould

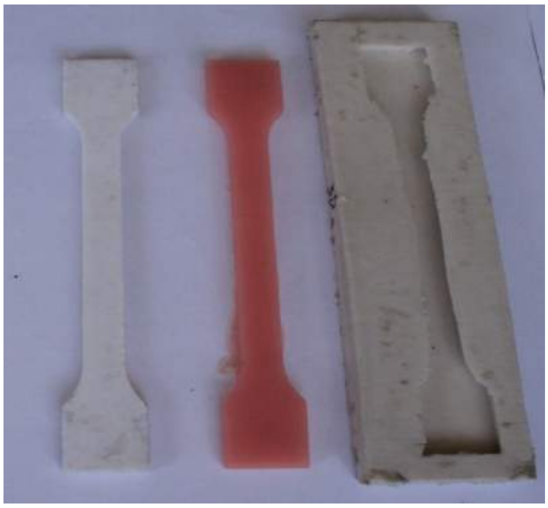

Figure 7. The physical model, the part and the mould

2.1.Advantages of the procedure

The advantages are the simplicity of the process, the moulds for complex parts are easily manufactured, the ability to make fine details, availability of material, good surface treatment and the process reliability.

2.2.Disadvantages of the procedure

The main disadvantage is a limited precision. This procedure is applied to less accurate parts with complex shapes because of the deformation of soft moulds. RTV casting technology is mainly used in the manual method of production, but automated technologies are emerging lately.

3. THE DIMENSIONAL ACCURACY

The major disadvantage of this procedure is the weak precision as already noted in the literature, i.e. small accuracy of dimensions. In order to verify and determine the accuracy we performed a research made with the 3D computer model of a part with certain dimensions. Then we made the 3D printer parts - physical models. The moulds are made from material TEKASIL 2k - Z010 - two-component mass using the physical models.

The functional parts were obtained by casting the plastic in the moulds. The plastic is a two-component mass. The first component is methyl methacrylate polymer as a fine powder, and the second ones is methyl methacrylate monomer in liquid form.
When the components mixed in the correct aspect ratio the mass can flow in a period of about 2 minutes (depending on the air temperature), after which it solidifies. The parts are removed from the mould soon after the solidification and they finished with fine mechanical extra work. The process is shown in Figure 2.-7.
Measuring dimensions of the parts was done after that by the instrument micrometer calliper.

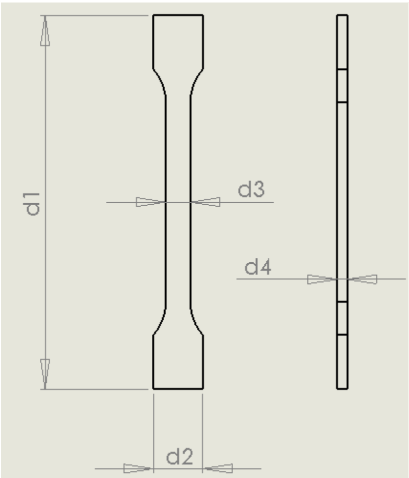

Figure 8. Four specimen's dimensions for measuring

Figure 9. Measuring of d4

Figure 10. Measuring of d3

Statistical results of measurements led to the data in Table 1.

Table 1. Statistical processing of the measurement results

	d_1	d_2	d_3	d_4
Default dimensions of the 3D computer model	*150*	*20*	*10*	*4*
$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$	*149.68*	*20.459*	*10.373*	*4.3882*
$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{k}(x_i - \bar{x})^2 f_i}$	*1.003295*	*0.40477*	*0.434409*	*0.525271*
$S = \sigma\sqrt{\frac{n-1}{n}}$	*1.057565*	*0.426665*	*0.457907*	*0.553684*
$\bar{x} + t_p \frac{S}{\sqrt{n}}$ (level of reliability 95%)	*150.4358*	*20.76393*	*10.70025*	*4.783904*
$\bar{x} - t_p \frac{S}{\sqrt{n}}$ (level of reliability 95%)	*148.9242*	*20.15407*	*10.04575*	*3.992496*
$\bar{x} \pm t_p \frac{S}{\sqrt{n}}$ (level of reliability 95%)	*149,68±0,755*	*20.459±0,305*	*10.373±0,327*	*4.3882±0,396*
Relative measuring error	*0,50%*	*1,49%*	*3,15%*	*9,02%*

As can be seen from table 1, the reliability interval (for level of reliability 95%) is quite wide. For dimension d_1 it is ±0,755mm; for d_2 ±0,305mm; for d_3 ±0,327mm and for d_4 ±0,396mm. Default value on the 3D computer model of d2 and d3 is not included in the reliability interval (Figure 12. and 13.). As we can see from table 1 the relative measurement error increases sharply with decreasing nominal dimensions. This means that the accuracy of making smaller dimensions is lot worse than the big ones.

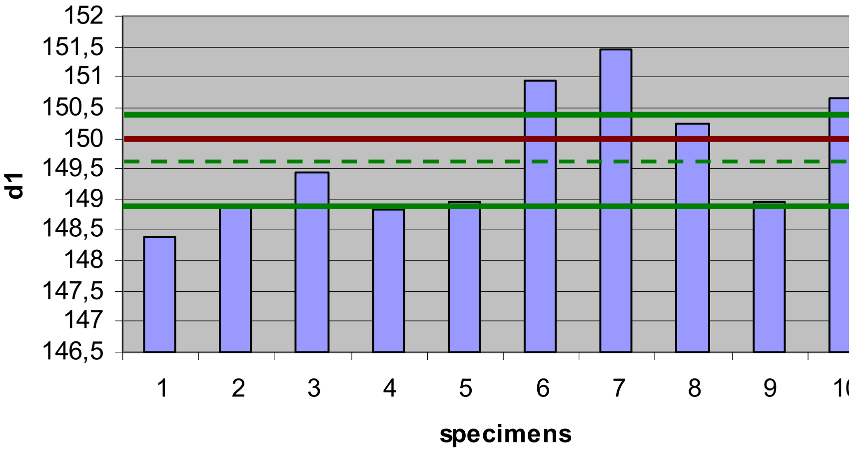

Figure 11. The results for dimension d_1

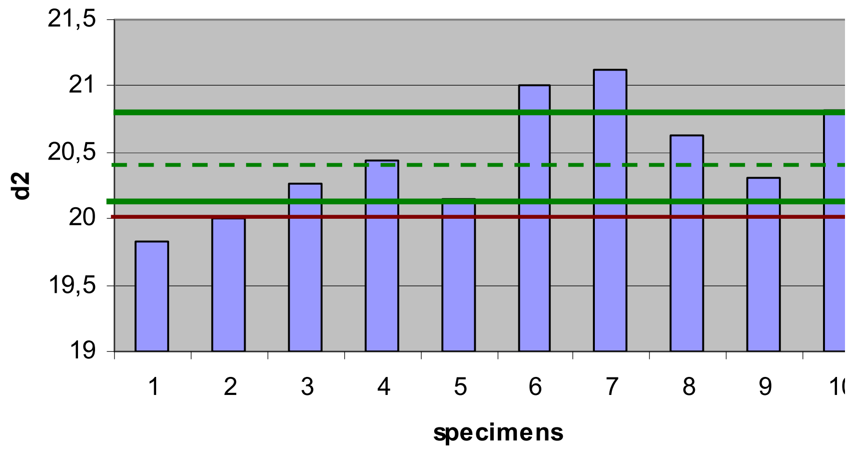

Figure 12. The results for dimension d_2

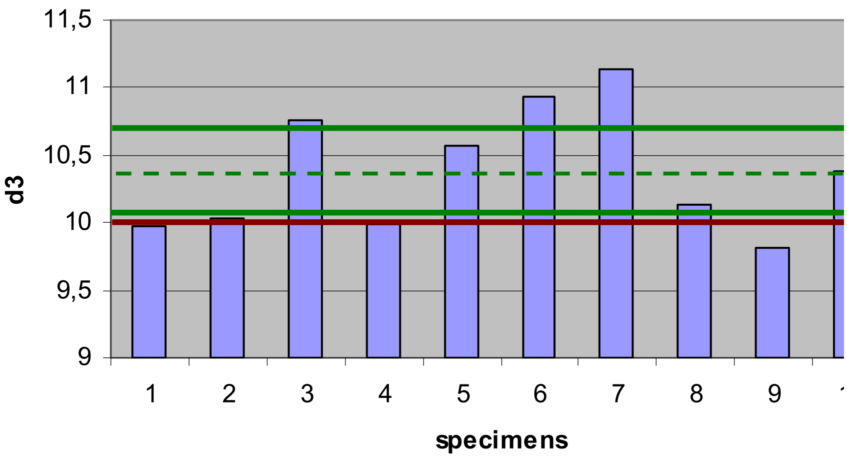

Figure 13. The results for dimension d_3

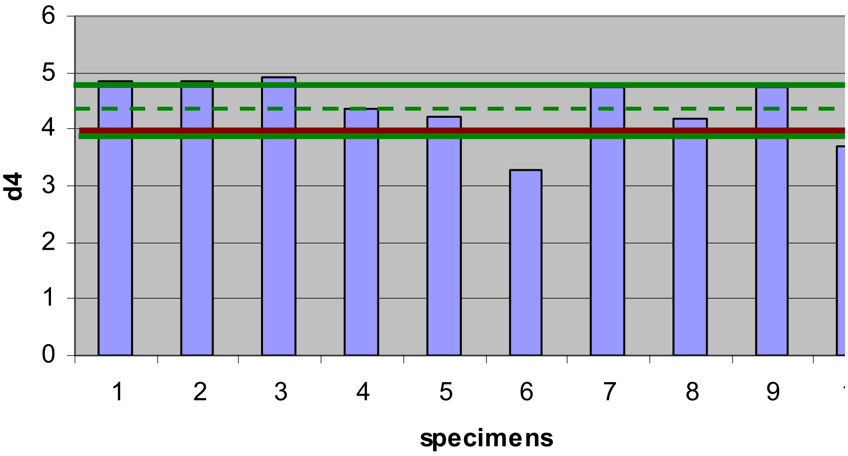

Figure 14. The results for dimension d_4

The results therefore indicate that this procedure give the dimensions of parts quite differ from those given in the 3D computer model. So, the procedure can not be applied when greater accuracy is required (when the dimensions' allowances are narrower).

4. CONCLUSION

The RTV casting process allows relatively quickly obtain the parts of certain materials, mainly plastics. The process is quick and easy, and it should be used for prototyping, when we need quickly replace a plastic part of a device, a machine or systems for the maintenance and so on.

However, if the part requires more precision, then this process can not be used. The reasons for the inaccuracy of casting dimensions are:

- This process is one of the indirect soft tooling. The mould is made indirect, i.e. we firstly make a model, than the mould. So, the total process' error includes the error of making model, the mould and the error of part casting.
- The moulds are soft, i.e. not rigid, but flexible, so it is necessary to ensure that the mould deformation is as less as possible during the casting process.
- The casting time is quite short for most of the materials casting in the mould, so it is necessary to quickly make casting.
- The procedure is done manually, but lately a researchers work at the automation of this technology.
- The casting process can cause the appearance of air bubbles in the material. Therefore, the vacuum casting technology developed in recent times. This avoids the problem [2].
- The accuracy of making smaller dimensions is lot worse than the big ones.

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OPTIMIZACIJA PARAMETARA PROCESA HIDROOBLIKOVANJA CIJEVI

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Bosna i Hercegovina

SAŽETAK

Postupak hidrooblikovanja cijevi nalazi sve veću primjenu u automobilskoj i avionskoj industriji pa su istraživanja iz ovog područja usmjerena na optimizaciju istog. Za uspješno izvođenje postupka hidrooblikovanja cijevi značajnu ulogu imaju ulazni parametri procesa, kao što su pritisak fluida u cijevi (radni pritisak), aksijalne sile, vrsta materijala i dr. Modeliranjem ovih veličina, primjenom metoda genetskog algoritma (GA) dobiven je GA model za optimizaciju parametara postupka hidrooblikovanja cijevi T-oblika

Ključne riječi: hidrooblikovanje, cijev, modeliranje, optimizacija, genetski algoritam.

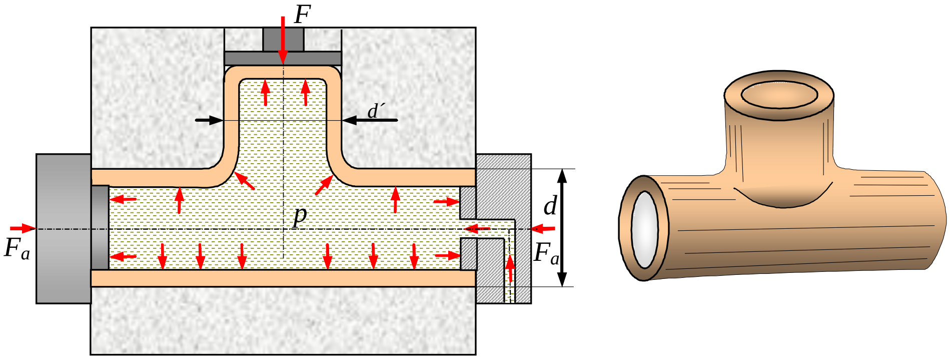
1. UVOD

Postupci hidrooblikovanja cijevi primjenjuju se još od 70-tih godina prošlog vijeka sa stalnom tendencijom razvoja i unapređenja. U automobilskoj industriji se uočava značajno povećanje primjene postupaka hidrooblikovanja, bilo da se radi o plastičnom oblikovanju lima ili cijevnih elemenata. Razlozi tome su svakako u prednostima i karakteristikama koje ovaj postupak pruža u odnosu na klasične načine oblikovanja cijevi [1-9]:

- Postupak je jednostavniji, relativno lako se izvodi i jeftiniji je.
- Relativno kratko vrijeme izrade složenog oblika cijevi.
- Moguća izrada dijelova složenog oblika i većih dimenzija.
- Za realizaciju je neophodan jedan alat koji odgovara definisanom obliku gotovog komada, što potvrđuje uštedu u izvođenju procesa.
- Uštede u materijalu, stalna potreba tržišta za uštedom materijala, opravdanost primjene tankostjenih cijevnih elemenata.
- Zadovoljavajuća kvaliteta izrade.
- Oblikovanje se može izvršiti na raznorodnim materijalima.

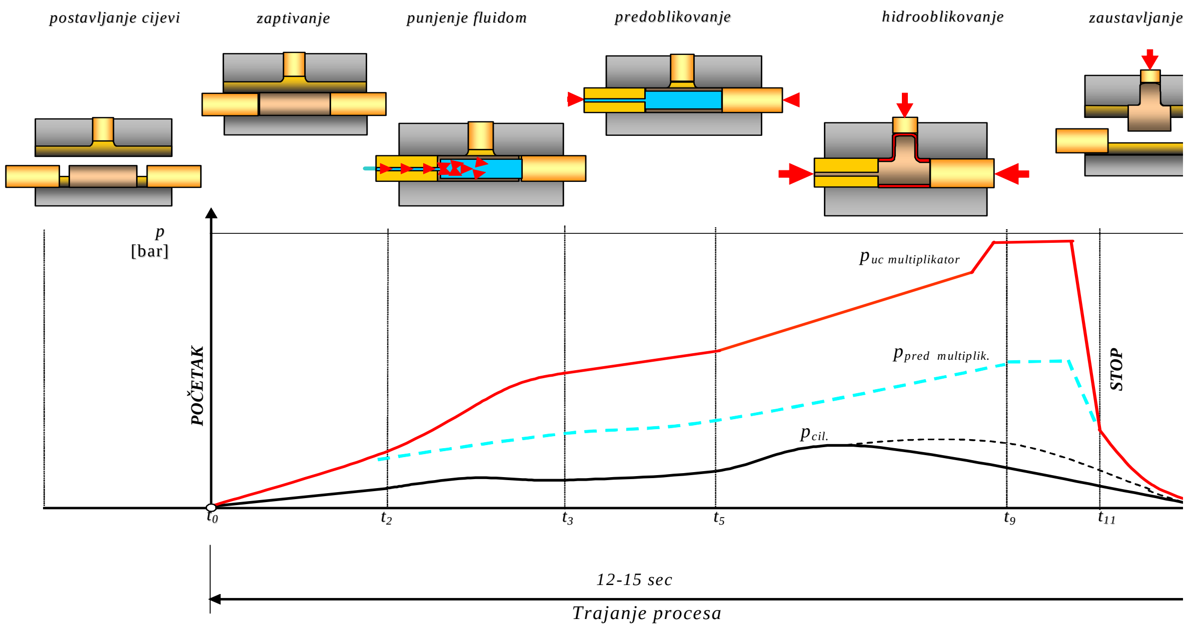
2. HIDROOBLIKOVANJE CIJEVI

Postupkom plastičnog oblikovanja cjevastih elemenata mogu se dobiti proizvodi jednostavnog, ali i veoma složenog oblika. U ovom radu data je analiza postupka hidrooblikovanja cijevi *T*-oblika, slika 1, karakteristike i parametri koji definišu uspješnost izvođenja procesa. Za uspješno oblikovanje cijevi neophodno je obezbjediti (postići) sinhronizovani rad unutrašnjeg fluida u cijevi (p) i aksijalnog pomjeranja tiskača, odnosno aksijalnog djelovanja sila (F_a) u toku procesa. Na oblikovanje *T*-račve utjecaj imaju još i sila pridržavanja (bočnog tiskača F) , trenje, konstrukcija i kvaliteta obrade alata, dimenzije i oblik radnog komada i dr. Svaki od navedenih faktora ima važnu ulogu u konačnom uspjehu procesa, što je bitno za razvojnu fazu projektovanja procesa hidrooblikovanja i njegovu optimizaciju [4,5,8,9].



Slika1. Hidrooblivanje cijevi T oblika

Postupak se izvodi u nekoliko faza, koje karakterišu različiti pritisci fluida u cijevi, kao što je dato na slici 2.

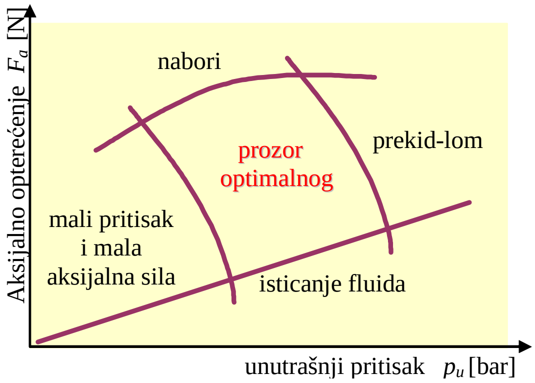


Slika 2. Faze djelovanja pritiska fluida u toku oblikovanja T cijevi [6]

Visina pritiska fluida u cijevi ima najveći utjecaj na formiranje izbočine u toku oblikovanja cijevi *T* -oblika. Pritisak nestišljivog fluida u cijevi treba da bude u dozvoljenim granicama. Bilo koje odstupanje dovodi do pojave greške u procesu hidrooblikovanja cijevi. Povećan pritisak (p_{max}) može da izazove razvlačenja stjenke cijevi u poprečnom presjeku dijela izbočine, što za posljedicu može imati pucanje/trganje izbočine kod hidrooblikovanja cijevi.

3. PARAMETRI PROCESA HIDROOBLIKOVANJA CIJEVI

Međusobna zavisnost ulaznih parametara procesa ima utjecaja na definisane izlazne parametre u analizi procesa hidrooblikovanja cijevi. Proces hidrooblikovanja cijevi trebao bi da se odvija optimalnim parametrima procesa oblikovanja, koji bi omogućili stabilan i uspješan postupak hidrooblikovanja, slika 3. Poznato je da unutrašnji pritisak fluida u cijevi i djelovanje aksijalne sile imaju najveći utjecaj na plastično oblikovanje cijevi, pa su i istraživanja bila usmjerena na modeliranje ovih veličina i njihovog međusobnog odnosa. Odnosom aksijalne sile i unutrašnjeg pritiska fluida u cijevi, za definisane veličine, dobije se optimalno područje za hidrooblikovanje *T* cijevi. Dobivene vrijednosti navedenih veličina van prozora optimalnog procesa dovele bi do pojave grešaka u vidu nabora, loma ili nedovoljno oblikovanog cijevnog komada [4,5,6,7].



Slika 3. Područje optimalnog izvođenja procesa hidrooblikovanja

Kod analize hidrooblikovanja cijevi dužine l=80mm i prečnika d_v=20 mm, ulazni parametri procesa za modeliranje i optimizaciju odnosili su se na tri vrste materijala ($\sigma_{0.2}$=164-290-412N/mm^2), debljine stjenke od 1-2-3mm i aksijalne pomake Δl=10-15-20 mm.

Tabela 1. Eksperimentalni rezultati hidrooblikovanja T cijevi [6]

Broj pokusa	Vrijednosti ulaznih parametara			Eksperimentalne vrijednosti	
	s_0	$\sigma_{0.2}$	Δl	p_{uc}	F_a
Nj	mm	N/mm^2	mm	bar	kN
1	1	164	10	432	37,6
2	3	164	10	1220	102,8
3	1	412	10	1120	128,0
4	3	412	10	2940	306,1
5	1	164	20	477	44,5
6	3	164	20	1298	119,7
7	1	412	20	1210	146,0
8	3	412	20	3090	355,2
9	2	290	15	1603.75	164,4

U Tabeli 1 navedene su vrijednosti samo određenog broja pokusa eksperimentalnih rezultata.

4. MODELIRANJE I OPTIMIZACIJA PARAMETARA PROCESA

Kod optimizacije parametara režima obrade polazi se od matematičkog modela koji opisuje proces obrade. Za analizu je korišten linijski model prvog reda za trofaktornu interakciju [1,2,3,6,7]:

$$y = b_0 + b_1 s_0 + b_2 \sigma_{0.2} + b_3 \Delta l + b_{12} s_0 \sigma_{0.2} + b_{23} \sigma_{0.2} \Delta l + b_{13} s_0 \Delta l + b_{123} s_{10} \sigma_{0.2} \Delta l \qquad \ldots(1)$$

Primjenom metode genetskog algoritma, koja se bazira na evolucijskim predviđanjima, dobiveni su *GA* modeli:

- za unutrašnji pritisak fluida u cijevi (p_{uc}):

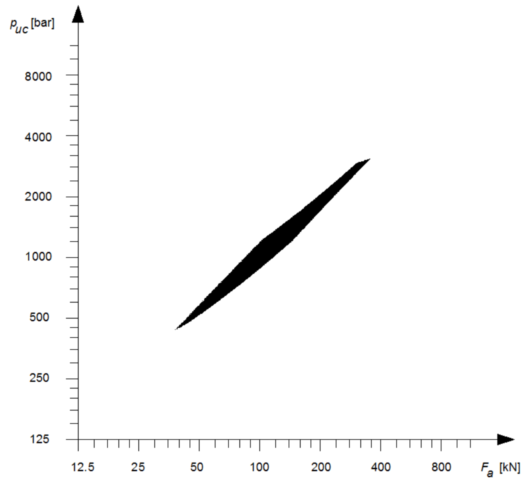
$$\mathrm{p}_{uc} = -81,1683 + 43,9205\, s_0 + 0,559208\, \sigma_{0.2} + 0,59908\, \Delta l + 2,02987\, s_0 \sigma_{0.2} + 0,0132628\, \sigma_{0.2} \Delta l + 0,860965\, s_0 \Delta l + 0,00514024\, s_0 \sigma_{0.2} \Delta l \qquad \ldots(2)$$

Ukupna razlika u odstupanju eksperimentalnih i *GA* rezultata za vrijednost pritiska fluida u cijevi po modelu *GA* je 7.66268, odnosno srednja vrijednost odstupanja u procentima je Δi = 0.85148%.

- aksijalnu silu (F_a):

$$\mathrm{F}_a = -19,4066 - 2,57952 s_0 + 0,137092 \sigma_{0.2} + 0,194186 \Delta l + 0,183978 s_0 \sigma_{0.2} - 2,51587\mathrm{e}-006 \sigma_{0.2} \Delta l - 0,213163 s_0 \Delta l + 0,00434577 s_0 \sigma_{0.2} \Delta l \qquad \ldots(3)$$

Ukupna razlika u odstupanju eksperimentalnih i *GA* rezultata za vrijednost aksijalne sile po modelu *GA* je 4.06689, odnosno srednja vrijednost odstupanja u procentima je Δi =0.451877. *Odnosom* *aksijalne sile i unutrašnjeg pritiska definisano je optimalno područje, slika 4, koje opisuje regresiju rješenja za izvedeni eksperiment [6].*



Slika 4. Optimalno područje hidrooblikovanja T cijevi za odnos F_a/p_{uc}

Rješenja dobivena u ovom području garantuju uspješnost oblikovanja sa optimalnim unutrašnjim pritiskom i aksijalnom silom za generisane nizove veličina: $s_0 = 1mm \div 3mm$, $\sigma_{0.2} = 164 \div 412 \ N/mm^2$ i $\Delta l = 10mm \div 20mm$.

5. ZAKLJUČAK

Hidrooblikovanje cijevi u posljednjih godina dobilo je značajnu ulogu i smatra se tehnologijom brzog razvijanja. Također, zahvaljujući brzom razvoju informatičkih tehnologija, oblikovanja, modeliranja i optimiziranja, postupak hidrooblikovanja daje uštede u materijalu, očuvanja mehaničkih karakteristika materijala i drugih značajnih parametara za proces oblikovanja. Dobiveni matematički modeli koji predstavljaju odnose između ulaznih i izlaznih parametara procesa mogu se sa dovoljno tačnosti iskoristiti za optimizaciju parametara procesa. Podaci o vrijednostima optimalnih ulaznih parametara procesa imaju direktan utjecaj na ekonomske rezultate i opravdanost realizacije tako projektovanog procesa.

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1st International Scientific Conference on Engineering
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MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

TEHNOLOGIJA ZAVARIVANJA ŠASIJE GRADSKOG AUTOBUSA

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IZVOD
U radu se analizira uticaj vrste zaštitnog gasa na geometriju poprečnog preseka šava kod gas metal arc welding (MAG) zavarivanja korenog prolaza srednjeg dela šasije gradskog autobusa. Korišćene su dve vrste zaštitnog gasa, 100%CO_2 gas (C1) i smeša gasova 82% Ar +18% CO_2 (M21). Izvršene su različite pripreme žleba i korišćene dve kombinacije postupka zavarivanja . Prva, gde se koren zavaruje MAG postupkom zavarivanja sa C1 gasom, a ispuna E postupkom zavarivanje. I druga , gde je koren zavaren MAG postupkom zavarivanja, sa M21 gasom, a ispuna je urađena E postupkom zavarivanja. Urađena je metalografska analiza karakterističnih uzoraka koja pokazuje kakav je uticaj vrsta postupaka na geometriju poprečnog preseka šava
Ključne reči: zavareni spoj, MAG,E, geometrija poprečnog preseka, metalografija

1. UVOD
Pri projektovanju tehnologije izrade srednjeg dela šasije gradskog autobusa bilo je neophodno da se eksperimentalno uporede postupci MAG zavarivanja u zaštiti čistog CO2, (C1) i u smeši gasova ferromix (smeša 82% Ar i 18% CO2), (M21) [1]. Srednji deo šasije je rešetkasta konstrukcija sastavljena od šavnih cevi pravougaonog poprečnog preseka debljine zida 5 mm. Ovo je najodgovorniji deo u izradi šasija autobusa, jer je konstrukcija noseća i dinamički opterećena. Zato je potrebno posebnu pažnju posvetiti izvođenju šavova kako bi se postigla što bolja provarenost po poprečnom preseku. Upotreba smeše zaštitnog gasa ima niz prednosti u odnosu na čist CO_2

2. EKSPERIMENT

2.1.Materijal za zavarivanje
Osnovni materijali konstrukcije umetka šasije su opšti konstrukcioni čelici. Materijal cevi je sa oznakom: S355J2H, sa hemijskim sastavom: C ≤ 0,22 %; Si ≤ 0,55 %; Mn ≤ 1,5%; P ≤ 0,035%; S ≤ 0,035%,sa zateznom čvrstoćom u opsegu 500 ÷ 700 MPa, sa minimalnim naponom tečenja 355MPa, Materijal poklopca cevi i zaštitne cevi je sa oznakom: S235JRG2, sa hemijskim sastavom:C ≤ 0,17 %; P ≤ 0,045 %; S ≤ 0,045 %; Si =0,03% 0,3 %; N ≤ 0,009%. Zatezna čvrstoća čelika je u opsegu od 370 ÷ 450 MPa a minimalni napon tečenja 235 MPa.

Kao dodatni materijal za zavarivanje korišćena je elektroda OK 48.00 (bazična debeloobložena elektroda za zavarivanje nelegiranih i niskolegiranih čelika i čeličnog liva), elektrodna žica OK Autrod 12.51 (specijalna pobakrena žica za zavarivanje u zaštitnom CO_2 gasu i smeši Ar i CO_2). Dodatni materijal za zavarivanje je proizvođača ESAB iz Švedske, [2]. Kao zaštitni gas koristio se čist ugljendiokid (CO_2), sadržaj min 99,8% CO_2 i sadržaj vode maks. 0,1 g/m^3 i smeša ugljendioksida i argona (ferromix): 82% Ar i 18% CO_2

2.2. Parametri zavarivanja

Nakon izvršene analize zavarljivosti osnovnog materijla, geometrijske složenosti konstrukcije i ekonomske analize izrade konstrukcije, izabrani su postupci elektrolučnog zavarivanja E i zavarivanja topljivom elektrodnom žicom u zaštiti ugljendioksida (MAG).

Za oba ova postupka zavarivanja, određuju se parametri režima zavarivanja svih karakterističnih šavova.Parametri režima zavarivanja svih horizontalnih šavova za MAG postupak zavarivanja prikazani su u tab.1, [3].

Tabela 1. Parametri režima zavarivanja

Postupak zavarivanja	d_e (mm)	*Iz (A)*	U_l *(V)*	v_z *(cm/h)*	Q *l/min*	*n*
MAG	*1*	*130*	*20*	*828*	*9*	*1.*
E	3,2	130	23	842		2.

2.3. Metalografska ispitivanja

Cilj eksperimenta je da se uporede osobine zavarenih spojeva dobijene MAG postupkom u zaštiti različitih gasova: CO_2 i ferromix. U prvom slučaju prvi zavar je urađen postupkom MAG u zaštiti CO_2, a u drugom slučaju prvi zavar je urađen postupkom MAG u zaštiti ferromix-a (smeša 82%Ar i 18% CO_2). Dobijeni uzorci su označeni prema tab. 2. Drugi zavar je u oba slučaja zavaren postupkom E. Parametri režima zavarivanja su isti.

Tabela 2. Oznaka uzoraka

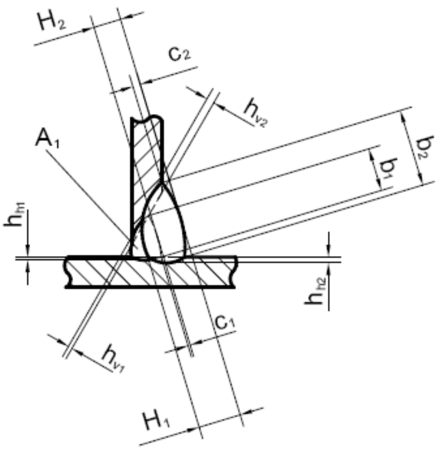
Oznaka	1	2	3	4	5	6	7	8
Postupak	CO_2	CO_2	CO_2	CO_2	ferromix	ferromix	ferromix	ferromix

Izvršena su makroskopska i mikroskopska metalografska ispitivanja uzoraka, koji su ispitivani na svetlosnom mikroskopu"ORTHOPLAN" firme Leitz Wetzlar, sa ugrađenom elektronskom kamerom za snimanje mikrostrukture.

3. REZULTATI EKSPERIMENTA

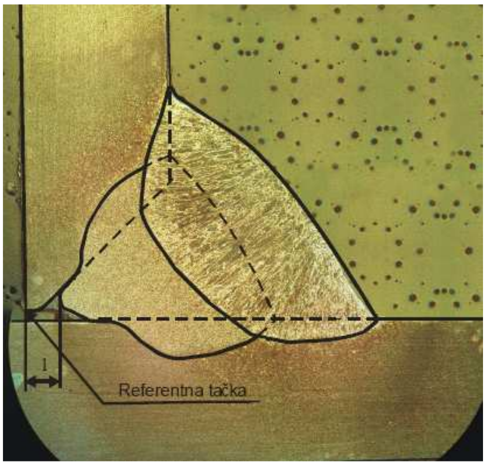
3.1. Makroskopska ispitivanja zavarenih uzoraka

Makroskopskim ispitivanjem uzoraka određivana je geometrija preseka zavara [4]. Merene su sledeće veličine: h_u – dubina uvara (mm), b – širina zavara (mm), c – nadvišenje zavara (mm), H – debljina zavara (mm) i A_1– površina poprečnog preseka prvog zavara, mm^2, sl.1. Rezultati merenja geometrije šava su dati u tabeli 3.

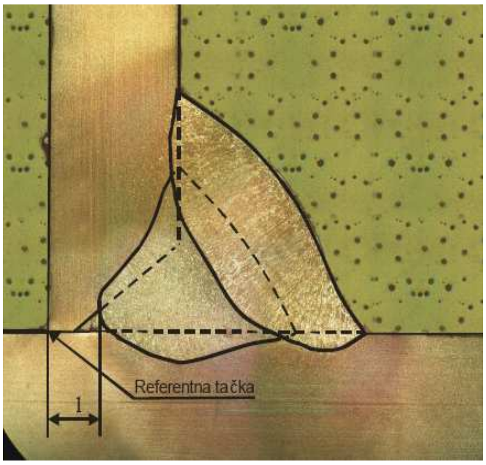


Slika 1:Geometrijski parametri poprečnog preseka šava

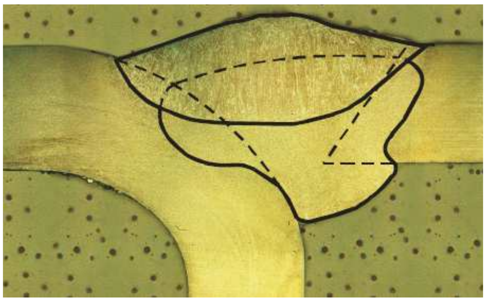
Prilikom zavarivanja prvog zavara nije uvek postignuta potpuna provarenost po celom poprečnom preseku. Zbog toga se definiše referentna tačka koja je zajednička za oba slučaja i od koje je moguće meriti provarenost. Što je veća udaljenost od referentne tačke to je provarenost manja.Udaljenost od referentne tačke u slučaju uzorka broj 1 iznosi l= 1,2 mm. Zbog neadekvatne pripreme žljeba na uzorku broj 1 (sl. 2) nije postignut ravnomeran provar po celom poprečnom preseku šava. Postignuta je dovoljna dubina uvara kod oba zavara.



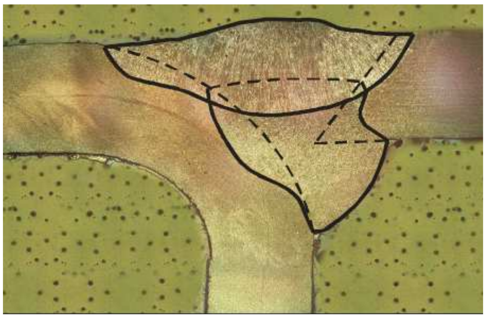
Slika 2:Izgled poprečnog preseka šava uzorka 1 (CO2 i E)



Slika 3:Izgled poprečnog preseka šava uzorka 5 (ferromix i E)



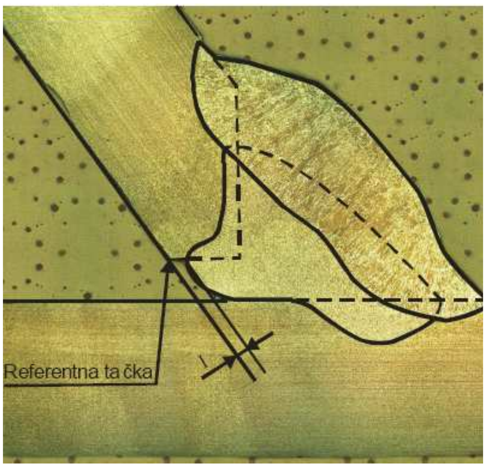
Slika 4. Izgled poprečnog preseka šava uzorka 2 (CO2 i E)

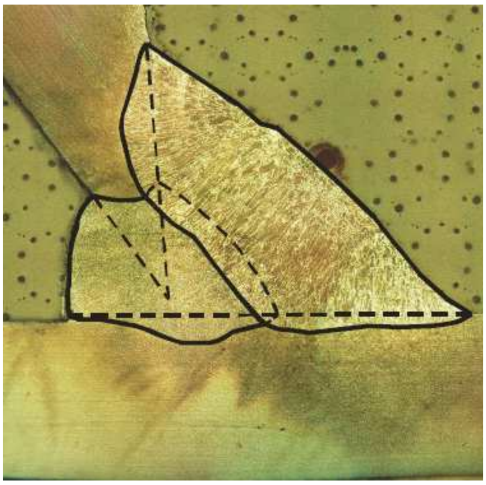


Slika 5. Izgled poprečnog preseka šava uzorka 6 (ferromix i E)

Udaljenost od referentne tačke kod uzorka broj 5 iznosi l= 1,8 mm. Rezultati makroskopskog ispitivanja uzoraka broj 1 i 5 su slični, osim kod dubine uvara. Postignuta je ravnomernija provarenost po poprečnom preseku uzorka broj 5 u odnosu na uzorak broj 1. Dodatni problem bio je nepostojanje razmaka u korenu žljeba na uzorku broj 5 (slika 3). Razmakom u korenu žljeba postigla bi se potpuna provarenost. Uzorak broj 5 je ravnomernije provaren po poprečnom preseku, tim pre što u ovom slučaju nije izvršena adekvatna priprema žljeba, tj. nema razmaka u korenu žljeba.

Uočava se provarenost po poprečnom preseku šava na uzorku 2 i 6, što je olakšano pripremom žljeba i položajem cevi pri zavarivanju. Međutim, provarenost je ravnomernija kod uzorka broj 6 (slika 5) nego kod uzorka broj 2 (slika 4).Uočava se da su dobijeni rezultati približno isti. U ovom slučaju sama priprema cevi je omogućila provar po poprečnom preseku šava.

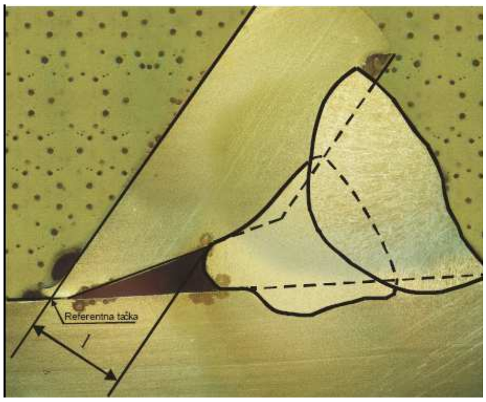


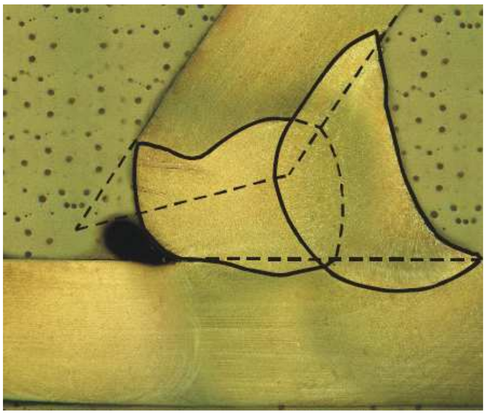


Slika 6. Izgled poprečnog preseka šava uzorka 3 (CO2 i E)

Slika 7. Izgled poprečnog preseka šava uzorka 7 (ferromix i E)

Udaljenost od referentne tačke kod uzorka 3 iznosi l= 0,4mm.Karakteristična je delimična neprovarenost po poprečnom preseku šava koja je definisana udaljenošću (l) od referentne tačke. Uviđa se ravnomernija provarenost po poprečnom preseku šava kod uzorka 7 u odnosu na uzorak 3. Konstatuje se da je prevelik ugao otvora žljeba u oba slučaja i da je zbog toga došlo do curenja materijala šava, pogotovo što pristup držača elektrodne žice mestu zavarivanja nije bio otežan, te je ugao otvora žljeba trebao biti manji. Postignuta je potpuna provarenost po poprečnom preseku šava. Uzorak 7 je po poprečnom preseku šava ravnomernije provaren.





Slika 8. Izgled poprečnog preseka šava uzorka 4 (CO2 i E)

Slika 9. Izgled poprečnog preseka šava uzorka 8(ferromix i E)

Udaljenost od referentne tačke je velika, iznosi l = 4 mm. Zbog nepostojanja razmaka u korenu žljeba kod uzorka 4 (slika 8), odnosno otežanog pristupa držača elektrodne žice mestu zavarivanja, dobija se prilično velika neprovarena zona poprečnog preseka šava.Sa slike 9 se vidi da se postojanjem razmaka u korenu žljeba eliminiše neprovarena zona, međutim, ovde je došlo do topljenja materijala.Šav je udubljen, što pogoduje dinamički opterećenim konstrukcijama. U ovom slučaju je otežan pristup držaču elektrodne žice mestu zavarivanja. Dubina uvara je veća kod uzorka broj 8 i vidi se provar po celom poprečnom preseku šava za razliku od uzorka broj 4.

Tabela 3:Elementi prvog zavara

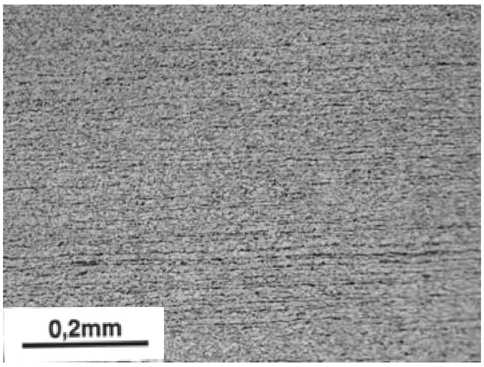
	h_{uv} [mm]	*h_{uh} [mm]*	*b[mm]*	*H[mm]*	*A [mm^2]*
Uzorak 1	*1,7*	*1,2*	*~6,8*	*~5*	*305*
Uzorak 5	*0,9*	*1*	*~7,3*	*~6*	*285*
Uzorak 2	*2,4*	*2*	*~9,8*	*7*	*505*
Uzorak 6	*2,6*	*2*	*~7,4*	*~7,6*	*430*
Uzorak 3	*1,6*	*1,4*	*~9*	*~5*	*280*
Uzorak 7	*1,8*	*0,9*	*~6*	*~4,8*	*240*
Uzorak 4	*0,5*	*1,1*	*~5,5*	*~5*	*245*
Uzorak 8	*1,9*	*0,45*	*~5*	*~4,7*	*295*

Napomena:Nadvišenje nije mereno

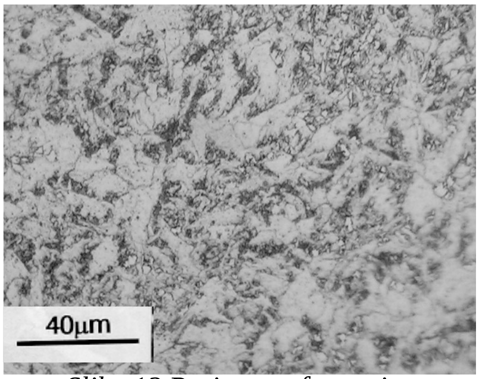
Iz tab.3 može se zaključiti da se prilikom zavarivanja u zaštiti ferromix-a dobija manja površina poprečnog preseka prvog zavara u odnosu na zavarivanje u zaštiti čistog CO_2, što je povoljnije s obzirom na zaostale napone i deformacije u zoni uticaja toplote [5,6].

3.2. Mikroskopska ispitivanje zavarenih uzoraka

Mikroispitivanje uzoraka je vršeno svetlosnim mikroskopom tipa LEITZ, pri uvećanjima od 100 puta i 500 puta. Mikrostruktura osnovnog materijala je feritno-perlitna. Perlit je zrnast. Izražena je trakavost perlita, sl. 11.

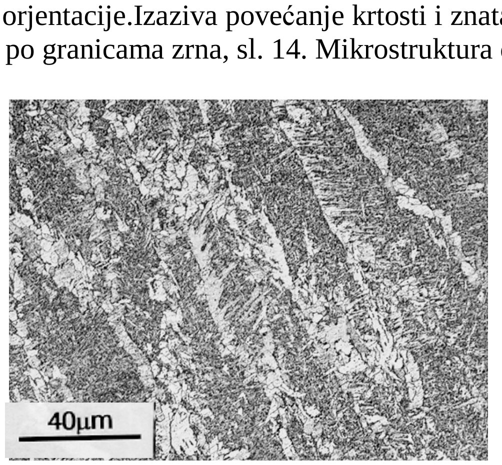


Slika 11.Osnovni materijal

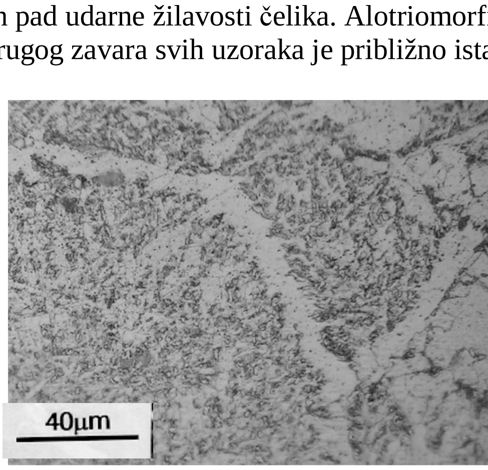


Slika 12.Prvi zavar ferromix ,

Mikrostruktura prvog zavara, koji je zavaren MAG postupkom u zaštiti čistog CO_2, i ferromixa su veoma slične, sastoji se od ferita i prelazne strukture beinita. sl. 12. Karakteristika drugog zavara je stubičasta struktura koja je tipična za metal šava, sl 13. Struktura se sastoji od beinita, alotriomorfnog ferita i Vidmanštetenove strukture. Vidmanštetenov ferit je igličasta struktura koja ima nekoliko pravaca orjentacije.Izaziva povećanje krtosti i znatan pad udarne žilavosti čelika. Alotriomorfni ferit je smešten po granicama zrna, sl. 14. Mikrostruktura drugog zavara svih uzoraka je približno ista.



Slika 13.Mikrostruktura drugog zavara



Slika 14.Mikrostruktura drugog zavara

4. ZAKLJUČCI

Zavarivanje u zaštiti gasnih smeša pruža niz prednosti u odnosu na zavarivanje u zaštiti čistih gasova.Te prednosti se ogledaju u boljem prenosu dodatnog materijalal, stabilnijem zavarivačkom luku, manjem razbrizgavanju, poboljšanon provarivanju, dobijanju povoljnijeg oblika šava, povećanju brzine zavarivanja itd. Pokazalo se da su rezultati ispitivanja na uzorcima zavarenim MAG postupkom u zaštiti ferromixa bolji od onih koji su zavareni u zaštiti CO_2 gasa.

Rezultati ispitivanja su pokazali da uzorci zavareni MAG postupkom u zaštiti ferromixa imaju manju površinu poprečnog preseka, kao i povoljniji oblik poprečnog preseka zavara sa većom dubinom uvara. Manja površina poprečnog preseka ukazuje da je i unos toplote koncentrisaniji.

Eksperiment je potvrdio da je veoma bitna adekvatna priprema žljeba pre zavarivanja, jer se u određenim slučajevima videlo da bi provar bio još bolji da je postojao razmak u korenu žljeba ili da je preciznije urađen ugao zatupljenja žljeba. Rezultati ovog rada su primenljivi u praksi u smislu tačnijeg definisanja tehnoloških operacija pripreme žljeba i zavarivanja.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

GENETIC MODELING AND GENETIC PROGRAMMING OF EXPLOSION-INDUCED DEEP DRAWING PROCESS

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ABSTRACT
Modeling, simulation and optimization of technological processes is continually present in technologically advanced industries where by applying these methods huge savings in material and energy are achieved and working systems' burden reduced, that is, a technological-economic level of working processes is upgraded. In this paper a genetic algorithm for explosion-induced deep drawing process modeling will be applied, thereby enabling forecasts in real process as early as in the stages of design and simulation with increased reliability and stability of the process in the implementing phase. The achieved mathematical model was modified into three different forms expressed with equations with pertaining coefficients, genetic modeling of those forms was performed, as well as the genetic programming and the obtained results were compared..
Key words: genetic modeling, genetic programming, explosion-induced deep drawing

1. INTRODUCTION

In the last twenty years studies have been significantly perfomed as well as the development of genetic algorithms. Genetic algorithm (GA) is a computer model based on the imitation of the biological evolution, which is used for the solution of the optimization problems, that is a heurisitc optimization method that imitates the process of evolution. Accurately explained, genetic algorithm is a recipe that tells us what to do with the genetic material in order to achieve a satisfactory solution to a given optimization problem with the certain probability after a certain period of time. Genetic material is a set of properties that describe an individual. Genetic algorithm does not determine the way the genetic material is stored in the database, nor how the genetic material should be treated, it only says that the genetic material is supposed to be exchanged, accidentally changed, and that the better individuals have a higher probability to survive the selection.

To present the work of genetic algorithm or to perform the modeling by genetic algorithm, we will modify the achieved mathematical model (1)[1], which adequately describes the pressure of

[1]Experiment is performed within the project "Measuring of the deformation of tools and analysis of the structure of materials in the process of deep drawing explosion" which was financed by the Federal ministry of science and education in 2008.

shock wave in explosion-induced drawing, in three different forms presented by equations (2), (4) and (5) with the associated coefficients and we will perform the modeling of these forms. [1,2]

$$p_V = 287{,}2739 \ln G + 322{,}6927 \ln V_E - 682{,}0897 \ln R - 1866{,}4059 \qquad \ldots(1)$$

Further, in the form from the example one or equation (2) we will perform the restricting of limits and compare the achieved results. We will also genetically model and present the model presented by equation (1) and compare the results with other models.

2. GA MODELING

Results achieved by genetic modeling or the values of model coefficients are presented in Figure (1) for the exponential form defined in advance, which is presented in the following equation:

$$p_V = C\, G^{\alpha_1} V_E^{\beta_1} R^{\gamma_1} \ \text{(bar)} \qquad \ldots(2)$$

Coefficients are given in Figure (1) and they have the following values: C = 740,33066, α_1 = 0,39415, β_1 = 0,20668 and γ_1 =-0,0447.

GA modeling was done by program MATLAB R2006a. A model with medium deviation error from experimental values of 8,66% was achieved for 10000 generations and population of 100 individuals within limits from [-1000, +1000]. The goal function through generations for the example from equation (2) is presented in Figure (2).

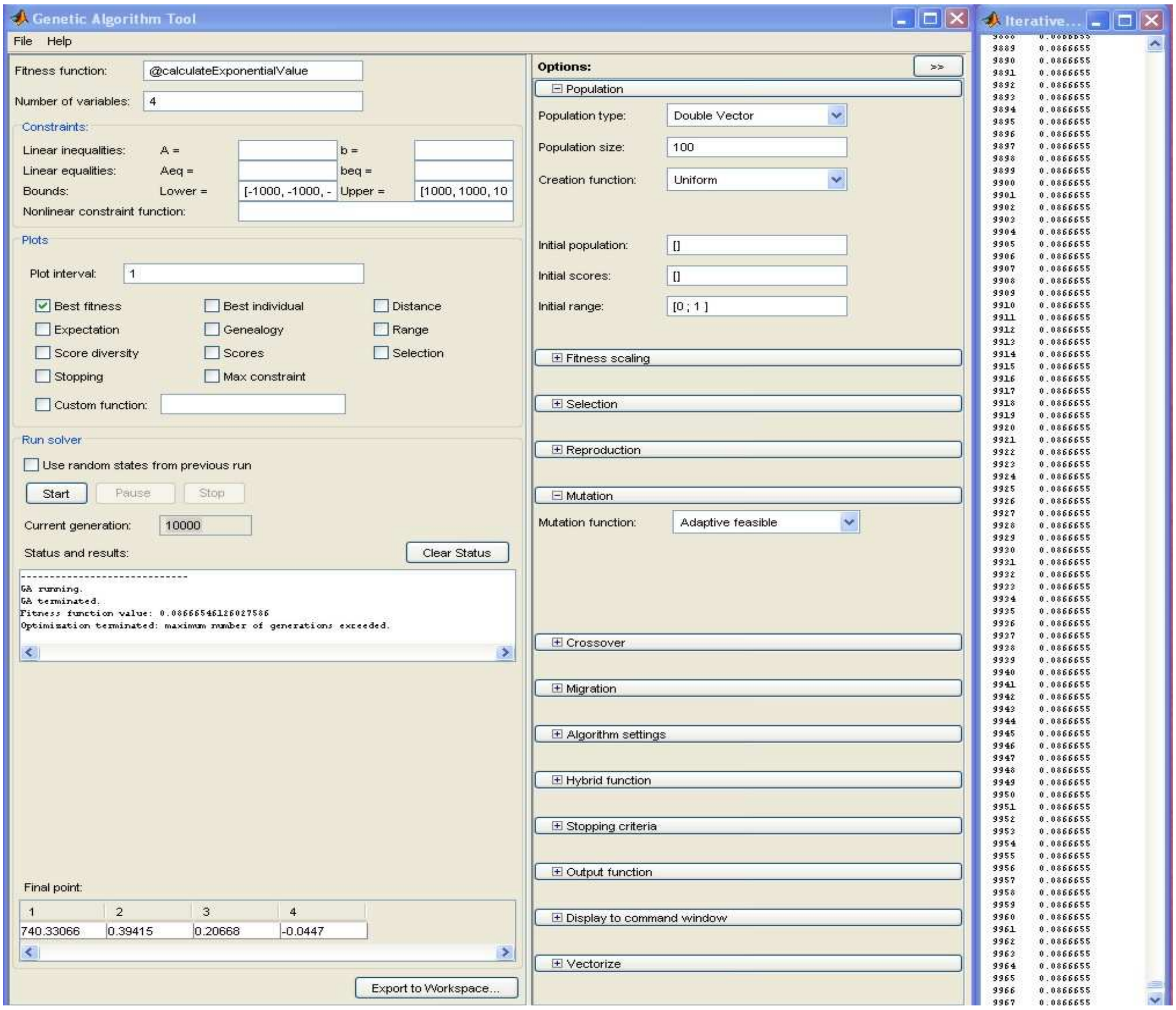

Figure 1. Coefficients value of the presented GA in Matlab for example 1.

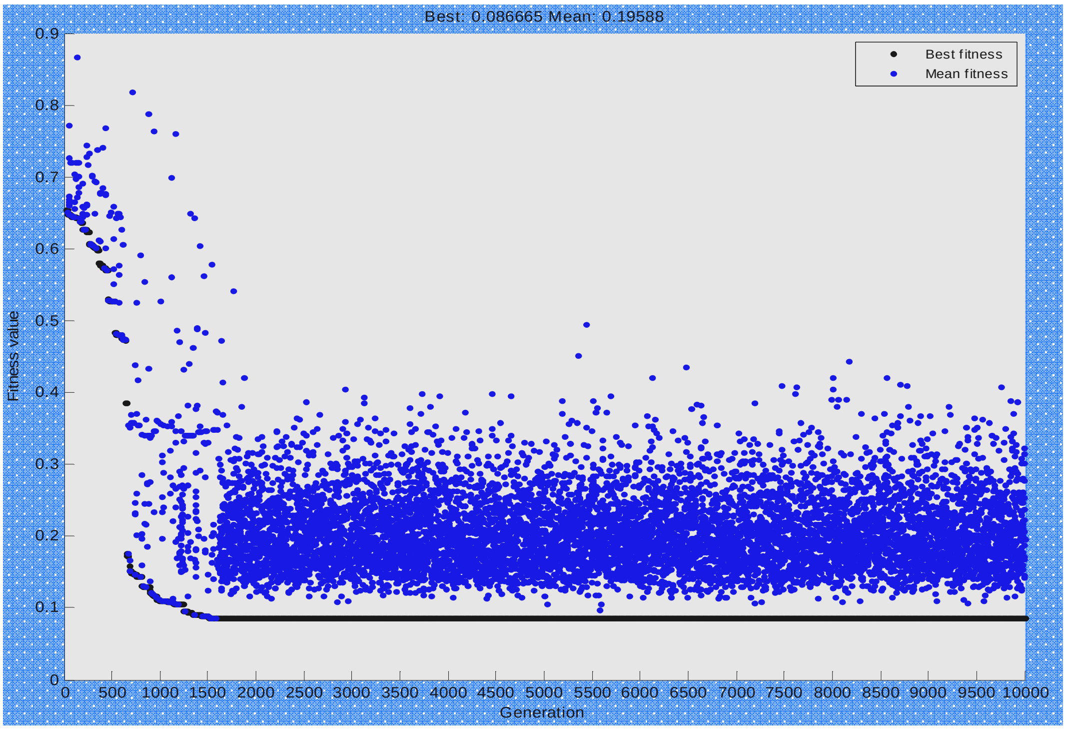

Figure 2. Goal function through generations for example 1.

In this example (example No. 2) the model is the same like in the example 1 the difference being only in the model's width of limits. In this example the limits are significantly narrower for the 2., 3. and 4. coefficient [-1000, -1, -1, -1] to [1000, 1, 1, 1] because in the previous example it was shown that such wide limits are not required. The coefficients have the following values: C=20,91275, α_1=0,38038, β_1=0,44881 and γ_1=-0,85385.
The modeling was performed for 10000 generations and population of 100 individuals and the achieved model has the medium deviation error from experimental values of 2,31% which is significantly better than in the example 1. and for the limits width of [-1000, +1000] with the associated coefficients. Deviation of 2,31% was achieved in the very beginning after 200 generations.
In this example (example No. 3) the start model was changed so it looks like this:

$$p_v = C + \alpha_1 \ln G + \beta_1 \ln V_E + \gamma_1 \ln R \quad \text{(bar)} \qquad \ldots(3)$$

The form of this model is the same like the form of the model achieved in equation (1). The values of coefficients of the model amount to:

C= -1705,38958,
α_1=296,11539,
β_1=314,89275 and
γ_1=-649,59211.

The modeling was performed for 10000 generations and population of 100 individuals and the achieved model has the medium deviation error from experimental values of 1,09% which is significantly better than in the presented example 1 and example 2. It is also better than the deviation achieved by mathematic modeling because medium deviation in that model is 1,21%.

Deviation of 1,09% was achieved in the first process quarter or after 2000 generations, which can be seen in Figure (3). These are the limits where the required model coefficients are: [-2000, -1000, -1000, -1000] to [2000, 1000, 1000, 1000].

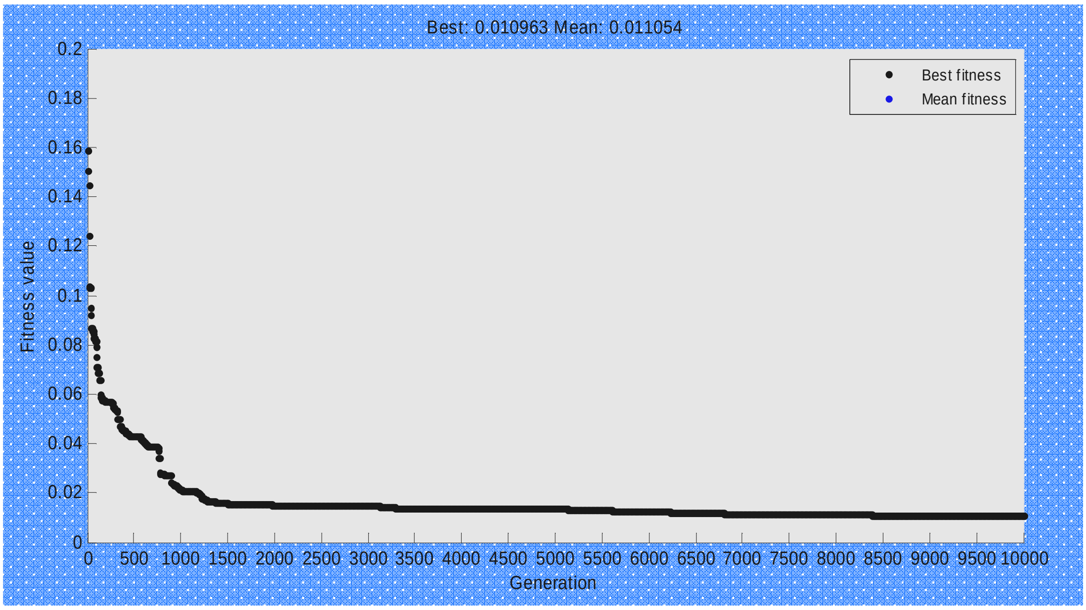

Figure 3. Goal function through generations for example 3.

In this example (example No. 4) a model with only one unknown coefficient was changed and it has the following form:

$$p_v = C \ln\left(\frac{G \cdot V_E}{R}\right) \quad \text{(bar)} \qquad \ldots(4)$$

The value of model coefficients amounts C=129,19491.
Modeling was performed for 10000 generations and population of 100 individuals and the achieved model has the medium deviation error significantly higher than experimental values. The error which this model provides amounts to 11,28% which is worse than in example 3, but the model has a more concise form which was responsible for the worse approximation.
In this example (example No. 5) changes are similar to the previous example. This model also has a concise form and it is presented by equation (5). The difference between equation (5) and equation (4) lies in the fact that in the last one a coefficient C was added which is added to the rest of the amount in equation (5) while in the previous equation this was not the case.

$$p_v = C + \alpha_1 \ln\left(\frac{G \cdot V_E}{R}\right) \quad \text{(bar)} \qquad \ldots(5)$$

The values of model coefficients amount to: C= -1188,40672 and α_1= 345,07485 and the goal function is presented in Figure (4).
Modeling was performed for 10000 generations and population of 100 individuals and the achieved model has the medium deviation error from experimental values 4,19%, which is worse than in example 3 where the genetically modelled expression was achieved by mathematic model (1) or (3) but significantly better result or smaller deviation error than the model from the previous model or example No. 4.
The amount of medium deviation error of this model in relation to deviation from experimental values is found in the conciseness of the model or in the smaller number of coefficients.

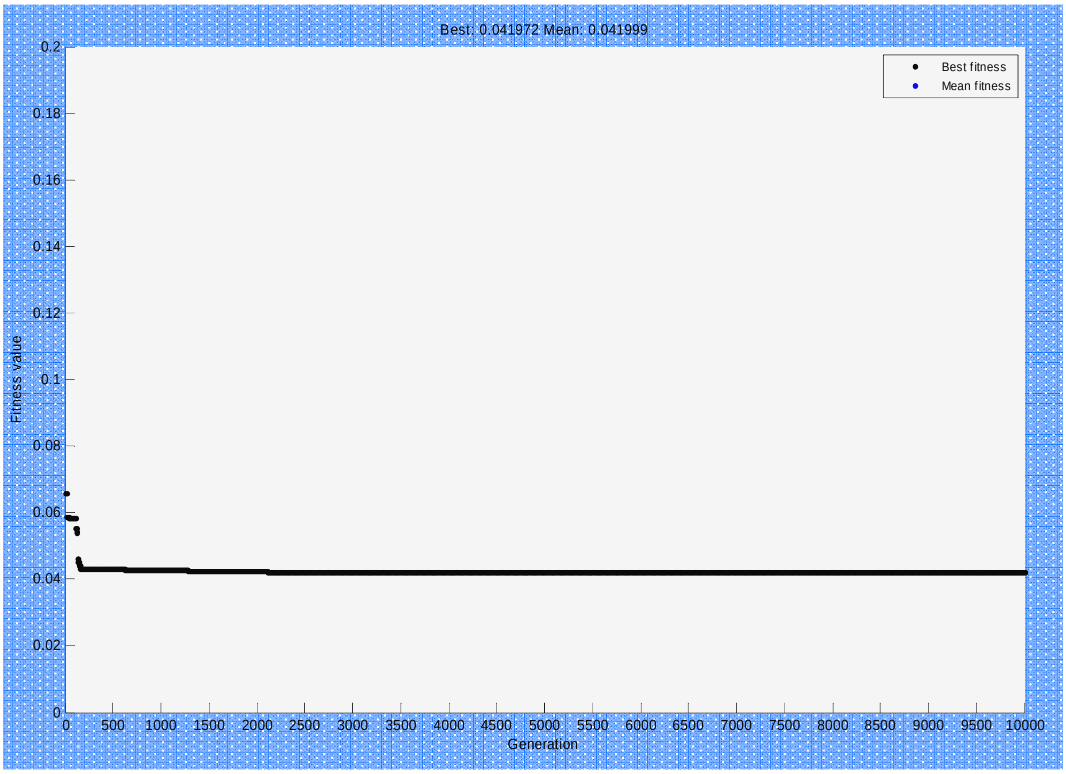

Figure 4. Goal function through generations for example 5.

3. GENETIC PROGRAMMING (GP)

Genetic programming is an often applied genetic algorithm and is regarded as the most acceptable method of the evolutionary learning [3,4,5]

Control parameters in our case for GP are:

- generation 1000
- population 1000
- intersection 90%
- operators (+, -, *, exp)

Based on these 4 operators (generation 1000; population 1000; intersection 90% and operators (+, -, *, exp) a mathematical model of shock wave pressure in the form (6) with the deviation from the experimental value of 11,22% is achieved which represents a significant deviation.

The final shape of the model after 1000 generations is given by the following equation:

(((x3+((x3+x3)+((((x2+x1)+x2)+x2)*x1)))-
(x3+(((x1*(x3+((x3+((x3+x3)+x2))*x1)))*x1)*((x3+x3)+((x3+
(((((x1*((((x2+x1)+x2)+x2)+(-4.716*x2)))+(x1*((-4.716*x2)+
(x1*((-4.716*x2)+(-4.716*x2))))))+(((x1*(-4.716*x2))+ …(6)
(x1*(-4.716*x2)))+(x3+x3)))+((-4.716*x2)*x1))*x1))+
(((((x1*(-4.716*x2))+(x1*(-4.716*x2)))+
(x3+x3))+(x1+x1))+
(x3+x3)))))))-((-4.716*x2)*x1))

GP programme was started one more time but with 2000 population of individuals and a significantly better result was achieved where the deviation from the experimental value was 2,829%.

Control parameters for GP in this case are:

- generation 1000
- population 2000

– intersection 90%
– operators (+, -, *, exp)

The final shape of the model after 1000 generations was given by the equation (7):

((x2-((((((((((((((-3.074*x1)-(((x3+((x3-((x3-x2)*(x1+x1)))-
(2.71828183exp6.246)))+x3)-(2.71828183exp6.246)))*x1)*(x3-
((2.71828183exp6.246)+x3)))*x1)*(x3-(x1-((x3-((x3-x2)*(x1+x1)))-
(2.71828183exp6.246)))))*((2.71828183exp6.246)-(-8.572- …(7)
(2.71828183exp6.246))))*x1)+(((2.71828183exp6.246)*x1)*(x2+
(-8.572*(2.71828183exp6.246))))))*x1)+x2)+(x2+
(-8.572*((2.71828183exp6.246)-x3))))*(-3.074*x1))-(x1-
(((x3+x3)-(2.71828183exp6.246))-
(2.71828183exp6.246))))+x3))-(x2+x1))

4. CONCLUSION

Based on the presented it is noticeable that it is necessary to approach to each problem to be solved and to deal with all its specific qualities to make the modeling work and for us to be satisfied with the achieved result. For successful optimisation it is necessary to define successfully the goal function which needs to copy the problem being solved. In practice there are often certain limitations which need to be overcome in some way. In its work the genetic algorithm generates generations or population whose fitness is better from cycle to cycle, in what we convinced ourselves in this work also. The reliability of results can be increased by repeated repetitions, and with good selection of coefficients or model limits time of work can be significantly reduced with the same or even better results.

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1st International Scientific Conference on Engineering
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FAKTORI KONCENTRACIJE NAPONA ZA SLUČAJ OTVORA SA CIJEVNIM PRIKLJUČKOM U POSUDI POD PRITISKOM

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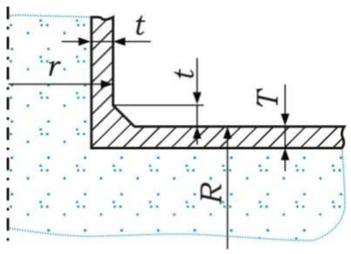
REZIME

U radu su primijenjene numeričke metode za istraživanje koncentracije napona oko otvora u cilindričnoj posudi pod unutarnjim pritiskom sa ojačanjem u obliku cijevnog priključka zavarenog na plašt posude. Za ovaj slučaj su razvijeni različiti matematički modeli (izrazi) za geometrijske faktore koncentracije napona definirane preko maksimalnih glavnih napona i ekvivalentnih von Mises napona na vanjskoj i unutarnjoj strani posude. Izrazi su razvijeni matematičkim modeliranjem u softveru MATLAB, na osnovu rezultata FEM analize u softveru ABAQUS na 34 modela sa različitom geometrijom, eksperimentalne tačke dobivene pomoću planiranja eksperimenta, također u softveru MATLAB. Dobiveni izrazi su evaluirani usporedbom sa postojećim izrazima u literaturi i sa rezultatima FEM analize na dodatnih 5 modela.

Ključne riječi: koncentracija napona, posude pod pritiskom, cijevni priključak, matematičko modeliranje, FEM analiza

1. OPIS PROBLEMA

U radu se istražuje koncentracija napona kod otvora u cilindričnim posudama pod pritiskom sa ojačanjem u vidu cijevi, tj, priključka na posudu u obliku cijevi i to izvedba kod koje je cijev zavarena na vanjski plašt zavarom koji prolazi kroz čitavu debljinu stjenke cijevi (*eng. set-on* ili *flush nozzle*). Četiri dimenzije usvojene u radu s kojim se u potpunosti može geometrijski definirati otvor i priključak su vanjski radijus posude pod pritiskom R, debljina stjenke posude pod pritiskom T , vanjski radijus cijevnog priključka r i debljina stjenke cijevnog priključka t s kojom je definirana i visina zavara, slika 1.



Slika 1. Poprečni presjek otvora sa cijevnim priključkom zavarenim na plašt cilindrične posude.

Pošto je istraživanje usmjereno na geometrijske uzroke koncentracije napona usvojene su tri utjecajne varijable u vidu geometrijskih odnosa četiri prethodno spomenute dimenzije:

$$x_1 = \frac{r}{R},\ x_2 = \frac{R}{T}\ x_3 = \frac{T}{t} \qquad ...(1)$$

Posuda i priključak su opterećeni unutarnjim pritiskom u posudi i cijevnom priključku p i aksijalnom silom na cijevnom priključku koja odgovara sili pritiska na otvoru cijevi F (slika 2), datom sa:

$$F = p \cdot A = p \cdot (r-t)^2 \cdot \pi \,, \qquad ...(2)$$

koja izaziva zatezni napon u priključku:

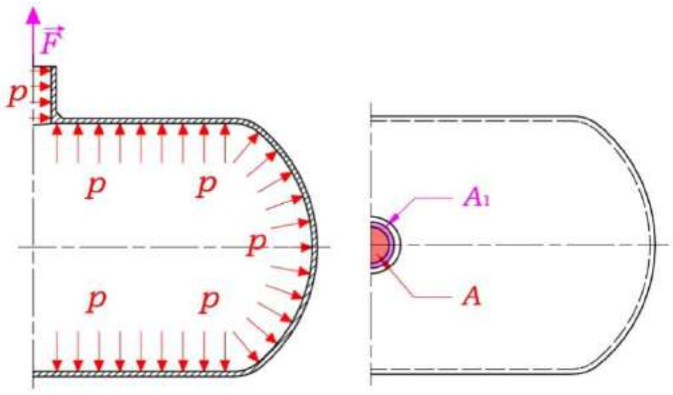
$$\sigma_1 = \frac{F}{A_1} = \frac{F}{\left[r^2 - (r-t)^2\right] \cdot \pi} \qquad ...(3)$$

U teoriji se faktor koncentracije napona definira kao odnos maksimalnog napona i nominalnog napona:

$$K = \frac{\sigma_m}{\sigma_n} \qquad ...(4)$$

Za nominalni napon uzet je teorijski poprečni (cirkularni) napon za tankostjene cilindrične posude, dat sa:

$$\sigma_n = \frac{p \cdot (R-T)}{T} \qquad ...(5)$$



Slika 2. Opterećenje posude i priključka.

Za maksimalni napon upotrijebljeni su maksimalni ekvivalentni von Mises napon i maksimalni glavni napon tako da su definirana dva tipa faktora koncentracije napona, jedan definiran preko ekvivalentnog von Mises napona (K_{VM}) i drugi definiran preko maksimalnog glavnog napona (K_P). Maksimalni naponi su očitavani na unutarnjoj strani posude (indeks i) i vanjskoj (indeks e) te su na taj način definirana četiri faktora koncentracije napona:

$$K_{VMi} = \frac{\sigma_{VMi}}{\sigma_n};\; K_{VMe} = \frac{\sigma_{VMe}}{\sigma_n};\; K_{Pi} = \frac{\sigma_{Pi}}{\sigma_n};\; K_{Pe} = \frac{\sigma_{Pe}}{\sigma_n} \qquad ...(6)$$

Također su određivani i faktori koncentracije napona koji daju maksimalnu vrijednost bez obzira na lokaciju napona, definirani sa:

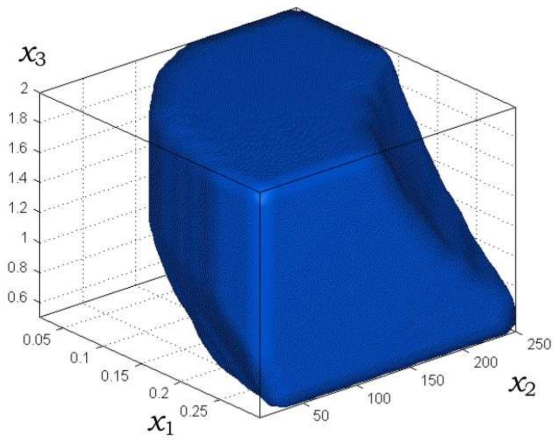
$$K_{VMmax} = \max\{K_{VMi}, K_{VMe}\}\;;\; K_{Pmax} = \max\{K_{Pi}, K_{Pe}\} \qquad ...(7)$$

Pri razmatranju koncentracije napona smatrano je da su dužina posude i dužina cijevnog priključka beskonačne, tj. dimenzija većih od neke kritične vrijednosti pri kojoj dalja promjena ne utiče više na koncentraciju napona.

3. PLANIRANJE EKSPERIMENTA

Za planiranje eksperimenta je korišten softverski paket MATLAB (ver 7.0) tj. njegov modul *Model-Based Calibration Toolbox*. Prije planiranja eksperimenta bilo je potrebno za svaku varijablu odrediti opseg koji će se istraživati i ograničenja u samom opsegu istraživanja u zavisnosti od međusobnih odnosa utjecajnih varijabli. Za opseg istraživanja usvojene su sljedeće granične vrijednosti za utjecajne varijable:

$$0{,}02 \le x_1 \le 0{,}3; \quad 10 \le x_2 \le 250; \quad 0{,}5 \le x_3 \le 2 \;........(8)$$



Slika 3. Prostor eksperimenta.

Pored samih opsega istraživanja za utjecajne varijable potrebno je bilo definirati još dva geometrijska ograničenja i to u pogledu odnosa radijusa cijevnog priključka i debljina stjenki, prvo stjenke posude i drugo stjenke cijevnog priključka. Ograničenja su usvojena da bi se izbjegle geometrije priključka koje bi bile neizvedive, nestandardne ili konstrukciono nelogične. Ograničenja su data sa:

$$r/T > 2; \quad 2 < r/t < 50 \qquad ...(9)$$

Ako se upotrijebe izrazi koji definiraju utjecajne varijable (1) ova ograničenja se mogu izraziti i kao:

$$x_1 > \frac{2}{x_2}; \quad \frac{2}{x_2 \cdot x_3} < x_1 < \frac{50}{x_2 \cdot x_3} \qquad ...(10)$$

Na osnovu datih ograničenja dobio se konačni oblik prostora eksperimenta prikazan na slici 3.
Za planiranje eksperimenta u MATLAB-u je odabrana opcija optimalnog dizajna eksperimenta i *V-optimal* kriterij za odabir eksperimentalnih tačaka. Za algoritam generiranja tačaka odabrana je grid metoda, tj. odabir tačaka iz prethodno definirane mreže tačaka i to na taj način da se za svaku utjecajnu varijablu definira određeni broj nivoa. Za varijablu x_1 definirano je 29 nivoa, x_2 25, a x_3 10 nivoa. Na kraju je dobiven plan eksperimenta od 34 tačke dat u tabeli 1.

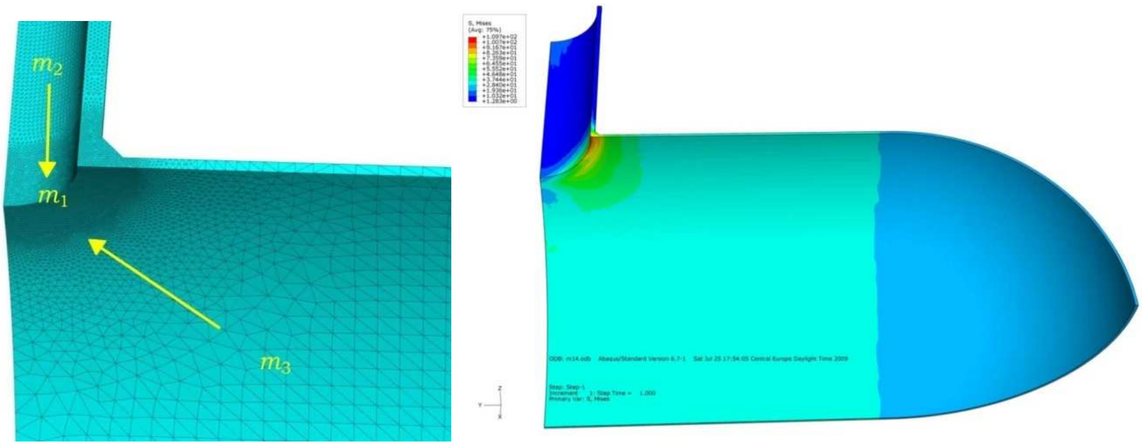
Tabela 1. Plan eksperimenta

Eksper. tačka / Varijabla	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
x_1	0,25	0,12	0,3	0,29	0,3	0,19	0,08	0,21	0,04	0,08	0,15	0,3	0,07	0,28	0,17	0,03	0,28
x_2	10	20	20	20	20	20	30	30	50	50	60	70	80	80	80	90	90
x_3	1,5	2	0,9	0,5	2	0,7	1,25	1,5	2	0,5	0,5	1,5	1,75	0,6	2	0,8	2
Eksper. tačka / Varijabla	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
x_1	0,16	0,02	0,07	0,3	0,03	0,14	0,2	0,02	0,3	0,05	0,27	0,02	0,07	0,02	0,16	0,14	0,05
x_2	110	150	160	160	170	170	180	200	220	230	250	250	250	250	250	250	250
x_3	1	1,25	0,6	0,9	2	1,75	0,5	0,5	0,5	1,25	0,7	1,75	2	0,8	1,25	0,7	0,5

Na osnovu dobivenog plana eksperimenta određene su sve ostale dimenzije potrebne za definiranje FEM modela u svrhu izvođenja numeričke analize na svakoj od eksperimentalnih tačaka. Kao polazna i konstantna dimenzija za svaku eksperimentalnu tačku je uzeta debljina stjenke plašta posude, i to vrijednosti $T = 5$.

4. FEM ANALIZA

Numerička analiza izvršena je pomoću softvera ABAQUS/CAE, verzija 6.7-1. FEM analiza se radila sa osminom (1/8) čitavog dijela, slika 4.b, pošto su se mogle definirati tri ravni simetrije.
Za izradu modela su odabrani 3D solid elementi u obliku tetraedra zbog modeliranja prijelaza sa ljuske posude na cijevni priključak. Oblik tetraedra je izabran zbog najjednostavnije automatske izrade mreže sa ovim oblikom. Upotrijebljene su tri veličine mreže (slika 4.a): veličina na mjestu koncentracije napona, tj. na prijelazu sa posude na priključak veličina mreže na priključku, veličina mreže na plaštu cilindrične posude. Prilikom izrade modela učinjen je veliki trud da se između različitih veličina mreže ostvari postepen prijelaz.



Slika 4. FEM analiza: a) prikaz mreže, b) raspored von Mises napona za model (eksp. tačku) 14

Pod navedenim uvjetima obavljena je FEM anliza na 34 različita modela (prema tabeli 1) i za svaki model su očitavane vrijednosti maksimalnog ekvivalentnog von Mises i glavnog napona na unutarnjoj (σ_{VMi} *i* σ_{Pi}) i vanjskoj strani posude (σ_{VMe} *i* σ_{Pe}). Na osnovu rezultata FEM analize za svaku eksperimentalnu tačku je određeno 6 faktora koncentracije napona prema (6) i (7). Izračunati faktori koncentracije napona su dati u tabeli 2.

Tabela 2. Rezultati FEM analize.

Model	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
K_{VMe}	1,36	1,29	1,53	1,32	2,03	1,29	1,22	1,81	1,16	1,33	1,44	3,81	1,53	2,78	3,08	1,35	5,31
K_{Pe}	1,58	1,50	1,79	1,53	2,47	1,50	1,43	2,09	1,37	1,57	1,66	4,50	1,81	3,32	3,62	1,60	6,08
K_{VMi}	3,31	2,94	2,84	2,10	3,70	2,29	2,73	3,13	2,75	1,87	1,93	4,34	2,61	2,54	3,60	2,37	6,49
K_{Pi}	3,26	2,95	2,89	2,12	3,69	2,29	2,74	3,11	2,75	1,90	1,94	3,96	2,62	2,54	3,23	2,41	4,47
K_{VMmax}	3,31	2,94	2,84	2,10	3,70	2,29	2,73	3,13	2,75	1,87	1,93	4,34	2,61	2,78	3,60	2,37	6,49
K_{Pmax}	3,26	2,95	2,89	2,12	3,69	2,29	2,74	3,11	2,75	1,90	1,94	4,50	2,62	3,32	3,62	2,41	6,08
Model	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
K_{VMe}	2,81	1,19	1,49	5,10	1,41	3,58	3,15	1,31	4,45	1,83	4,90	0,94	2,61	1,18	4,32	3,50	1,49
K_{Pe}	2,99	1,44	1,78	5,92	1,66	3,99	3,60	1,58	4,86	2,07	5,60	1,06	3,12	1,39	4,59	3,86	1,73
K_{VMi}	2,78	2,47	2,00	4,76	2,59	4,09	2,46	1,82	4,43	2,47	4,97	1,96	3,17	2,09	4,14	3,01	1,82
K_{Pi}	2,80	2,51	2,01	3,85	2,60	3,33	2,46	1,87	3,08	2,48	3,67	1,98	2,81	2,13	3,45	2,73	1,84
K_{VMmax}	2,81	2,47	2,00	5,10	2,59	4,09	3,15	1,82	4,45	2,47	4,97	1,96	3,17	2,09	4,32	3,50	1,82
K_{Pmax}	2,99	2,51	2,01	5,92	2,60	3,99	3,60	1,87	4,86	2,48	5,60	1,98	3,12	2,13	4,59	3,86	1,84

5. MATEMATIČKO MODELIRANJE FAKTORA KONCETRACIJE NAPONA

Vrijednosti faktora koncentracije napona određenih FEM analizom su korištene za matematičko modeliranje izraza za faktore koncentracije napona. Ponovno je korišten MATLAB modul - *Model-Based Calibration Toolbox.* Za sve faktore odabrani su matematički modeli sa varijablama x_1, x_2 i x_3 (1) u obliku polinoma trećeg reda (jedan član trećeg reda - $x_1 \cdot x_2 \cdot x_3$) sa 11 članova u obliku:

$$K(R) = C + x_1 + x_2 + x_3 + x_1^2 + x_2^2 + x_3^2 + x_1 \cdot x_2 + x_2 \cdot x_3 + x_1 \cdot x_3 + x_1 \cdot x_2 \cdot x_3 \qquad ...(11)$$

Na modele dobivene u obliku (11) je primijenjena *stepwise*[1] regresija s ciljem smanjenja broja članova u izrazima. U MATLAB-u alatu za *stepwise* regresiju date su opcije analize modela i isključivanja nepotrebnih članova preko minimiziranja PRESS[2]-a, te dodavanja ili oduzimanja članova na osnovu njihove statističke značajnosti (*forward selection* i *backward selection*). U svakom modelu faktora koncentracije napona su kao obavezni članovi postavljeni konstanta *C* i članovi prvog reda x_1, x_2 i x_3. Na taj način su dobiveni matematički modeli (izrazi) sa 7 do 9 članova, izrazi (12) - (17), čije su statističke karakteristike (PRESS i RMSE[3]) date u tabeli 3.

Tabela 3. Statističke karakt. modela.

Model	Broj varijabli	PRESS	RMSE
K_{Pe}	7	0,26831	0,23397
K_{pi}	8	0,13305	0,11344
K_{Pmax}	9	0,31659	0,25419
K_{VMe}	7	0,21434	0,19107
K_{VMi}	7	0,30399	0,26428
K_{Vmax}	7	0,31175	0,27045

$$K_{Pe} = 0,27348 + 3,0613 \cdot x_1 + 0,01537 \cdot x_2 + 0,1513 \cdot x_3$$
$$-3,9985 \cdot 10^{-5} \cdot x_2^2 - 0,003939 \cdot x_2 \cdot x_3 + 0,079389 \cdot x_1 \cdot x_2 \cdot x_3, \qquad ...(12)$$

$$K_{Pi} = 1,09966 - 3,27651 \cdot x_1 + 0,00104462 \cdot x_2 + 2,08996 \cdot x_3$$
$$+13,3122 \cdot x_1^2 - 0,00330398 \cdot x_2 \cdot x_3 - 0,544791 \cdot x_3^2 + 0,0325689 \cdot x_1 \cdot x_2 \cdot x_3, \qquad ...(13)$$

$$K_{P\max} = 1,43784 - 7,29789 \cdot x_1 + 0,000105632 \cdot x_2 + 1,77632 \cdot x_3 + 23,5808 \cdot x_1^2$$
$$+0,0257301 \cdot x_1 \cdot x_2 - 0,00401808 \cdot x_2 \cdot x_3 - 0,436422 \cdot x_3^2 + 0,051932 \cdot x_1 \cdot x_2 \cdot x_3, \qquad ...(14)$$

$$\mathrm{K_{VMe}} = 0,33158 + 2,3346 \cdot x_1 + 0,012213 \cdot x_2 + 0,08551 \cdot x_3$$
$$-3,0437 \cdot 10^{-5} \cdot x_2^2 - 0,0035661 \cdot x_2 \cdot x_3 + 0,073645 \cdot x_1 \cdot x_2 \cdot x_3, \qquad ...(15)$$

---

[1] regresiona analiza kod koje se odabir varijabli obavlja pomoću automatske procedure
[2] PRESS RMSE - Root mean squared error of predicted errors
[3] RMSE - Root mean squared error

$$K_{VMi} = 2,09081 - 9,45074 \cdot x_1 + 0,000341899 \cdot x_2 + 0,699098 \cdot x_3 + 29,2076 \cdot x_1^2 - 0,00449633 \cdot x_2 \cdot x_3 + 0,0700269 \cdot x_1 \cdot x_2 \cdot x_3, \quad ...(16)$$

$$K_{VM\max} = 1,85115 - 6,4398 \cdot x_1 + 0,00158961 \cdot x_2 + 0,695058 \cdot x_3 + 22,013 \cdot x_1^2 - 0,00478669 \cdot x_2 \cdot x_3 + 0,0681525 \cdot x_1 \cdot x_2 \cdot x_3, \quad ...(17)$$

Vrijednosti faktora koncentracije napona izračunatih preko modela (12)-(17) pokazuju dobro slaganje sa rezultatima FEM analize i za većinu tačaka odstupanja su ispod 10%.

6. EVALUACIJA MATEMATIČKIH MODELA FAKTORA KONCENTRACIJE NAPONA

U literaturi su pronađena dva izraza (matematička modela) za faktor koncentracije napona kod otvora sa cijevnim priključkom u cilindričnim posudama pod pritiskom. Oba modela su bazirana na tenzometrijskim mjerenjima i definirana su na osnovu maksimalnog glavnog napona.
Uspoređujući različita istraživanja Money [5] je ustanovio da faktor koncentracije napona ima najbolju korelaciju sa faktorom:

$$M = \left(r/t\right)^2 \left(T/R\right) \quad ...(18)$$

i dao izraz za faktor koncentracije napona (*SCF*) u ovisnosti od *M* (u opsegu 1<M<100) u obliku:

$$\log SCF = 0,2042 \cdot \log M + 0,3979 \quad ...(19)$$

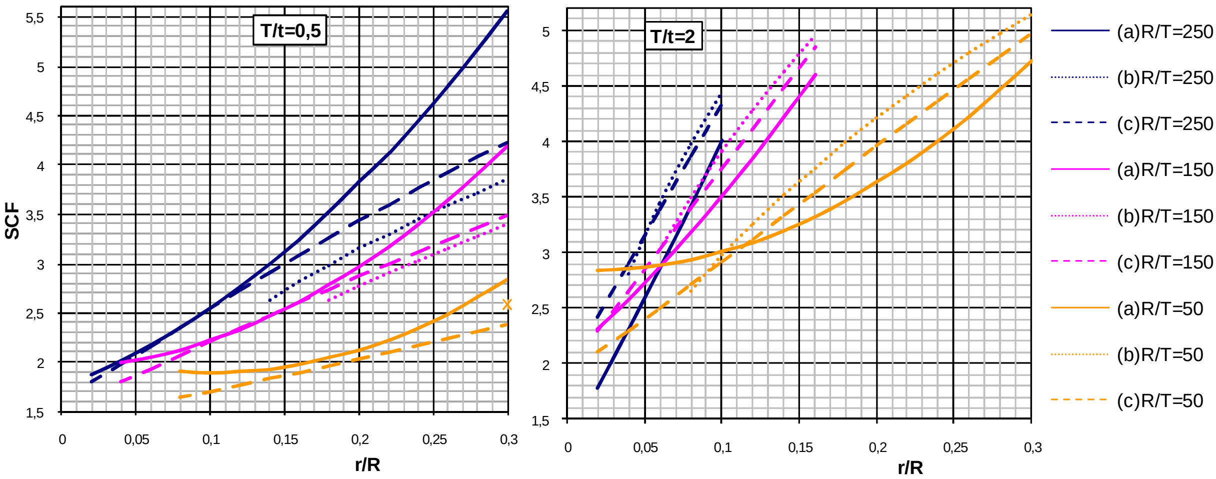
Izraz (19) se koristio za izradu standarda BSI 5500 u revidiranom obliku (povećanje koeficijenta sa 0,2042 na 0,25) u obliku:

$$\log SCF = 0,25 \cdot \log M + 0,3979 \quad ...(20)$$

Decock [4] je na osnovu 29 tenzometrijskih mjerenja na posudama pod pritiskom u opsegu odnosa dimenzija $D/T = 15 \div 255$ i $d/D = 0,0087 \div 0,9$ dao model u obliku:

$$SCF = \frac{2 + \dfrac{2d}{D}\sqrt{\dfrac{dt}{DT}} + \dfrac{1,25d}{D}\sqrt{\dfrac{D}{T}}}{1 + \dfrac{t}{T}\sqrt{\dfrac{dt}{DT}}} \quad ...(21)$$

Sa ova dva modela iz literature uspoređen je njima odgovarajući model definiran preko maksimalnog glavnog napona (14). Usporedba je obavljena pomoću dijagrama faktora koncentracije napona (crtanih za svaki model u opsegu njihovih validnosti), a na slici 5 su prikazani dijagrami za vrijednosti za T/t = (0,5; 2) gdje su uočene najveće razlike.



Slika 5. Dijagrami faktora koncentracije napona (SCF) prema različitim modelima:
(a)-K_{Pmax} (14), (b)-Money (20), (c)-Decock (21), za T/t = (0,5; 2) i tri nivoa $R/T = 50; 150; 250$

Za područja T/t =(0,75; 1 i 1,5) model (14) je pokazao vrlo dobro podudaranje sa modelima iz literature, ali zbog nedostatka prostora u radu ti dijagrami nisu prikazani.

U radu nije vršena detaljnija analiza uočenih razlika jer nisu bili dostupni svi detalji istraživanja Money-a i Decock-a, te eksperimentalna postavka i rezultati na osnovu kojih su razvijeni modeli (20) i (21).

Na pet dodatnih evaluacijskih eksperimentalnih tačaka izvršila se FEM analiza s ciljem usporedbe tih rezultata sa vrijednostima koje su se dobiju putem matematičkih modela faktora koncentracije napona izvedenih u ovom radu. Evaluacijske eksperimentalne tačke su definirane sa varijablama x_1, x_2 i x_3 kao i modeli. Dopunske eksperimentalne tačke se nalaze unutar granica prostora eksperimenta (8) uz definirana ograničenja u prostoru eksperimenta (10), a odabrane su tako da se nalaze između eksperimentalnih tačaka korištenih za dobijanje modela faktora koncentracije napona, tabela 1. Dopunske eksperimentalne tačke sa osnovnim dimenzijama posude su date u tabeli 3. U tabeli 4 su dati rezultati evaluacije, maksimalne i minimalne procentualne vrijednosti odstupanja za svaki faktor koncentracije napona, te prosjek apsolutnih vrijednosti odstupanja.

Tabela 3. Dodatne eksperimentalne tačke za evaluaciju modela koncentracije napona

Eksp. tačka.	Utjecajne varijable		
	x_1	x_2	x_3
1.	0,1	140	0,746
2.	0,11	200	0,5
3.	0,14	100	1,515
4.	0,153	30	2
5.	0,23	120	1

Tabela 4. Odstupanja evaluacijskih eksperimentalnih tačaka.

	Faktori koncentracije napone					
Odstupanje	K_{VMe}	K_{Pe}	K_{VMi}	K_{Pi}	K_{VMmax}	K_{Pmax}
Max.	1,5%	-3,4%	0,6%	5,6%	-2,4%	-0,2%
Min.	-12,4%	-7,7%	-7,0%	-3,7%	-13,1%	-12,6%
Prosjek (aps. vr.)	6,4%	6,0%	4,2%	2,5%	6,7%	4,9%

7. ZAKLJUČAK

U radu su za istraživani slučaj koncentracije napona razvijena četiri različita matematička modela (izraza) za faktore koncentracije napona definirana preko maksimalnih glavnih napona i ekvivalentnih von Mises napona na vanjskoj i unutarnjoj strani posude (K_{pe}, K_{VMe}, K_{Pi}, K_{VMi}), te još dva matematička modela (izraza) za faktore koncentracije napona definirana na osnovu maksimalnih glavnih napona i ekvivalentnih von Mises napona bez obzira na lokaciju (K_{pmax}, K_{VMmax}). Matematički modeli faktora koncentracije napona su razvijeni na osnovu rezultata FEM analize na 34 različite geometrije, eksperimentalne tačke dobivene pomoću planiranja eksperimenta u softveru MATLAB.

Predvidljivost dobivenih matematičkih modela za faktore koncentracije napona je evaluirana pomoću dodatnih FEM analiza i ovdje je ustanovljena dobra podudarnost, sa prosječnim odstupanjima ispod 10%. Matematički model faktora koncentracije napona definiran preko maksimalnog glavnog napona (K_{Pmax}) je uspoređen sa dva modela iz literature (20) i (21) putem usporednih dijagrama koji su pokazali podudaranje krivih faktora koncentracije napona u većem dijelu istraživanog opsega.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

INFLUENCE OF RESIDUAL STRESSES ON CRACK KINKING INTO THE INTERFACE BETWEEN THE TWO ELASTIC MATERIAL

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ABSTRACT
In this paper is considered influence of residual stresses on crack deflection into the interface between the twp different elastic materials. The crack approaching interface can propagate in such a way that it would either penetrate the interface or it would deflect and continue to advance along the interface. The "competition" between the penetration and deflection can be estimated by comparison of the ratio of the energy release rate needed for crack deflection into the interface and energy release rate needed for crack to penetrate the interface and ratio of the fracture toughness of the interface and the fracture toughness of the material across the interface. The residual stresses, which are the result of the difference in the thermal expansion coefficients of the two materials, influence the two mentioned energy release rates. Results presented in this paper confirm the significant influence of the difference in the thermal expansion coefficients on the "competition" between the crack penetration and deflection.
Keywords: Crack deflection, residual stresses, interface, energy release rate

1. INTRODUCTION

One of the important problems in considering the crack on interface between the two different materials represents the question what is the role of interface when the crack is approaching it. When the crack comes to an interface it can cross it and continue to propagate in the material above it, or it can deflect into the interface and continue to propagate along it. Those type of questions are important for instance for design of interface between fibers and substrate in the fiber-reinforced composite materials, where the goal is for the crack, which is initiated in the substrate and is approaching the fiber, to deflect and continue to propagate along the interface leaving the fiber intact.

In the paper by He and Hutchinson [1] was analyzed the behavior of a crack which is approaching interface between the two materials at the right angle. The crack behavior is analyzed based on the ratio of the energy release rate for the crack that is deflecting into the interface G_d and the energy release rate for the crack that is crossing the interface G_p. The "competition" between the crack crossing the interface and deflection into it is determined by comparison of the ratio G_d/G_p to the ratio of fracture toughness of the interface, G_{IC} and fracture toughness of the material across the interface G_C. Results presented in [1] are combined with the linear elastic fracture mechanics principles for the interfacial crack, presented in [2], in order to explain the role of the interface in the layered materials. However, in papers [1, 2] the residual stresses were neglected, though in some cases they can be significant. The effect of residual stresses on behavior of a crack approaching interface is considered in this paper.

2. PROBLEM FORMULATION

The crack that is attacking interface at the right angle is shown in Figure 1. For the group of problems illustrated in Figure 1 the start is a semi infinite crack perpendicular to interface in the plane strain conditions with the crack tip at the interface, Figure 1.a).

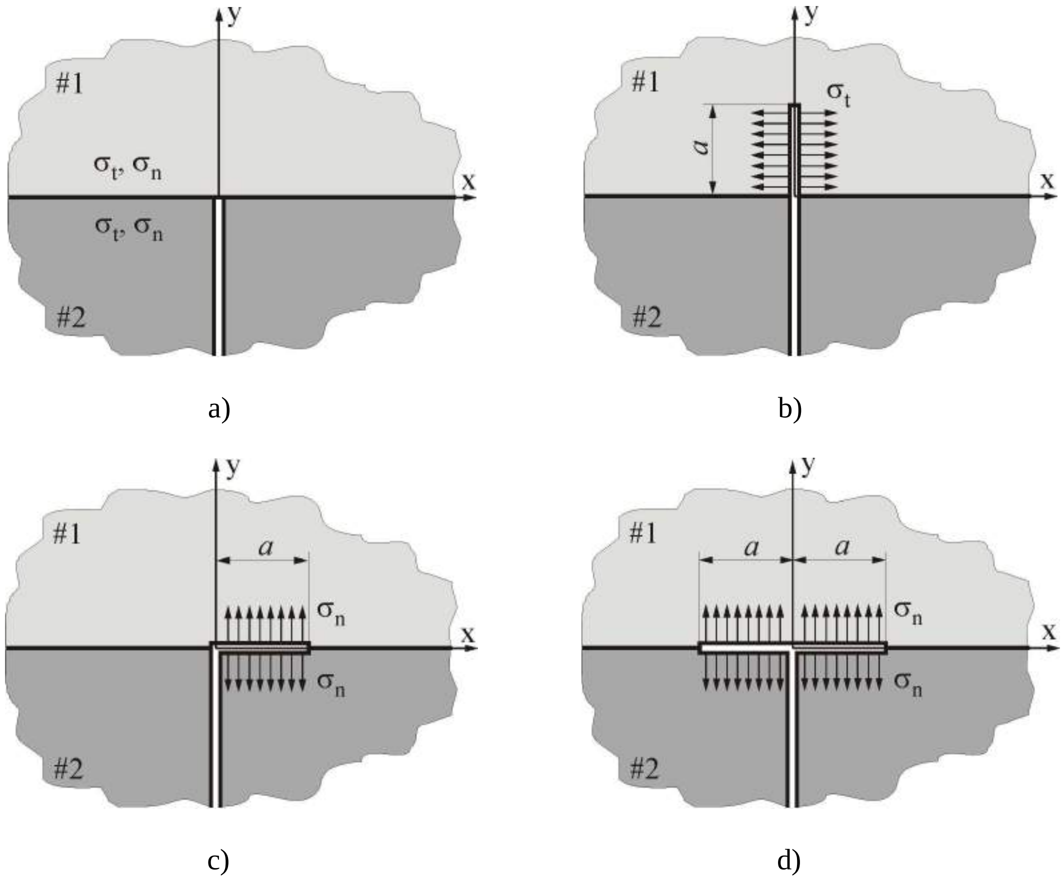


Figure 1. *Crack attacking interface at the right angle*

For the case presented in Figure 1.a) stresses ahead of the crack tip in material 1 are:

$$\sigma_{xx}(0,y) = k_I(2\pi y)^{-\lambda} \quad \ldots(1)$$

where λ is the real variable which is called the stress singularity exponent and it depends on Dundurs parameters α and β according to [1]:

$$\cos\lambda\pi = \frac{2(\beta-\alpha)}{1+\beta}(1-\lambda)^2 + \frac{\alpha+\beta^2}{1-\beta^2}. \quad \ldots(2)$$

The Dundurs-parameters, for the plane strain conditions, are [3]:

$$\alpha = \frac{\bar{E}_1 - \bar{E}_2}{\bar{E}_1 + \bar{E}_2}, \qquad \beta = \frac{\mu_1(1-2\nu_2) - \mu_2(1-2\nu_1)}{2(\mu_1(1-\nu_2) + \mu_2(1-\nu_1))}, \quad \ldots(3)$$

where E, μ and ν are the Young elasticity modulus, the shear modulus and the Poisson' ratio, respectively, and $\bar{E} = E/(1-\nu^2)$. The oscillatory index ε depends on β and is defined as, [3]:

$$\varepsilon = \frac{1}{2\pi}\left(\frac{1-\beta}{1+\beta}\right). \quad \ldots(4)$$

Facto k_I is proportional to load and it is not necessary to know it explicitly. Due to existence of residual stresses, two new dimensionless parameters are introduced: $\eta_n = \frac{\sigma_n a^\lambda}{k_I}$ and $\eta_t = \frac{\sigma_t a^\lambda}{k_I}$, …(5)

where a is the length of a crack that is deflecting into the interface or s crossing it and for which is assumed that is small in comparison to the length of the main crack.

In Figure 1 are then presented three more cases that are important for applications. In Figure 1.b) is shown a crack that passes across the interface. Crack crossing the interface occurs in conditions of the pure Mode I. The crack deflection into the interface happens in conditions of the mixed load mode existence. Crack deflection into the interface can be single sided, Figure 1.c) or double sided, Figure 1.d). Whether crack deflection would be single or double sided depends on the load conditions at the crack tip. The more probable and more frequent is the form of double sided deflection, which occurs when the load phase angle is ψ<45°. The single sided crack deflection into the interface occurs when predominant is the Mode II load at the crack tip. In those cases the load phase angle ψ is greater than 45°.

In the case when the crack is passing across the interface, Figure 1.b), the stress field ahead of the crack tip corresponds to pure Mode I conditions. Based on the dimensional analysis, one comes up to the conclusion that the stress intensity factor amounts to:

$$K_I = c(\alpha,\beta)k_I a^{1/2-\lambda} + h(\alpha,\beta)\sigma_t a^{1/2}, \qquad ..(6)$$

where $c(\alpha, \beta)$ and $h(\alpha, \beta)$ are the dimensionless functions of α and β. In order to decrease the number of parameters, only the influence of parameter α will be considered, while the influence of parameter β is neglected, i.e., β=0. the energy release rate is:

$$G_p = \frac{1-\nu_1}{2\mu_1}K_I^2 = \frac{1-\nu_1}{2\mu_1}(c^2k_I^2a^{1-2\lambda} + 2chk_I\sigma_t a^{1-\lambda} + h^2\sigma_t^2 a)\cdot \qquad …(7)$$

Stress field at the interface ahead of the tip of a crack that is deflecting into the interface, Figure 1.c) and 1.d), is described by [3]:

$$\sigma_{yy}(x,0) + i\sigma_{xy}(x,0) = (K_1 + iK_2)(2\pi r)^{-1/2} r^{i\varepsilon}, \qquad …(8)$$

Where $r=x-a$. Taking into account that β=0, K_1 and K_2 can be considered as the stress intensity factors for Mode II and Mode II, according to the dimensional analysis, one would obtain:

$$K_1 + iK_2 = k_I a^{1/2-\lambda} d(\alpha) + \sigma_n a^{1/2} e(\alpha), \qquad …(9)$$

where d(α) and e(α) are the dimensionless complex functions of α and β=0. The strain release rate for the crack that is deflecting into the interface is:

$$G_d = \frac{(1-\alpha)\bar{E}_1}{1-\beta^2}\left\{k_I^2 a^{1-2\lambda}|d|^2 + k_I\sigma_n a^{1-\lambda}(d\bar{e} + \bar{d}e) + \sigma_n^2 a|e|^2\right\}, \qquad …(10)$$

where $(\bar{\ })$ denotes the complex conjugate function. Ratio G_d/G_p does not depend on a and on k_I and is given with:

$$\frac{G_d}{G_p} = \frac{1}{1-\alpha}\frac{|d|^2 + \eta_n(d\bar{e} + \bar{d}e) + \eta_n^2|e|^2}{c^2 + 2\eta_t ch + \eta_t^2 h^2}. \qquad …(11)$$

Relative tendency of a crack to deflect into the interface or to continue to propagate across it can be determined based on equation (11) and it depends on dimensionless parameters α, η_t and η_n.

The load phase angle, which measures relative value of Mode II with respect to Mode I, for the crack that is deflecting into the interface will be:

$$\psi = \tan^{-1}\left(\frac{K_2}{K_1}\right) = \tan^{-1}\left(\frac{\mathrm{Im}(d) + \eta_n \mathrm{Im}(e)}{\mathrm{Re}(d) + \eta_n \mathrm{Re}(e)}\right). \qquad …(12)$$

If G_{Ic} is the fracture toughness of the interface and G_c is the fracture toughness of material 1, then the crack attacking interface will deflect into it if the following holds:

$$\frac{G_{IC}}{G_C} < \frac{G_d}{G_p}. \quad \ldots(13)$$

3.The crack will pass across the interface if the inequality sign in (13) is reversed.

3. RESULTS AND DISCUSSION

Ratio G_d/G_p is presented in Figure 2 as a function of α and η_t for three values of parameter η_n, i.e., for η_n = - 0.1, 0 and 0.1. Diagrams were obtained by application of equation (11) and "fitting" of the tabular results for dimensionless functions *c*, *h*, *d* and *e*, presented in [4], by the programming routine *Mathematica*.

From Figure 2 can be seen that the ratio G_d/G_p is decreasing with increase of parameter η_t.

In Figure 3 is presented influence of parameter η_n on ratio G_d/G_p for three values of parameter η_t.

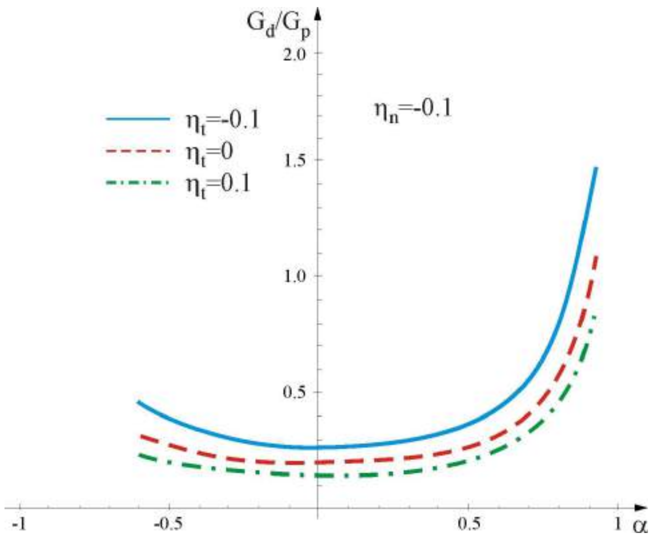
From Figure 3 can be seen that the ratio G_d/G_p increases with increase of parameter η_n, what is a consequence of influence of the residual stresses, that are perpendicular to interface, values change from the positive towards the negative.

In Figure 4 is presented variation of the load phase angle for the interfacial crack for different values of parameter η_n.

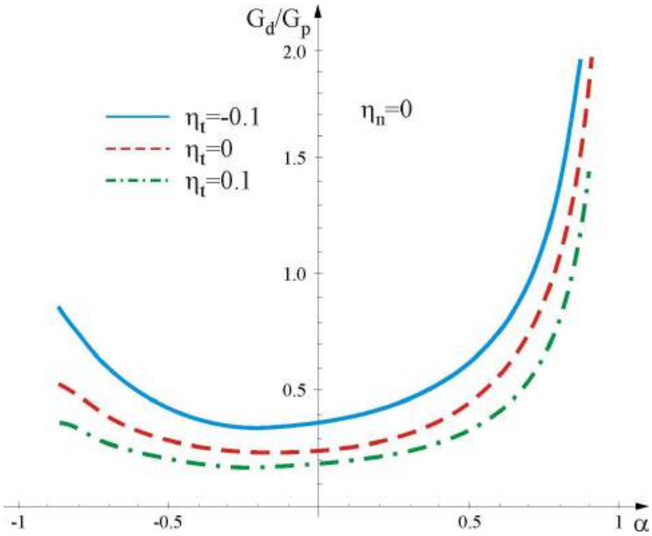
Figures 2, 3 and 4 can be used in combination with equation (13) for predicting whether the crack will deflect into the interface or will continue to propagate across it. When the interface is exposed to residual tensile stresses, two factors are influencing the phenomenon that the crack becomes unstable, those factors being: parameter η_n increases when the crack length *a* increases and when parameter η_n increases the load phase angle ψ decreases, causing decrease of the interface's fracture toughness G_{Ic}. The residual compressive stresses, on the other hand, lead to stable crack propagation either along the interface or across it, because η_n or η_t are becoming more negative as the crack propagates.

4. CONCLUSION

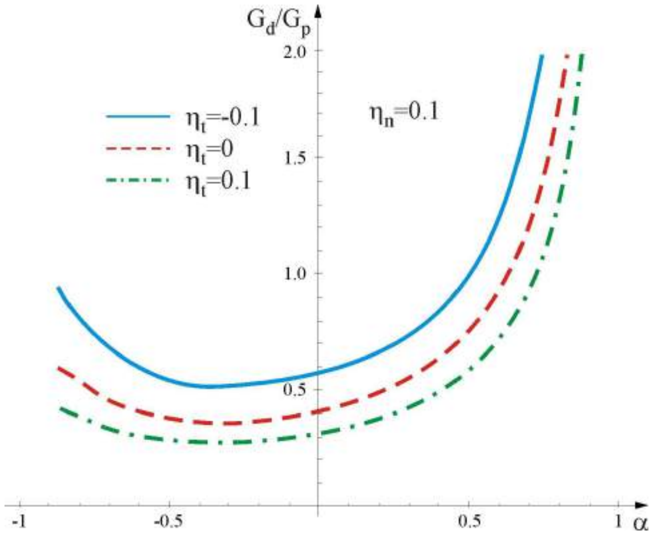
Residual stresses that are results of difference in the thermal expansion coefficients have significant influence on competition between the interfacial crack propagation along the interface, i.e., deflection into it, and the crack passing the interface, i.e., propagating across it in the material above it. This influence of residual stresses can be used in layered materials for design of such an interface that will enable decrease of the undesired material behavior, namely the fracture.



(a)

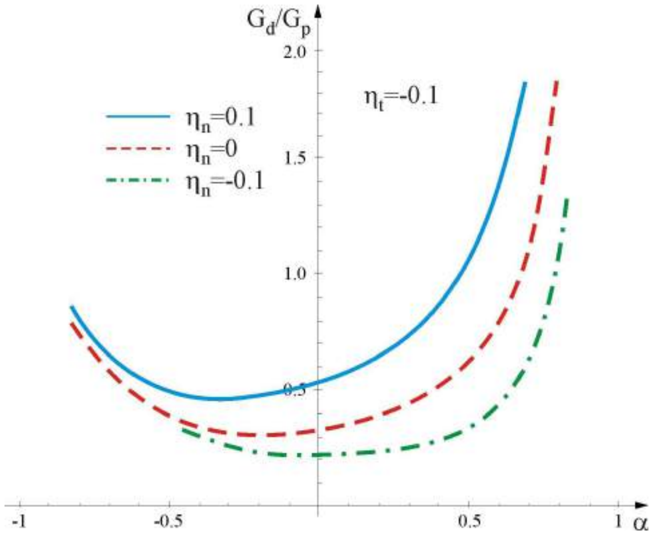


(b)

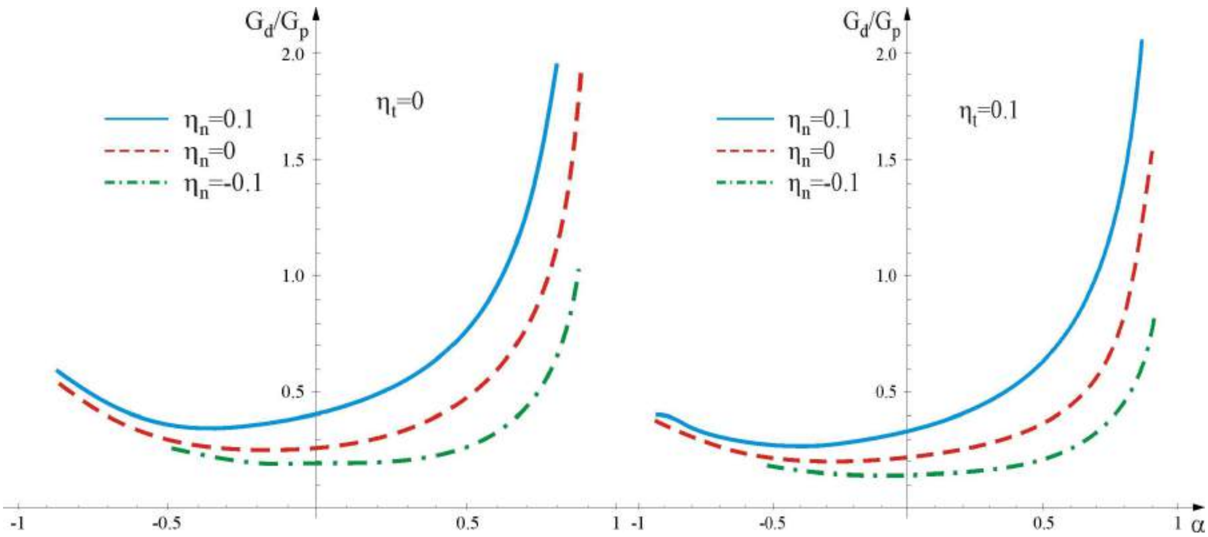


(c)

Figure 2. *Energy release rate as a function of α for different values of parameter η_t and three values of parameter η_n = -0.1, 0 and 0.1.*



(a)



(b) *(c)*

Figure 3. *Energy release rate as a function of α for different values of parameter η_n and three values of parameter η_{t} = -0.1, 0 and 0.1.*

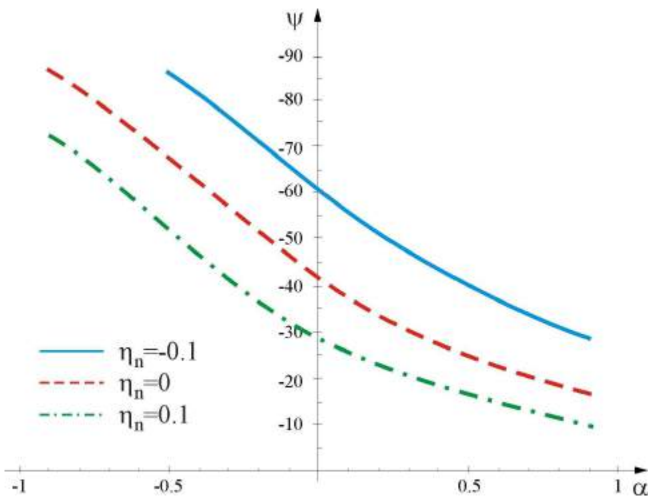


Figure 4*. Load phase angle as a function of α*
For three different values of parameter η_n = -0.1, 0 and 0.1.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

ROLLING BEARING FAILURE CAUSE IDENTIFICATION ON STONE MILL

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ABSTRACT
Working spindle of stone mill is lean out on two spherical roller bearing. Spindle is connected by latchets with electric-motor of 75 kW power. Bearings in spindle supports were losing out their working ability, so their changing was very often needed. In order to identify the cause of failure, activities of technical diagnostic were managed, including measuring and analysis of vibrations, SPM method for bearing condition analysis, temperature measuring, analysis of alignment of bearings center, as well as string of visual overviews. This paper presents the description of technical diagnostics methods which are managed, and analysis of referred bearings failure cause.
Keywords: rolling bearing, failure cause, analysis of vibrations, SPM method, axis alignment

1. INTRODUCTION
Schematic layout of stone grinding mill in asphalt base is shown on Figure 1.a). Mill is for grinding up to maximal dimensions of 150 mm stone. At Figure 1.b) is photo of mill. Working spindle is driven by 75 kW power and 1485 min^{-1} rotation speed electro motor. Connection between working spindle and electro motor is by transmission belt consisting of 5 trapezium belts mark SPB x 4250 DIN 7753. In working spindle supports there are two spherical roller bearing 22220K. While working, strong superheating of bearings occured. Bearing in spindle supports were losing their working capability fast. That was the reason for their often changing. Because of that, activities of technical diagnostic, in order to deduce failure causes and to anticipate necessary activities so stated failure would not occure again. In this paper, applied diagnostic activities are shown, the analyse of failure cause is given as well as conclusions on necessary sanation measures, in other to prevent repeatedly premature bearings failure.

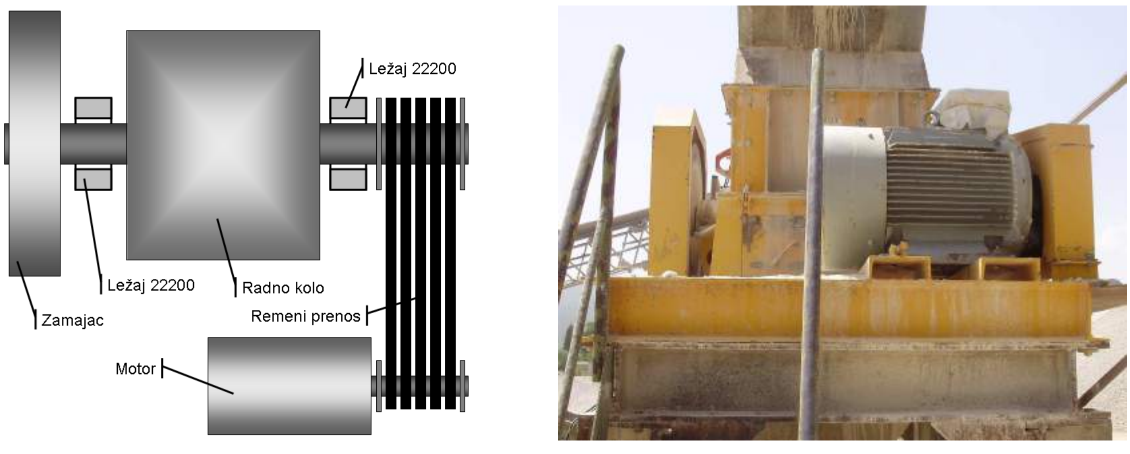


Figure 1. Schematic and photo layout of stone grinding mill

2. APPLIED TECHNICAL DIAGNOSTIC METHODS DESCRIPTION

Technical diagnostic as scientific - technical discipline has the aim to confirm some technical system condition by becomingly theories, methodes and technics in limited information conditions and to reveal some potentially defects in constructive solutions, mounting, exploitation or maintenance. This task accomplishment depends on diagnostic technics and relevant parameters regular choice, then on regular choice of measuring points on object, measurement equipment reliability level, as well as on applied software quality for data acquisition and analyze and competency of person who do diagnostic. The best results are achieved by various technics combination and durable tracking of system conditions in exploitation conditions, with often data sampling about relevant dynamically process.

For bearing condition diagnosis, what is the scope of this work analyse, techniques as temperature measurement, vibration measurement and analyse and shock pulse measurement and analyse are applied in this work. Measurement is done by device for machines condition testing type T30, producer SPM Instrument from Sweden. T30 is multi function analyzer with top-level performances. It encourages vibration measurement and analyse, shock pulse measurement and analyse (SPM method for rolling bearings diagnostic), rotation speed measurement and temperature measurement. T30 works as separated measuring device, butalso as „Data Loger“, and connected with computer with appropriate software it is very powerfull diagnostic tool. At Figure 2. system T30 for machines condition diagnose is shown, which consists of following parts:

1. Measuring instrument for measurement results presentation, collecting and processing;
2. Measuring sondes for shock pulse measurement TRA-22 and TRA-30;
3. Sensor for vibration speed TRV-22;
4. Sensor for rotation speed TAD-18;
5. Sonde for temperature TEN-10.

Figure 2. Measuring device T30 with equipment

2.1. Temperature measurement

For temperature measurement temperature sonde TEN-10 is used, which allows temperature measuring in range from -20 to 350^oC. Measurement is done by direct contact of sonde`s top to object. Measurement results are being compared to allowed, usually prescribed by manufacturer. By insight to manufacturer`s documentation, it is stated that bearing temperature has to be lower than 60^oC. Temperature values higher than that indicate on anomalies in bearings work.

2.2. Shock pulse measurement and analyse (SPM method)

The Shock Pulse Method (SPM) was developed by SPM Instrument AB in Sweden. Its exclusive purpose was - and still is - to monitor the operating condition of rolling bearings, to get advanced warning of developing bearing damage and enable planned bearing replacements with a minimum of downtime and risk for machine failure. Over the years, the method was refined to evaluated the lubrication condition of undamaged bearings, so that the user can not only detect existing damage on rollers and raceways but prevent the most common cause of early bearing failures by optimising bearing lubrication in any given application. The Shock Pulse Method (SPM) has always treated the bearing as a “shock generator” rather than a “vibration generator”. Instead of trying to extract the transients caused by shocks from a vibration record, it uses a specially transducer and measuring circuit to measure shocks directly. This makes it the most sensitive method known for bearing condition monitoring.

Shock pulse transitory waves of very low energy, lower than energy which causes vibrations in machines, but their frequency is multy bigger than vibration frequency. Commence at the moment of two bodies crush, when shock wave is building up and as an explosion relays through material in all directions (Fig. 3). Their intensity and pattern is directly related to the thickness of the oil film between rolling element and raceway, and to the mechanical condition of the bearing surfaces.

Shock pulse during work occure at all rolling bearings, as at spent, so at new ones. At new bearings shock pulse occure as consequence of roughness of bearings elements contact surfaces. When the oil film in the bearing is thick, the shock pulse level is low, without distinctive peaks (Fig. 3.a.). The level increases when the oil film is reduced, but there are still no distinctive peaks. (Fig.3.b.). Damage causes strong pulses at apparently irregular intervals. (Fig.3.c.).

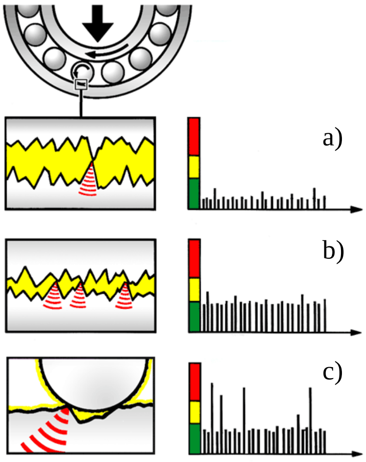


Figure 3. How commence shock pulse

For bearing condition evaluation by shock pulse method, so called dBm/dBc technique is used. At Fig. 4. simplified grafic presentment of values used for bearings condition evaluation by dBm/dBc technique is shown. Every vertical line in diagram demonstrates one pulse. Thick string of approximatively same low pulse defines „Carpet of values". Respective longer lines demonstrate shock pulse of stronger intensity. The intensity of shock pulse is measured in dBsv (decibel shock value). Maximal average value of shock pulse-dBm is used for evaluation of bearing operational condition. Carpet of values dBc helps during such bearing operational condition identification. By failure development dBc and dBm values growe too, as well as the difference between these values.

A bearing in good condition should have a dBm value below 20 and a dBc value approximately 5 to 10 dB lower. The pattern shown in Fig. 3.c. is typical for damaged bearing surfaces: a dBm above 35 dB, a large gap between dBm and dBc, and a random pattern of strong pulses. The strength of the maximum value dBm indicates the degree of damage: 35-40 dBsv - slight damage, 40-45 dBsv - severe damage and > 45 dBsv high breakdown risk.

A high carpet value, very close to the maximum value, is typical for dry running bearings. The dBm does not always reach the red zone - typical for poor lubrication is that the gap between dBm and dBc is very small. If the signal is strongest on the bearing housing, it can have several causes:

1. insufficient lubricant supply to the bearing (poor oil flow; old , caked, or cold grease)
2. very low or high bearing speed (preventing the build-up of an oil film separation between the loaded rolling elements and the raceway)
3. installation fault or out of round bearing housing
4. misalignment or bent shaft
5. excessive load

If possible, grease the bearing or increase the oil flow. Measure immediately afterwards, and again a few hours later. In case 1 (see above), the shock pulse level should drop and stay low. In case 2, one can try lubricants of a different viscosity or use additives to prevent metal to metal contact between the bearing surfaces. In cases 3, 4 and 5 (installation faults, unround housings, misalignment and excessive load), the shock pulse level may drop after lubrication but will soon rise again. Try to eliminate the cause for the bad lubrication condition.

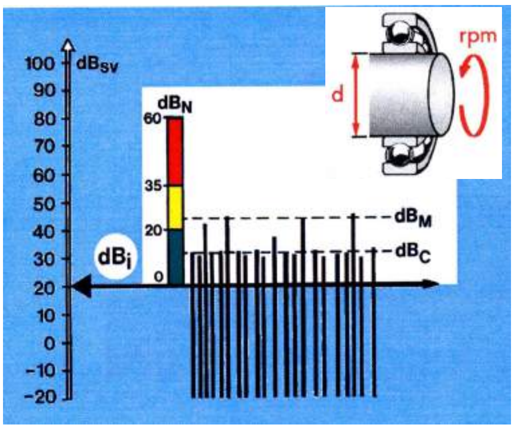


Figure 4. Diagram for bearing condition evaluation by dBm/dBc technique

2.3. Vibrations measurement and analyse

Whereas T30 device has very powerfull tool for bearing condition diagnostic (SPM method), technique of vibration measurement is used only for machine general condition, trought effective value of vibration strenght - RMS-a. Effective value of vibration strenght indicates very well on connection between vibration displacement and perturbation forces. However, machine foundation has great impact on strenght indicates, as well as other parameters which are characteristic for every single machine. That is the reason why data on allowed vibration strenght in standards are ranked according to categories depending on type of machine. The evaluation is based on international industrial standard ISO 10816, which gives recommendations for evaluation of absolute vibration of bearing housing, on the basis of measured RMS values. According to this standard, industrial machines are divided into four categories as per machine size, foundation characteristics and machine rigidity, as follows:

– **Category I**: Small machines up to 15kW.
– **Category II**: Medium-sized machines (e.g. elektro motors from 15kW up to 75kW), without special foundations, rigidly mounted machines up to 300kW on detached foundations
– **Category III**: Big machines with great rotating weights, on massivne foundations, with great rigidity in the direction of vibration measurement.
– **Category IV**: Big machines with great rotating weights, on massivne foundations, relatively elastic in the direction of vibration measurement. E.g.: Turbo-generators power more than 10MW.

Evaluation of condition consists of measured values comparison to limit values, according to recommendations prescribed by ISO 10816 standard (Figure 5.). With relation to vibrations strenght, condition of machine is ranked to four groups: Good (Zone A), Acceptable (Zone B), Bad (Zone C), Unacceptable-Very Bad (Zone D).

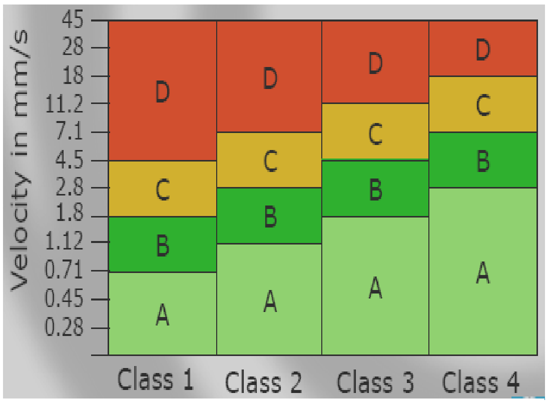


Figure 5. Vibration strength limit values according to ISO 10816

3. DIAGNOSTIC PROCEEDING

Beside regular choice of measurement techniques and reliable measuring equipment, good and effective diagnostic conducting implicates and appropriate systematic procedure according to international recognized and all over the world accepted standards.

First of all, regular choice of measurement points has to be done, according to each system constitution and sub-constitution characteristics and fitted aim of diagnostic. The general rule is that for measuring points bearings places must be choosen, becouse these points have the best picture of all machine malfunction. This is and the basic aim of diagnostic in this task: „rolling bearings condition validation“. At the scheme in Table 1 position and marks of measuring points is shown. Under the scheme, there are measurment results and appropriate conclusions, got on the basis of conducted technical diagnostic activities.

Rearching metodology previses determination of necessary measuring techniques for each measuring point, and limit values of controlled parameters. It is already said that for diagnose in this task it is choosen temperature measuring techniques, measuring and analyses of vibrations and measuring and analyses of shock pulse. Temperature measuring technique is very simple and cheap. However, by this technique usage it can be discovered only potentially bearing condition irregularity, but the cause and level of damage can not be estimated. Better diagnoistic of condition can be obtained by usage of vibration measurement and analyses method and shock pulse method (SPM). These methods are very good in presenttation of almost all construction characteristics, manufacturing, assembling and exploitation of bearings. Besides that, by these methods usage conclusions on condition of entire system bearing is built in can be obtained.

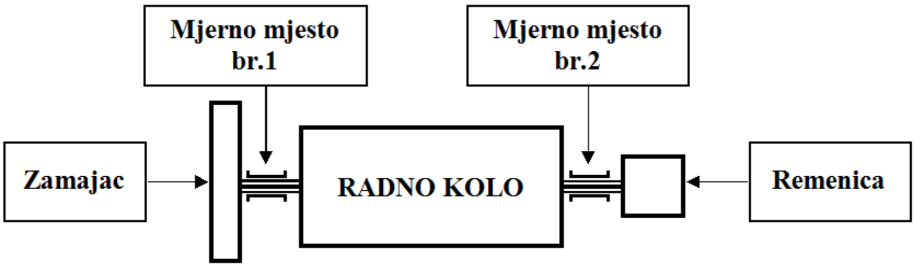
Parameters limit values are defined according to recommendations of ISO 10816 standard and recommendations of T30 device manufacturer, as previously stated.Temperature limit value is defined according to recommendations of mill manufacturere. With respect to motora power (75 kW), and foundation characteristics, machine is ranked into II chategory, which is in accordance with standard ISO 10816 recomenndations. For analyses of condition, values of RMS are measured in all of three characteristic directions (horizontal, vertical and axial). Measured RMS values, shock pulse values and temperature values are shown in Table 1 for each measuring point, respectively.

4. ANALYSE OF GAINED RESULTS

By measured and limit values matching, evaluation of bearing condition is gained for each measurement, respectively, as well as general evaluation for bearing condition. These data are alo shown in Table 1. At the end of table it is general machine condition. On the basis of gained results, it is concluded that general machine condition and bearing condition is very bad.

Table 1. Report with measuring results on tecnical diagnostic of stone mill condition

Mašinski fakultet u Podgorici TEHNIČKA DIJAGNOSTIKA	**Broj: TD 01-06/08**
IZVJEŠTAJ **o izvršenoj tehničkoj dijagnostici stanja mašina u** **“MEHANIZACIJA i PROGRAMAT“ a.d. Nikšić**	**Strana:** 6/6 **Datum:** 03.06.2008
Postrojenje / Uređaj: **Mlin čekićar BL-5**	Ocjena stanja prema preporukama **ISO 10816**



KLASA MAŠINE: **Klasa II**	Snaga motora: **75 kW**

PRVO MJERENJE

Mjerno mjesto: 1		Oznaka ležaja: **22220K**		Proizvođač: **nepoznato**	
		Nazivni prečnik: **100 mm**		Broj obrtaja: **n=1005**	**dBi: 17**
Mjerna tehnika		Rezultati	Stanje ležaja	OPŠTE STANJE ULEŽIŠTENJA: **Neprihvatljivo**	
Temperatura ležaja		107°C	**Neprihvatljivo**		
SPM	**dBM**	30	**Loše**	NAPOMENA: Relativno visoka očitavanja vibracija izmjerena su u svakom smjeru. Izrazito visoka očitavanja u vertikalnom radijalnom pravcu govore o vjerovatno slaboj krutosti strukture mašine ili postolja.	
	dBc	16			
RMS	**Hor**	4.6	**Loše**		
	Ver	11.9	**Neprihvatljivo**		
	Aks	4.2	**Loše**		

Mjerno mjesto: 2		Oznaka ležaja: **22220K**		Proizvođač: **nepoznato**	
		Nazivni prečnik: **100**		Broj obrtaja: **n=1005**	**dBi: 17**
Mjerna tehnika		Rezultati	Stanje ležaja	OPŠTE STANJE ULEŽIŠTENJA: **Neprihvatljivo**	
Temperatura ležaja		131°C	**Neprihvatljivo**		
SPM	**dBM**	32	**Loše**	NAPOMENA: Relativno visoka očitavanja vibracija izmjerena su u svakom smjeru. Dominantna očitavanja u radijalnom pravcu govore o vjerovatno slaboj krutosti strukture mašine, povezanoj sa oštećenjima čekića mlina.	
	dBc	23			
RMS	**Hor**	6.2	**Loše**		
	Ver	9.4	**Neprihvatljivo**		
	Aks	3.1	**Loše**		

DRUGO MJERENJE

Mjerno mjesto: 1		Oznaka ležaja: **22220K**		Proizvođač:**nepoznato**	
		Nazivni prečnik: **100**		Broj obrtaja: **n=1005**	**dBi: 17**
Mjerna tehnika		Rezultati	Stanje ležaja	OPŠTE STANJE ULEŽIŠTENJA: **Neprihvatljivo**	
SPM	**dBM**	30	**Loše**		
	dBc	17			

Mjerno mjesto: 2		Oznaka ležaja: **22220K**		Proizvođač:**nepoznato**	
		Nazivni prečnik: **100**		Broj obrtaja: **n=1005**	**dBi: 17**
Mjerna tehnika		Rezultati	Stanje ležaja	OPŠTE STANJE ULEŽIŠTENJA: **Neprihvatljivo**	
SPM	**dBM**	37	**Loše**		
	dBc	26			

OPŠTE STANJE MAŠINE: Neprihvatljivo.

Postoje visoka očitavanja vibracija u radijalnom pravcu, koja su vjerovatno posledica slabe krutosti mašine ili slabe krutosti postolja udružene sa pojavom malog debalansa. Vjerovatno su ove vibracije i uzrok otkaza ležajeva.

Higher temperature values indicate on meaningly friction of bearing working surfaces, which can be the consequence of poor lubrication. In support of this conclusions are high dBc values of shock pulse and gently hoten dBm values. However, by bearings lubrication and shock pulse re-measurement after two hours, according to SPM recommendations, dBc and dBm values changed few, which indicates that bearings are already damaged and that poor lubrication is not a reason of its failure.
High vibrations values are measured on bearings, too, especially in verical radial direction. This indicates that the most probably cause of bearing bad condition is poor rigidness of machine structure or poor rigidness of foundation. Because of technological reasons mill is situated on high foundation, buil of I-profiles (Figure 6.). The connection between vertical and horizontal girders is done by two screws on each of four foundation legs. During mill`s working, because of strong dynamic loads very fast occure of slacken and foundation rigidness diminish is recognized, as well as appearance of very high values of vertical vibrations. That was the reason for displacement of centre of orifice in bearing housing and mill`s working spindle steepening (Figure 7). That was the main cause of bearings failure. Results of geometric measurements have confirmed that conclusion. These results let see that vertical displacement of bearing orifice centre was about 4 cm, which corresponded to working spindle steepening of about 2^{o}. These values are much more than allowed in case of spherical roller bearing (1.5^{o}). Because of that, as recommended sanation measures, it is prescribed that after foundation horizontal leveling, machine rigidness by plates 10 mm thickness have to be done. Plates are connected to vertical and horizontal I-girders by welding according to Figure 8.

Figure 6. Stone crushing system

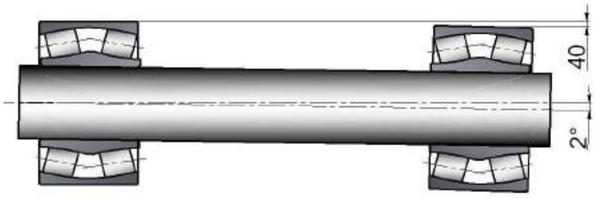


Figure 7. Working spindle steepening

Figure 8. Rigidness solution presentment

5. INSTEAD CONCLUSION

Presented diagnostic procedure and sanation of stone mill is done two years before. By that moment, mill worked without unplanned stoppage. The best proofs on quality of failure cause estimation are time and results of ulteriorly periodic controls, which have evinced that measured vibration and temperature values in bearings was always inside limits.
Presented example evinces on the best way how by regular usage of simple technical diagnostic methods reliable estimation of mechanical system can be obtained, and effective identification of such condition causes.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

IDENTIFIKACIJA NESTACIONARNIH PROCESA VERTIKALNIH HIDROAGREGATA VELIKIH SNAGA MJERENJEM INTENZITETA VIBRACIJA UGRAĐENE OPREME

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REZIME:
U radu će, na osnovu provedenih višegodišnjih detaljnih mjerenja na vertikalnim hidroagregatima instalisanim u HE na Neretvi – Jablanica koje je obavio Institut Mašinskog fakulteta Univerziteta „Džemal Bijedić" iz Mostara, biti prikazani mogući uzroci nastanka i djelovanja perturbacijskih sila u procesu proizvodnje električne energije, kao i uticaj tih sila na pripadajuću opremu. Biti će i definisane karakteristične pozicije sklopova opreme vertikalnih hidroagregata na kojim se pojavljuju perturbacijske sile i na kojim je neophodno vršiti stalna i periodična mjerenja intenziteta vibracija. Na osnovu analize rezultata mjerenja bit će prikazan trend rasta vibracija opreme vertikalnog hidroagregata djelovanjem perturbacijskih sila. Također, na osnovu kriterija o evaluaciji intenziteta vibracija opreme, prezentirati će se i iskustveni podaci relevantni za planiranje preventivnog i korektivnog održavanja opreme.
Ključne riječi: hidroelektrane, nestacionarni procesi, perturbacijske sile, vibracije.

1. UVOD

Električna energija se proizvodi u hidroelektranama koristeći prirodno obnovljivu energiju vode i isporučuje u elektroenergetsku mrežu po tačno definisanim tehničkim parametrima i sa zahtijevanim kvalitetom. Pri tome je zajednička karakteristika ovih postrojenja da se proizvodnja temelji na složenim dinamičkim procesima koji djeluju interaktivno i treba da čine homologan sistem sa visokim stepenom sigurnosti i minimalnim negativnim uticajem na okolinu.

Proces proizvodnje u hidroelektranama, posmatran tehnološki od ulaza vode u akumulaciji pa do izlaza iz difuzora turbine na odvodu, ne obezbjeđuje uvijek pouzdane uslove za funkcionisanje homolognog sistema kao cjeline. Poremećaj nekog od uticajnih faktora u proizvodnom lancu može uticati na stabilnost uspostavljenog dinamičkog procesa i izazvati pojavu vibracija visokog intenziteta čime, ukoliko se ne djeluje pravovremeno, može doći do kvarova i ispada iz proizvodnje

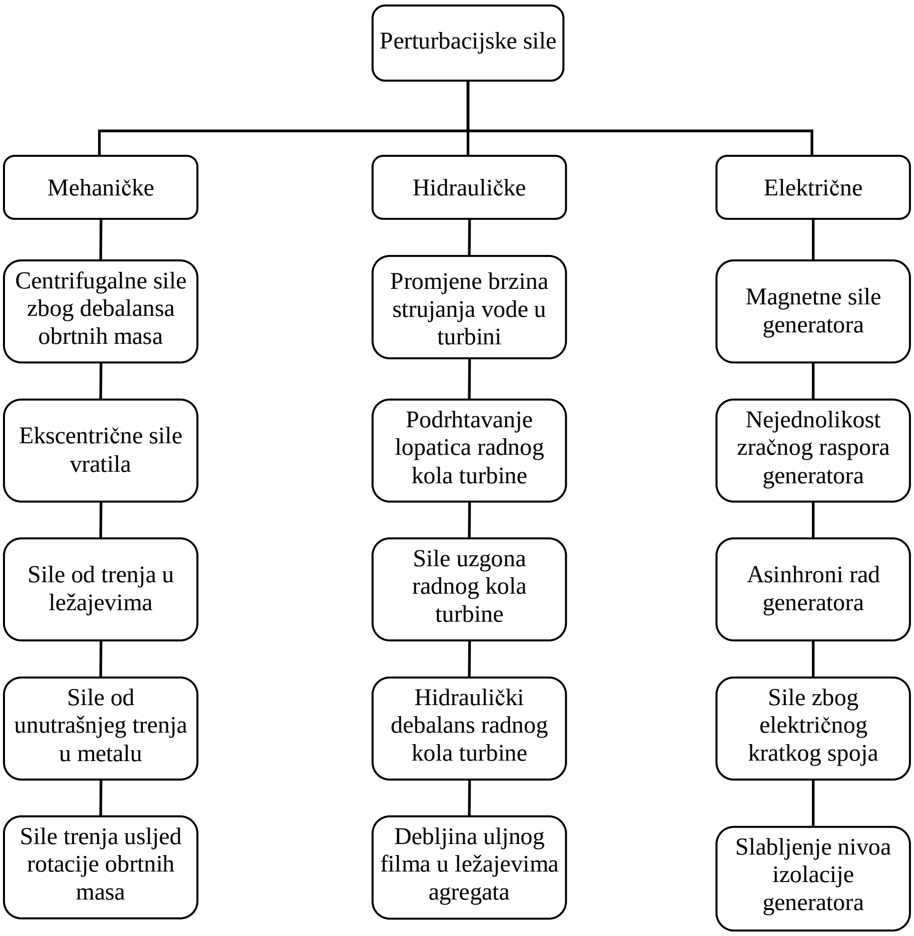
Ignorisanje ovih pojava može voditi ka destrukciji opreme i postrojenja, izazivajući gubitak značajnih finansijskih sredstava.

2. IDENTIFIKACIJA NESTACIONARNIH PROCESA

Smetnje u funkcionisanju opreme hidroagregata uzrokovane nestacionarnim procesima mogu se pojaviti kada je hidroagregat u procesu starta i sinhronizacije sa mrežom, zatim kada je u radu sa zadatom snagom i ako je u stanju prelaznog režima rada. Na poremećaj procesa proizvodnje djeluju perturbacijske sile prouzrokovane od:

1. mehaničkih uticaja,
2. električnih uticaja i
3. djelovanjem elektromagnetnih sila generatora ili druge elektro opreme.

Odstupanja zadatih parametara u radu, u odnosu na projektovane veličine, dovodi do promjena u proizvodnom procesu koje se manifestuju kao nenormalan rad ugrađene opreme i oscilovanje zadate snage generatora. Izvori pojava perturbacijskih sila na pojedinim sklopovima opreme hidroagregata mogu se sistematizovati kao što je prikazano na slici 1.



Slika 1: Prikaz izvora perturbacijskih sila hidroagregata

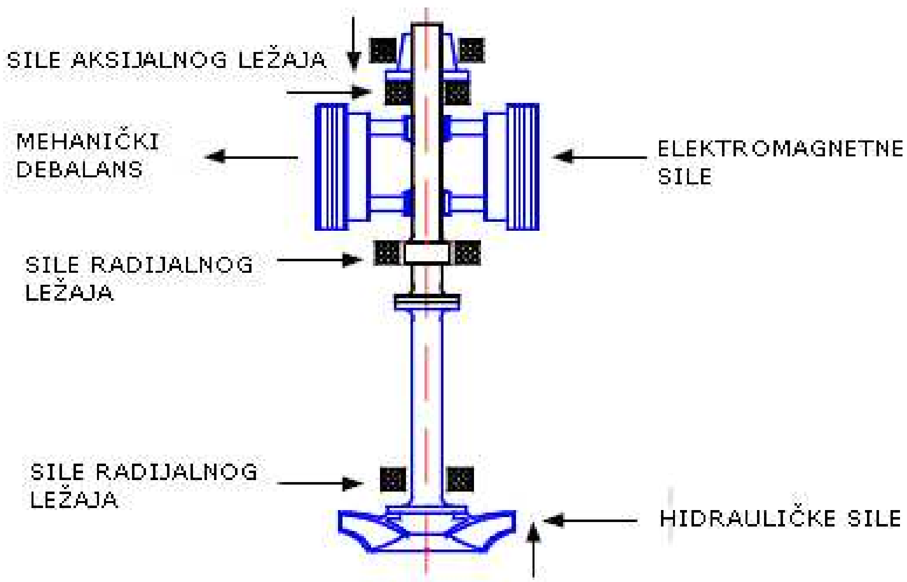
Posebno pogodna situacija za nastanak i djelovanje perturbacijskih sila je prelazni režim rada hidroagregata u momentu totalnog rasterećenja od maksimalne snage generatora djelovanjem zaštitnih uređaja, te pojava hidrauličnog udara u protočnom traktu hidroelektrane. Manifestacija ovih pojava je nagli porast broja okretaja, promjena intenziteta zvuka hidroagregata, te povećan nivo buke i vibracija na sklopovima opreme. U slučaju daljnjeg razvoja nestacionarnog procesa mogu nastati rezonantne vibracije sa mogućnošću destrukcije opreme i havarija na postrojenjima hidroelektrane.

3. KONTROLA PERTURBACIJSKIH SILA NA OPREMI HIDROAGREGATA

Hidroagregati predstavljaju strojeve izuzetno složene konstrukcije koji kvalitetnim procesom održavanja mogu doživjeti dugi radni vijek. Ako su projektovani sa velikim instalisanim snagama, u pravilu čine krut sistem bez fleksibilnih veza između komponenti i sa stalnom mogućnošću pojave nestacionarnih procesa. Najčešće pojave perturbacijskih sila kod vertikalnih hidroagregata mogu nastati zbog.:

- mehaničkog debalansa rotirajućih dijelova,
- elektromagnetnog debalansa nastalog slabljenjem izolacije statora ili rotora generatora,
- hidrauličkog debalansa uzrokovanog diskontinuitetom protoka vode u protočnom traktu turbine ili dovodnog cjevovoda,
- ekscentričnosti vratila u odnosu na središnjicu rotacije težišnih masa hidroagregata,
- latentne rezonancije rotora generatora,
- oscilovanja tijela ili brtvenog prstena predturbinskog zatvarača.

Kvarovi na ugrađenoj opremi hidroagregata nastali djelovanjem navedenih sila su karakteristični i razvijaju se uslovno sporo, pa se radni parametri sklopova opreme, pored stalnog mjerenja, trebaju i periodično kontrolisati u definisanim intervalima. Za kontrolu nastanka nestacionarnih procesa i razvoja perturbacijskih sila relevantna su mjerenja nivoa buke i vibracija na pozicijama hidroagregata prikazanim na slici 2.



Slika 2: Pozicije vertikalnog hidroagregata na kojima se javljaju perturbacijske sile

Perturbacijske sile nastale djelovanjem mehaničkog debalansa rotirajućih masa uvijek su u izvjesnom stepenu prisutne na hidroagregatu. Iznos energije nastale djelovanjem sila od mehaničkog debalansa rotirajućih masa povećava se sa kvadratom porasta broja okretaja hidroagregata.

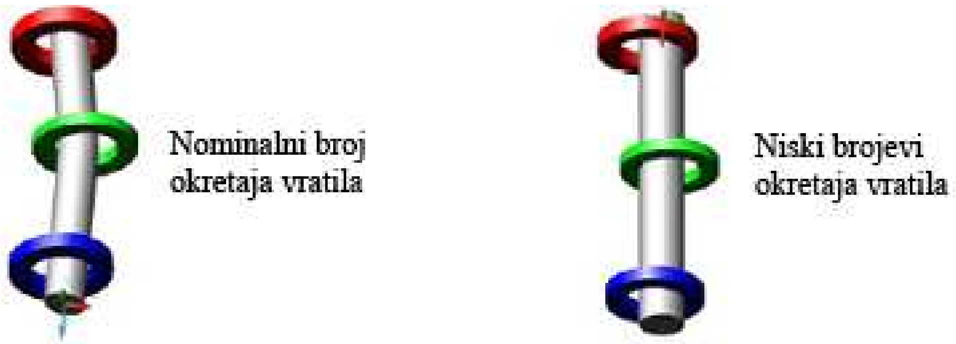
Karakterističan slučaj u procesu proizvodnje je pojava iznenadnog rasterećenja hidroagregata sa maksimalne radne snage nastala djelovanjem zaštitnih uređaja. Zbog djelovanja hidrauličkog momenta od energije vode, koja u tom momentu prolazi kroz protočni trakt turbine, dolazi do naglog povećanja broja okretaja hidroagregata („pobjeg turbine“), pojave enormnih vibracija čitavog sistema hidroagregata, te ugrožavanja mehaničke stabilnosti generatora, turbine i pripadajućih betonskih konstrukcija. U slučaju otkazivanja zaštitnih uređaja moguće su i havarije na opremi.

Elektromagnetni debalans hidroagregata se najčešće pojavljuje zbog nastanka „kratkih spojeva“ u električnim krugovima namotaja polova rotora generatora, što za posljedicu ima opadanje intenziteta magnetnog polja u samom polu. Elektromagnetni debalans se detektuje mjerenjem amplituda i faze vibracija vertikalnog vratila kada se generator nalazi u fazi „pobuđenog stanja“, a prije samog čina sinhronizacije (oko 60% intenziteta magnetnog polja generatora je sadržano u „pobuđenom stanju“).

Uobičajena je praksa da se mehanički i elektromagnetni debalans rotora generatora provjerava u tvornici proizvođača prije isporuke opreme.

Perturbacijske sile nastale kao posljedica hidrauličkog debalansa najčešće su uzrokovane neravnomjernom preraspodjelom količine vode između lopatičnih kanala spiralnog kućišta ili radnog kola turbine. Uzroci navedenih pojava mogu biti konstruktivne prirode i to zbog lošeg geometrijskog oblika samih izlaznih ivica lopatica turbine, zatim lomovi dijelova lopatica, kao i djelimična začepljenja lopatičnih kanala nastala zbog ostataka drveća ili nagomilanih materijala od plastike. Hidraulički debalans raste sa povećanjem protoka vode kroz turbinu i identifikuje se karakterističnom frekvencijom u funkciji broja lopatica radnog ili sprovodnog kola turbine. Neravnomjernost protoka vode iza izlaznih ivica lopatica turbine (vrtlozi tipa Karman) lako se razaznaje jer ima karakterističnu frekvenciju oscilovanja u dijapazonu od 0,25 do 0,35 Hz.

Ekscentričnost središnjice vertikalnog vratila u odnosu na poziciju težišta rotacije obrtnih masa hidroagregata može uzrokovati neočekivane vibracije visokog intenziteta na kućištima ležajeva vratila. Uzrok navedenih vibracija može biti loša horizontalnost kliznih površina aksijalnog ležaja, eventualni lom središnjice vertikalnog vratila sastavljenog iz više dijelova, kao i ekscentričnost pozicije kućišta vodećih ležajeva. Vibracije nastale zbog ekscentričnosti pozicije kućišta ležajeva su prisutne pri niskim, kao i pri nominalnom broju okretaja hidroagregata. Deformacije vertikalnog vratila hidroagregata nastale zbog ekscentričnosti pozicije vodećih ležajeva su prikazane na slici 3.



Slika 3: Deformacije vertikalnog vratila hidroagregata nastale zbog ekscentrične pozicije vodećih ležajeva

Navedene vibracije se detektuju mjerenjem brzine i/ili ubrzanja pomjeranja kućišta vodećih ležajeva vertikalnog vratila u svim režimima rada hidroagregata.

Latentna rotorska rezonancija se pojavljuje pri kritičnom broju okretaja vratila hidroagregata kod kojih je odnos dužine i prečnika vratila veliki. Zbog moguće ekscentričnosti središnjice vratila u odnosu na centar rotacije u vodećim ležajevima, rezonantne vibracije se pojavljuju prije dostizanje nominalnog broja okretaja. Kritične brzine vratila ne predstavljaju veliku opasnost za sigurnost opreme, ali je njihovo prisustvo blizu nominalnog broja okretaja nepoželjno jer usložnjava proces sinhronizacije agregata sa električnom mrežom i komplikuje naknadni proces balansiranja rotirajućih masa generatora.

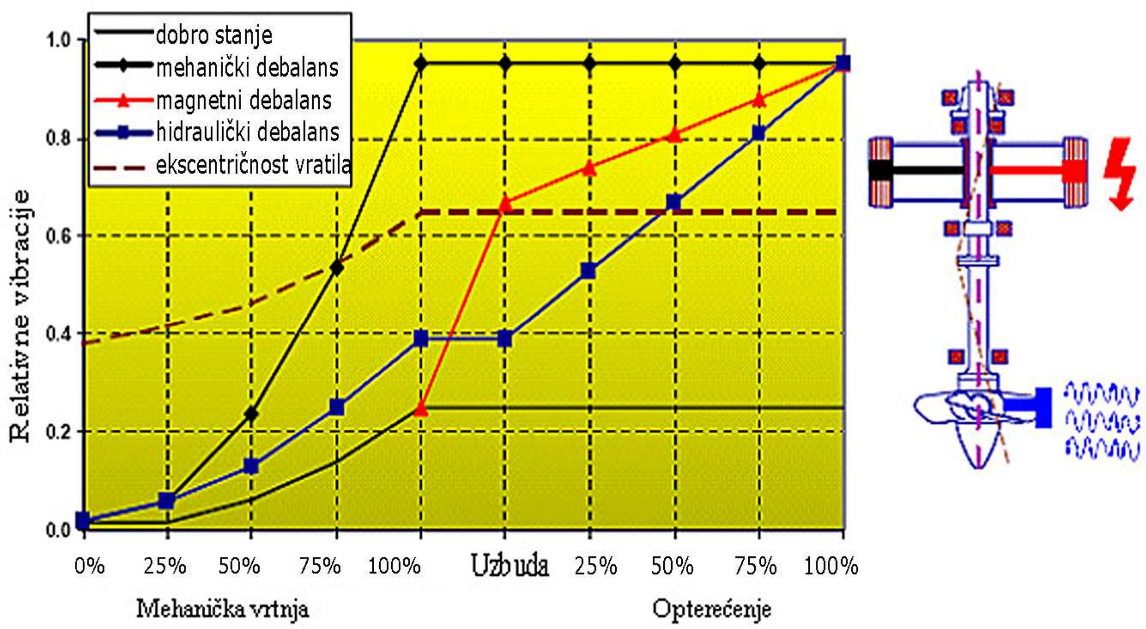
Rezonantne vibracije predturbinskog zatvarača mogu biti izazvane oscilovanjem brtvenog prstena ili samog tijela zatvarača kada se zatvarač nalazi u otvorenom položaju i pri maksimalnom protoku vode. Razlozi za pojavu navedenih vibracija su gubitak pritiska vode za upravljanje brtvenim prstenom zatvarača ili ekscentričnost pozicije tijela zatvarača u odnosu na središnjicu tlačnog cjevovoda. Zbog podudaranja frekvencije oscilovanja brtvenog prstena ili tijela zatvarača sa frekvencijom oscilovanja pritiska vode u tlačnom cjevovodu ili vodostanskoj komori, može doći do rezonantnih vibracija u čitavom protočnom traktu hidroelektrane sa neugodnim posljedicama po opremu ili građevinske objekte.

4. KRITERIJI ZA EVALUACIJU PRIHVATLJIVOSTI INTEZITETA VIBRACIJA

Za relevantnu ocjenu uticaja intenziteta vibracija na opremu hidroagregata koriste se kriteriji međunarodnih standarda i to:

- ISO 7919, dio 5; kriteriji za mjerenje i evaluaciju vibracija rotirajućih dijelova,
- ISO 10816, dio 5; kriteriji za mjerenje i evaluaciju vibracija fiksnih dijelova.

Na osnovu provedenih mjerenja i analize vibracija na vertikalnim hidrogregatima velikih snaga u HE na Neretvi trend porasta vibracija nastalih djelovanjem perturbacijskih sila može se prikazati slikom 4.



Slika 4: Prikaz trenda rasta vibracija vertikalnog hidroagregata djelovanjem perturbacijskih sila

Višegodišnjim istraživanjima pojava nestacionarnih procesa u hidroelektranama potvrđeno je da su za ocjenu uticaja perturbacijskih sila kod vertikalnih hidroagregata velikih instalisanih snaga ključna mjerna mjesta na sljedećim pozicijama:

- Kućište turbinskog ležaja ,
- Kućište generatorskog ležaja,
- Gornji križ generatora sa betonskom konstrukcijom.

Na navedenim lokacijama neophodna je ugradnja opreme za stalni monitoring vibracija. Periodične kontrole vibracionog stanja se trebaju provoditi na pozicijama:

- Generatorski sklop agregata,
- Konusni nosač aksijalnog ležaja,
- Kućišta sprovodnih lopatica turbine,
- Betonska konstrukcija turbine.
- Kućište difuzora turbine,
- Oprema tlačnog cjevovoda sa predturbinskim zatvaračem.

Za planirane redovne aktivnosti preventivnog i korektivnog održavanja, na osnovu analize stalnih ili periodičnih mjerenja intenziteta vibracija opreme hidroagregata, mogu, u odnosu na kriterije navedenih ISO standarda, poslužiti iskustveni podaci za evaluaciju vibracija prikazani u tabeli 1.

Tabela 1: Iskustveni kriteriji za evaluaciju intenziteta vibracija opreme hidroagregata

	Nije potrebna intervencija	Planirati aktivnosti održavanja	Intervenisati odmah
Relativna amplituda vibracija vratila u kućištu radijalnog ležaja (μm)	< 60%	60 – 80 %	> 80%
Brzina srednje vrijednosti signala neobrtnih dijelova (mm/s)	< 0,76	0,76 – 3,04	> 3,04
Promjena intenziteta vibracija	< ± 25%	< (± 25 – 50) %	> ± 50%

5. ZAKLJUČCI

U cilju dostizanja visoke efikasnosti hidroelektrane i stalnog poboljšanja procesa proizvodnje neophodno je, pored propisanih kontrola radnih parametara hidroagregata, obavljati mjerenja i analize uticaja nestacionarnih procesa prema sljedećim preporukama:

- Na hidroagregatima ugraditi opremu za stalni monitoring procesnih veličina uključujući i mjerenja vibracija na ključnim mjernim mjestima i povezati je sa informacionim sistemom hidroelektrane,
- Periodične kontrole vibracionog stanja hidroagregata obavljati redovno na preporučenim mjernim mjestima,
- Redovno analizirati izmjerene podatke o vibracionom stanju hidroagregata i, na osnovu promjena u odnosu na projektovane parametre, planirati preventivne i korektivne aktivnosti održavanja,
- Interpretaciju rezultata izmjerenih veličina o vibracionom stanju opreme hidroagregata obavljati sa projektantima opreme i drugim relevantnim institucijama.

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1st International Scientific Conference on Engineering
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MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

STUDYING THE INFLUENCIA OF THE WORKLOAD LIFTING IN DYNAMIC BEHAVIOUR OF TOWER CRANES USING FINITE ELEMENTS APPLICATIONS

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ABSTRACT

Tower Cranes are heavy lifting devices used mostly in Constructions Industry. Their structure is known with big dimensions, complex systems and mechanisms and high security requests. They work mostly in open environment under the influence of wind. Their working usage is high. Main cycles of the work of Tower Cranes can be divided into: lifting of the workload, moving the workload – translation and rotation, and lowering the workload. In this study work we will study the dynamic behavior of the tower crane while lifting the workload when fully engaged. The aim is to see the effects of dynamic forces (or moments) in the crane's construction during this work cycle, particularly at the start and end of the lifting process and effects on some other elements, like cables. The study will be done for some different lifting speeds. Results will be presented graphically with comments. For this case we created virtually Tower Crane using Finite Elements and model design applications and did simulations [3]. By using the modeling applications and applying simulations, we consider that we will have better view of occasions in case of load lifting and give some conclusions for enforcing safety and design rules for avoiding instability and overturning. Dimensions of tower crane and other properties are from standard manufacturers [1].

Keywords: Tower crane, workload, lifting, momentum, FEM, stress, simulations.

1. CRANE PROPERTIES

Dimensions of the tower crane: Lifting height – 31 m. Length of the Boom – 33 m. Mass of crane with upper ballast, 34000 kg. Distance of the workload from mast – 31.5 m. Material of crane construction: ANSI Steel, Modulus of elasticity: E=2.1e+11 Pa; Yield Stress: 3.31e+8 Pa.

Other parts are designed from standard crane manufacturers [1]. In Fig.1 is shown virtual model of crane with dimensional parameters. Workload has the mass together with the mass of hoist, hook and cables: Q =2600 kg = 25506 N. Simulation will be lifting of the load in three phases: Phase one-Startup of lifting without workload lifting (simulation time 0 s<t< 1 s); Phase two – lifting of the load at the height of H = 10 m; Phase three – stoppage of lifting.

2. TENSION FORCE IN CABLES

From the theory of the load lifting for cables [2], maximal tension force in one branch of the lifting cables (cables):

$$F_c = \frac{F_0}{\eta_{po}^{ng}} = \frac{Q}{m \cdot \eta_{po}^{ng}} \frac{2600 \cdot 9.81}{4 \cdot 0.99} = 6440.9 \quad [N] \qquad \dots (1)$$

Working coefficient of hoist:

$$\eta_{po}^{ng} = \frac{(1-\eta^{i_{po}})\eta^{t}}{i_{po}(1-\eta)} = \frac{(1-0{,}98^{2})\cdot 0.98^{0}}{2(1-0.98)} = 0.99 \qquad \dots (2)$$

Hoist ratio:

$$\mathrm{i}_{po} = \frac{\mathrm{m}}{\mathrm{a}_t} = \frac{4}{2} = 2 \qquad \dots (3)$$

m = 4 – number of rope branches participating in the lifting of weight
a_t = 2 – number of rope branches rolling around the drum
Coefficient of usage of pulley based on ball bearings η = 0.98. Number of deviation pulleys: t = 0

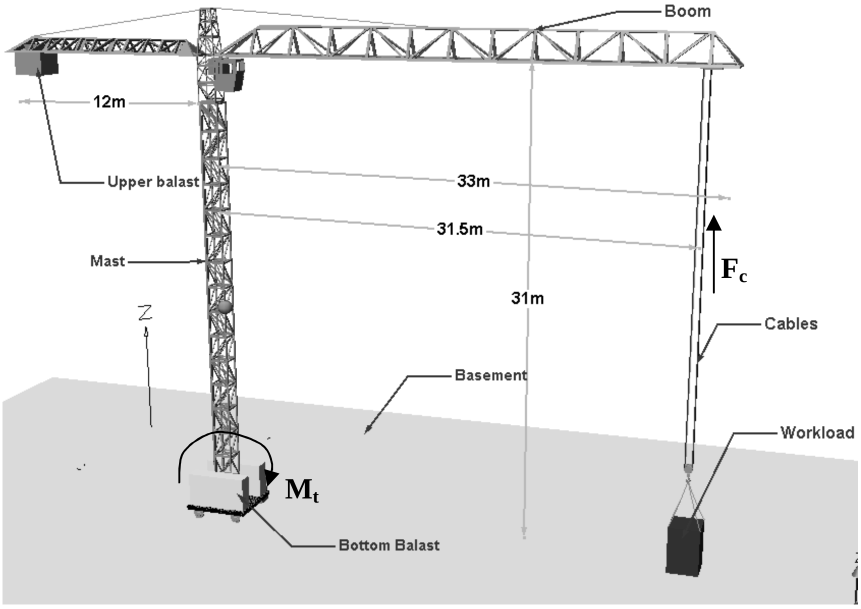
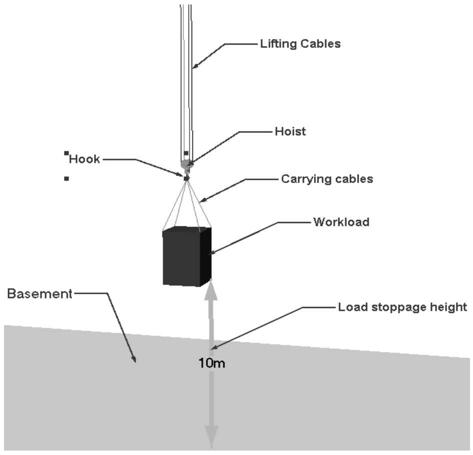


Fig.1. Model of the tower crane

Equation (1) gives the tension force for the case of static conditions. This equation will help us compare the static vs. dynamic force that occurs during the lifting process. After implementing all the properties in the virtual model, simulation process of load lifting has been initiated. Weight (workload) at the end of boom is in the position of relative rest lying on the basement.

Graph in Fig.3 and Fig.4 represents the tension force in cables while lifting the workload. In the graph we can see there is a dynamic process with oscillations. On phase one, between 0<t<1 s, there is no lifting and therefore no force in lifting cables. Carrying cables are a bit loosed so that we have as much accurate simulation. In time t = 1 s starts the lifting process. From Fig.3, at the lifting speed of v_1 = 1 m/s we can notice rapidly increasing curve, with heavy oscillations. After this, at phase two (1.7s <t<11s, 0.7<H<10 m), we have e period of smooth oscillations with small increasing value of tension force. At the stoppage time of lifting (Phase three, t =11 s, H = 10 m) the value of tension force gets the max value of F_{cdyn} = 6875 N. Compared to static value of tension force (1) this is increase of 7%. After this we have a drop in value of force close to static value, with lesser oscillations (t>11.2 s). From these simulations, we can notice that highest values are reached at the beginning of lifting and at the stoppage time with almost same maximal values of tension force. From this result, it is important to have a proper breaking system for smoother lifting and stoppage. Fig.4 represents the graph with the speed of v_2 = 0.5 m/s. From this graph, we can conclude that lower lifting speed gives less oscillations and more optimized lifting process.



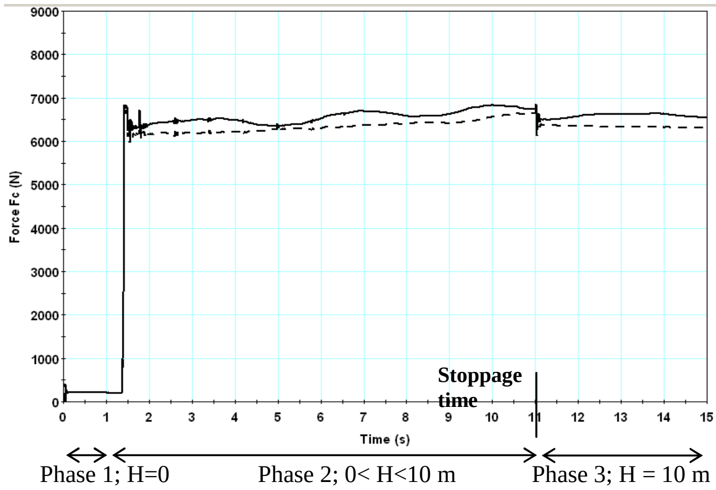


Fig.2. Lifting system ; *Fig.3. Tension force F_c in lifting cables for the lifting speed v_1 = 1 m/s*

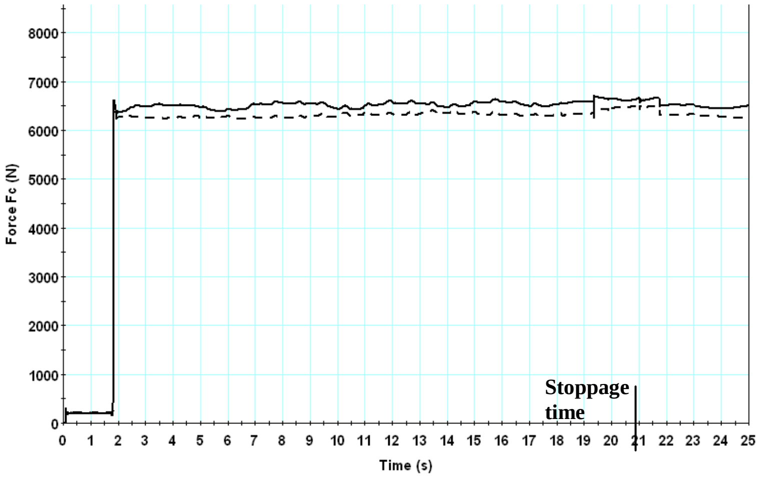
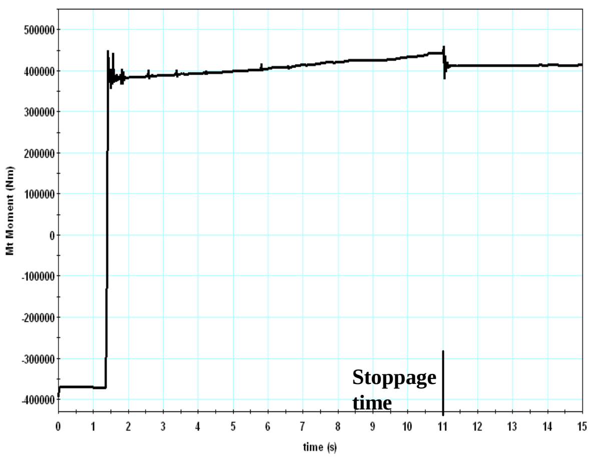


Fig.4. Tension force F_c in lifting cables for the lifting speed v_1 = 0.5 m/s

3. MOMENTUM AROUND MAST

This momentum is calculated at the lowest point of mast, at crane's base. We consider that momentum around mast is very important for studying overall dynamic response of crane during the workload lifting. Simulation will be carried for the cases of lifting speed v_1= 1 m/s and v_2= 0.5 m/s.



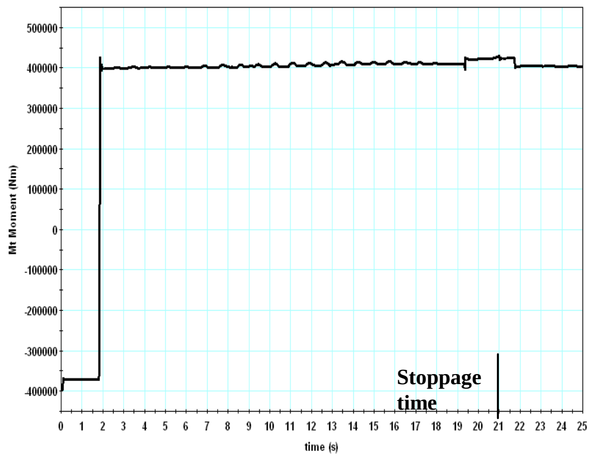


Fig.5. Momentum around mast M_t , v_1 = 1 m/s *Fig.6. Momentum around mast M_t , v_2 = 0.5 m/s*

In the graph of Fig. 5 is shown the dynamic momentum around mast during lifting for v_1 = 1 m/s. We can notice similarities of the curves with those of cable's force (Fig.3). Phase one (0<t<1 s) shows negative value of momentum, while workload is not yet lifted and tipping fulcrum is on the side of upper ballast. Phase two is during workload lifting, where we have rapid increase of curve, and tipping fulcrum is on the side of workload. After phase three there is very little dynamic activity, while workload hangs with little swings. Graph of Fig.6 gives smoother curve at v_2 = 0.5 m/s, similar to the one of Fig.4, which confirms conclusion that lower lifting speed gives more optimized lifting.

4. STRESSES IN THE CRANE'S CONSTRUCTION

In order to monitor the behavior of the crane's construction, best parameter is to monitor overall stress of the boom or mast. In this case we monitor overall stress in mast construction or column. Calculation will be done using Finite Elements Method (FEM) [3]. Fig. 7 shows the spread of stresses in the mast with max value of stresses $\sigma_i = 4.656 \cdot 10^6$ Pa at the bottom of column. Fig. 8 shows the graph of stresses during the lifting. We can notice that stress curve changes significantly in all phases, especially at the beginning of workload lifting t = 1.2 s, where we have rapid change between values of stress. This is the time when mast of crane undergoes heavy stresses. After this, during the phase two, stress value will increase up to the stoppage time, where it will reach its maximal value. At phase three, value of stress will fall down close to the value of phase one with less oscillations. We can conclude that stress graph shows heavy dynamic process during the workload lifting.

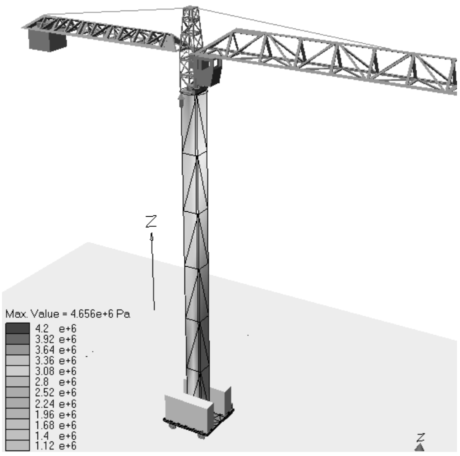


Fig.7. Stresses of the mast

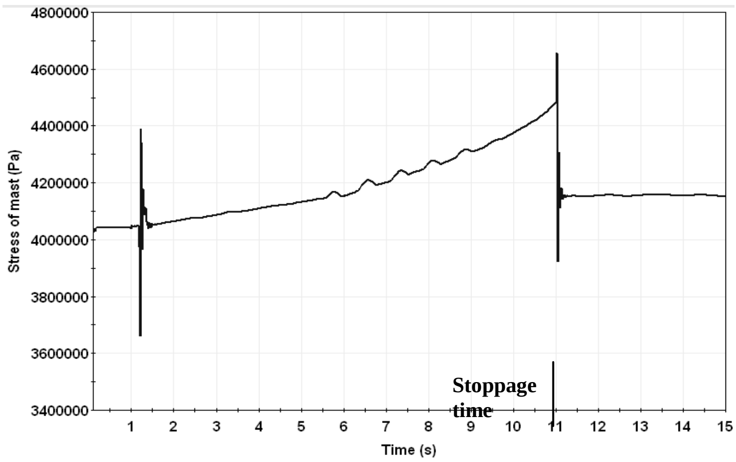


Fig.8. Graph of stresses on the mast construction, for v_1 = 1 m/s

5. CONCLUSION

Creating computer models of cranes and applying simulations is a good way for studying these devices. It helps engineers before and after construction of crane. We can see that lifting of workload at tower cranes is complex process with dynamic activity. We can conclude that speed of lifting is influential parameter of oscillations and overall dynamic process. By looking at the graphs we should always take in consideration oscillations of workload which produces oscillation of other parts, tension of cables, momentum around the mast and monitor the stresses in order to prevent possible failures of crane. Also, it is very important that before and during the lifting, workload is properly hanged, symmetric with vertical axes of hoist and cables and speed is optimal.

6. REFERENCES

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DOPRINOS SINTEZI MEHANIZAMA ZA OBAVLJANJE OPERACIJA SJEČENJA KOD AGREGATNIH LINIJA

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REZIME
U ovom radu je prikazan pristup razvoja novog mehanizma za sječenje za «Automatsku liniju za izradu rešetkastih armaturnih zavarenih nosača tipa SP – 008» koji je zasnovan na novim pristupima realizacije, novim metodama koje se koriste u konstruisanju, a to su modeliranje i simulacija.
Ključne riječi: *SP nosač, mehanizam, simulacija, modeliranje*

1. UVOD
Funkcija mašinskog sistema je polazna činjenica na osnovu koje se razvija oblik, dimenzije, bira materijal i dr. kod mašinskih sistema. Od njih se polazi pri određivanju dimenzija dijelova u sklopovima kao što su dužine nosača, položaji oslonaca mehanizama, smještajni prostor za pokretne dijelove, položaji i veličine spojeva, sistemi za podešavanje itd. Sve navedene dimenzije, koje izračunavaju ili su u vezi sa funkcijom sistema i pripadaju grupi funkcionalnih mjera.

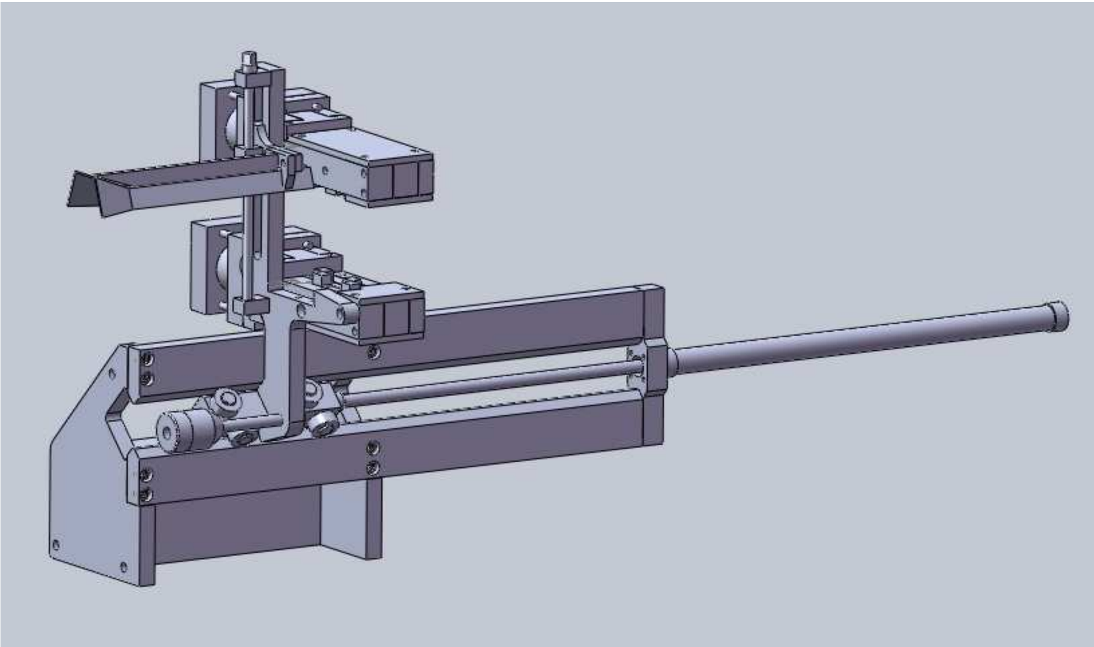
Automatske linije za izradu armaturnih rešetkastih zavarenih nosača imaju nekoliko važnih mehanizama koji omogućavaju fleksibilnu proizvodnju čitave familije tih nosača. Među njima je i mehanizam za sječenje gotovih zavarenih nosača.

Analizirajući do sada korištene mehanizme za sječenje žice, konstatovano je da razni mehanizmi koji se koriste, omogućavaju nesmetani dugotrajni rad na proizvodnji SP-nosača pri konstantnoj brzini. Kada je potrebno promijeniti brzinu proizvodnje nosača, koja ujedno zahtjeva i promjenu brzine sječenja, usložnjava se priprema mašine za izradu novih SP-nosača.

Podešavanje mašine je mukotrpno, jer promjene koje moraju da se naprave na mehanizmima iziskuju 6 do 8 sati rada. Zbog toga se prišlo osmišljavanju novog mehanizma za sječenje žice, koji ce omoguciti brzo i efikasno sječenje pri promjeni dimenzija SP - nosaca.

2. MEHANIZAM ZA SJEČENJE ŽICE

Mehanizam za sječenje se sastoji od gornjeg dijela alata koji siječe jednu žicu i i dojnjeg dijela sa noževima koji istovremeno sijeku četiri žice. (Slika 1). Pomjeranje ovih dijelova alata pri promjeni visine nosača se ostvaruje navojnim vretenom.



Slika 1. Mehanizam za sječenje žice

Horizontalno pomjeranje alata se ostvaruje pomoću pneumatskog cilindra koji pričvrsti alat za nosač i istovremeno se kreće s njim i u hodu ostvaruje sječenje žice. Nakon izvršenog sječenja žice cilindar se odvaja od nosačaa a povratno kretanje alata ostvaruje drugi pneumatski cilindar.

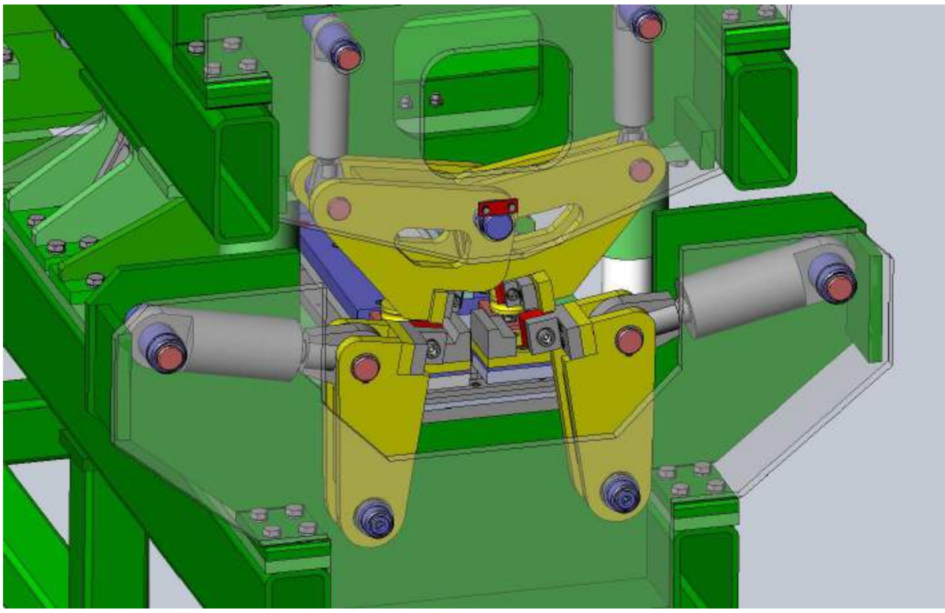
Za vrijeme operacije sječenja nosača proces izrade nosača se ne prekida.

3. SINTEZA MEHANIZMA SJEČENJE

Na osnovu provedene analize utvrđeno je da za sječenje zavarenih nosača najbolje odgovara mehanizam koji je prikazan na slici 2.

Mehanizam ostvaruje sva kretanja koja su potrebna za opeeraciju sječenja gotovih nosača, te miruje za vrijeme izrade i zavarivanja nosača.

Hidraulični cilindri ostvaruju silu sječenja koja je veća od sile sječenja koja je potrebna za sječenje najnepovoljnije kombinacije dimenzija žica u nosaču.

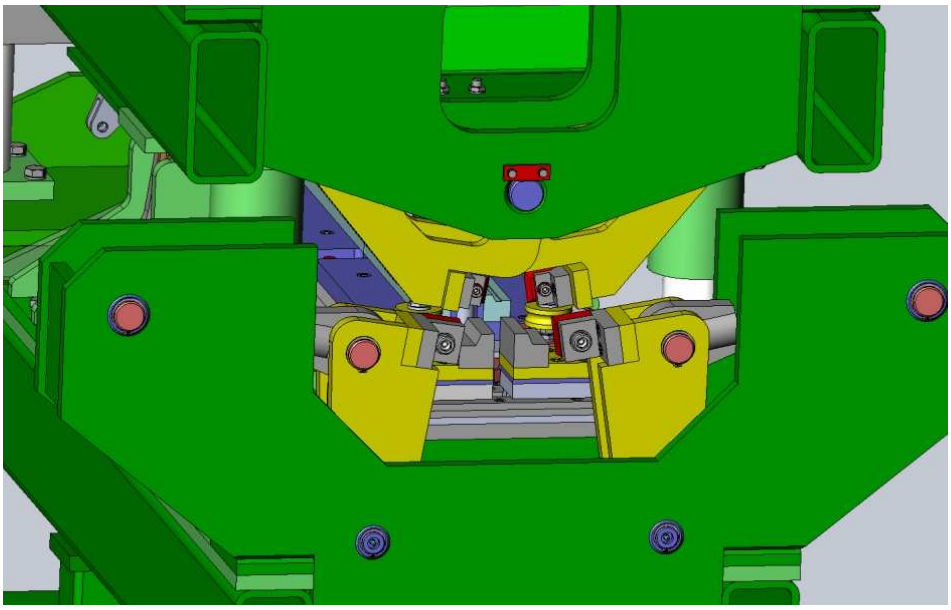


Slika 2. Mehanizam za sječenje žice

Navedeni mehanizam ostvaruje sječenje žice u predviđenom vremenskom intervalu i lako se podešava prema zadanoj visini i zadanoj širini standardnih tipova zavarenog armaturnih SP nosača.

4. NOŽ ZA SJEČENJE ŽICE

Nož za sječenje žice omogućava sječenje svih predviđenih dimenzija zavarenih građevinskih nosača. Zamjena noževa je jednostavna.



Slika 2. Nož za sječenje žice

5. ZAKLJUČAK

Provedena istraživanja pokazala su da sintezom dobiveni mehanizam ostvaruje potrebnu silu sječenja i za najnepovoljniju kombinaciju dimenzija žica u SP nosaču. Mehanizam ostvaruje i sva potrebna kretanja za sve tipove i sve dimenzije SP nosača. Podešavanje alata pri promjeni visine nosača je automatsko.

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[3] *Badžak, I., Dedić, R., Manjgo M., – Doprinos sintezi mehanizama kod fleksibilnih linija, DEMI, Banjaluka, 2009.*

1st International Scientific Conference on Engineering
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DOPRINOS SINTEZI MEHANIZAMA ZA OBAVLJANJE OPERACIJA SAVIJANJA KOD AGREGATNIH LINIJA

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REZIME

Proces konstruisanja je zasnovan na principu analiza koja se odvija prije početka konstruisanja, u periodu istraživanja, a proces sinteze je okrenut stvaranju novih tehničkih rješenja, na prvom mjestu to su novi principi rada, novi oblici, novi izvršioci funkcija.

U radu je prikazan pristup razvoja mehanizma za savijanje žice za «Automatsku liniju za izradu rešetkastih armirnih nosača tipa SP – 008» koji je zasnovan na novim pristupima realizacije, novim metodama koje se koriste u konstruisanju, a to su modeli, modeliranje i simulacija.

Osnovni cilj istraživanja je definisanje optimalnog mehanizam za oblikovanje žice nosača koji će koristiti što manje energije, imati veću brzinu izvršenja funkcije, biti produktivniji, a uz to imati jednostavnu konstrukciju sa mogućnošću kompjuterizacije cijeloga procesa.
Ključne riječi: SP nosač, mehanizam, simulacija, modeliranje

1. UVOD

U industrujskoj proizvodnji se koristi veliki broj različitih mašina i opreme za razne namjene. Svaka mašina sastavljena je od dijelova kojima je tačno u sklopu namjenjena određena uloga. Brzi razvoj tehnike zahtjeva da se veći broj dijelova mijenja kako bi se poboljšala mašina sa aspekta produktivnosti, kompjuterizacije procesa, brzine izvršenja funkcije. Ovisno o situaciji, analizom tržišta, potrebno je predložiti i novo konstruktivno rješenje.

Kako je tržišni vijek sadašnjeg mehanizma za oblikovanje žice nosača u odnosu na stepen savršenosti dostigao maksimum isti se potiskuje i uvode se novi. Znajući to pristupilo se konstruisanju istog:

- dobijanje jednostavnog konstrukcijskog rješenja mehanizma koji će biti vođen procesorom i koji će omogućiti jednostavno formiranje proizvoda,

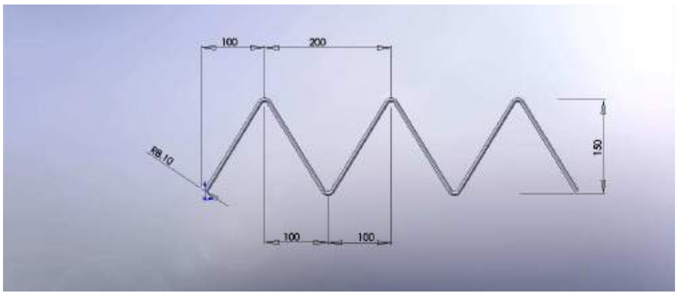
- modeliranje oblika mehanizma koji omogućava razvoj transformacije i manipulacije oblikom, razvoj tehnologije za izradu, razvoj modela za analizu stanja u eksploataciji primjenom CAD i CAE programa

2. TEHNIČKI OPIS NOSAČA

Armaturni, zavareni, rešetkasti nosač izrađen je od ugljeničnog čelika dobre zavarljivosti. Konstrukcija nosača trouglastog presjeka garantuje potrebnu nosivost betonskih konstrukcija u građevinarstvu, kod međuspratnih i krovnih ploča u stanogradnji, industrogradnji itd.

Polazeći od osnovnog modela cik-cak žice, može se uočiti da je žica nakon savijanja oblika jednakokrakog trougla. Na slici 1. prikazan je izgled nosača, a na slici 2 osnovne dimenzije cik-cak žice. Kao što je vidljivo sa slike, cik-cak žica se formira u jednom ciklusu kretanja izvršnog mehanizma.

Slika 1. Nosač



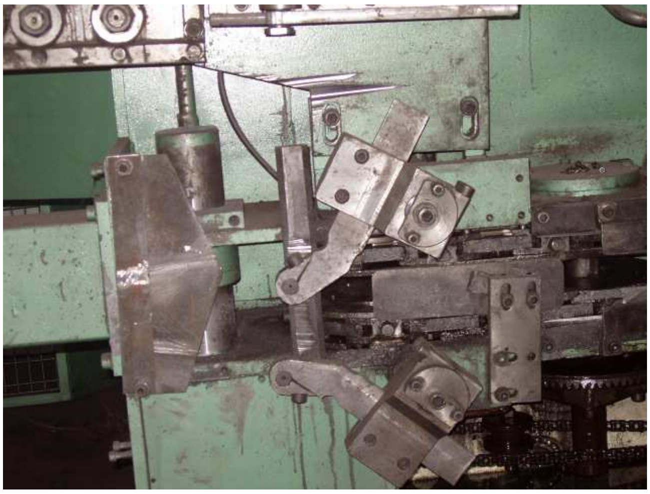
Slika 2. Cik – cak žica

Mašina, odnosno linija za izradu zavarenog armaturnog nosača SP 088 omogućava izradu nosača trouglastog presjeka slijedećih dimenzija:

- baza trougla B =40, 60, 80mm
- visina trougla H = 90 – 250mm
- dužina nosača L = 3000 – 12000m

3. ANALIZA MEHANIZMA

Analizirajući do sada korištene mehanizme za izradu cik-cak žice, konstatovano je da razni mehanizmi koji se koriste, omogućavaju nesmetani dugotrajni rad na proizvodnji jednog oblika tj istih dimenzija SP-nosača. Kada je potrebno promijeniti visinu i širinu nosača, koje ujedno zahtjeva i promjenu i dimenzije cik-cak žice, usložnjava se priprema mašine za izradu novih SP-nosača.

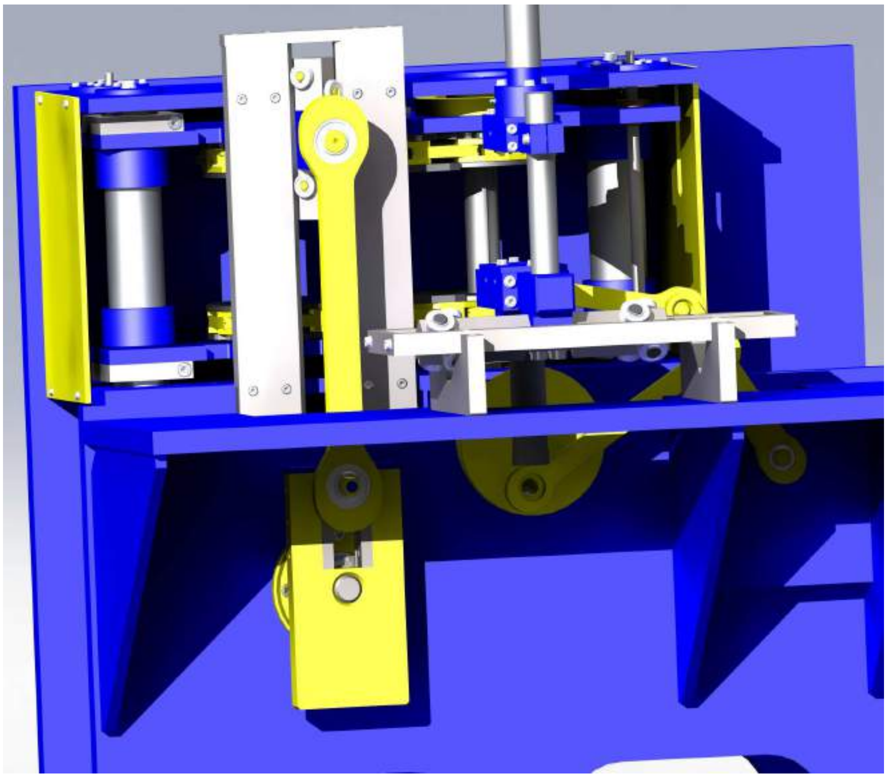


Slika 3. Mehanizam za izradu cik-cak žice u upotrebi

4. NOVO KONSTRUKTIVNO RJEŠENJE

Na osnovu linije koja je rađena 1988 godine na Institutu Mašinskog fakulteta u Mostaru, predlaže se nova linija jednostavnijeg konstrukcijskog rješenja mehanizma koji će biti vođen procesorom i koji će omogućiti jednostavnije formiranje proizvoda

Mehanizmi, koji mogu proizvesti takvo kretanje tačaka, odnosno koji ostvaruju cik-cak kretanje vrlo su složeni jer su to višečlani mehanizmi. Primjenom takvih mehanizama promjena dimenzija je komplikovana i iziskuje mnogo vremena koje je potrebno da se ostvari željena promjena.



Slika 4. Novo, originalno rješenje mehanizma za savijanje cik-cak žice

5. ZAKLJUČAK

Na osnovu linije koja je rađena 1988 godine na Institutu Mašinskog fakulteta u Mostaru, predlaže se novi mehanizam, jednostavnijeg konstrukcijskog rješenja koji će biti vođen procesorom i koji će omogućiti jednostavnije formiranje proizvoda.

Na glavnom pogonu sa promjenom mehanizma za savijanje cik-cak žice mijenja se i uvodi jednostavnija konstrukcija tj. izbacivanjem dosadašnja dva elektro motora sa planetarnim prenosnikom, kao i četverozglobnog mehanizma sa lančanim prenosnim kretanjem.

U razvoju, novog, optimalnog mahanizma za oblikovanje žice nosača zadovoljeni su uslovi od koji se pošlo. Novo, originalno, riješenje mehanizma podrazumjeva novi princip rada.

6. LITERATURA

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[2] *Badžak, I., Dedić, R. – Novo rješenje fleksibilne linije za proizvodnju građevinskih armaturnih nosača, Naučna konferencija "Industrijski sistemi", Novi Sad, 1990.*

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MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

OCJENA DINAMIČKOG PONAŠANJA STRUKTURE IZVOZNOG KOŠA

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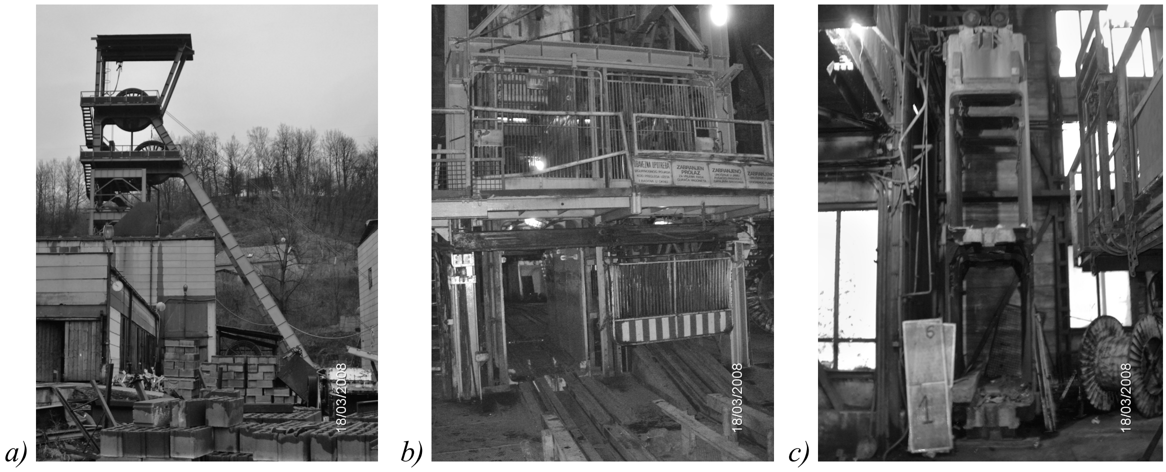
REZIME
Ovaj rad se bavi u osnovi problemom analize strukture izvoznog koša izvoznog postrojenja u stacionarnim, a naročito u prelaznim režimima rada (periodi ubrzanja i usporenja) pogonskih mehanizama, gdje nije moguća upotreba standardnih procedura za dinamičku analizu. U smislu kompleksne analize naponsko-deformacionog stanja konstrukcije izvoznog koša u statičko-dinamičkim uslovima ponašanja primjenjena je metoda konačnih elemenata. U konkretnom slučaju numerička analiza podrazumijeva diskretizaciju kompleksne strukture koša, određivanje graničnih uslova koji će opisivati realno ponašanje konstrukcije, a zatim za različite kombinacije statičko-dinamičkih veličina opterećenja po fazama analize dati deformaciono-naponske odzive za sve elemente strukture.
Ključne riječi: izvozno postrojenje, numerička analiza, naponsko-deformaciona stanja.

1. UVOD
Izvozna postrojenja su složene transportne mašine prekidnog transporta koje karakteriše periodična smjena više različitih operacija i pokreta njenih pogonskih mehanizama prilikom premještanja tereta u toku jednog radnog ciklusa. Njihov rad se odlikuje velikim brojem upuštanja mehanizama u pogon, kočenja i pauza. Svaki pokret se u principu sastoji iz perioda ubrzanja, stacionarnog kretanja i kočenja. Zbog brze smjene navedenih perioda kretanja elementi izvoznog postrojenja su u toku rada izloženi promjenljivom opterećenju koje u pojedinim slučajevima može dovesti i do zamora materijala, zatim loma elemenata i otkaza mehanizma, odnosno izvoznog postrojenja kao cjeline, [1].

Predmet uže analize jeste izvozni koš izvoznog postrojenja rudnika ''Raspotočje'', slika 1. Isti služi za transport radnika u i iz jame, kao i transport materijala u vagonetima. Dimenzije izvoznog koša su 3750 x 6000 x1400 (mm^3), [2]. Analiza strukture izvoznog koša izvoznog postrojenja u stacionarnim, a naročito u prelaznim režimima rada (periodi ubrzanja i usporenja) pogonskih mehanizama, gdje nije moguća upotreba standardnih procedura za dinamičku analizu, je veoma kompleksna.

Cjelokupna istraživanja u smislu kvalitetne analize strukture izvoznog koša izvoznog postrojenja podrazumijevaju analitičke postavke zakona kretanja masa i promjene zatezne sile elastične veze modela u zatvorenom obliku, preliminarnu numeričku analizu statičkog i dinamičkog ponašanja sistema, kao i realizaciju velikog broja eksperimenata sa variranjem uticajnih faktora. U ovom radu akcent je dat na numeričku analizu kompleksnog sistema izvoznog koša.



Slika 1. Prikaz izvoznog postrojenja rudnika ''Raspotočje'': a) pogonski sistem, b) sistem izvoznih koševa, c) izgled jednog izvoznog koša

2. NUMERIČKA ANALIZA

U smislu kompleksne analize naponsko-deformacionog stanja konstrukcije izvoznog koša, kao krajnjeg elementa dinamičkog lanca sistema, u statičko-dinamičkim uslovima ponašanja primjenjena je metoda konačnih elemenata. U konkretnom slučaju numerička analiza podrazumijeva diskretizaciju kompleksne strukture koša, određivanje graničnih uslova koji će opisivati realno ponašanje konstrukcije, a zatim za različite kombinacije statičko-dinamičkih veličina opterećenja po fazama analize je moguće dati deformaciono-naponske odzive za sve elemente strukture, [3,4]. Na ovaj način se mogu analizirati pojedine veličine strukture izvoznog koša, kao npr:

- fleksioni pokazatelji, odnosno polja pomjeranja i maksimalna pomjeranja, krutost, polja napona i maksimalni napon, te raspodjela energije deformacija,
- sopstvene oscilacije sistema, raspored kinetičke i potencijalne energije po strukturi, frekventni i vremenski domen za karakteristične tačke,
- uticaji na promjenu opterećenja, pojedinačnim ili istovremenim variranjem relevantnih faktora itd.

Za statičku analizu opterećenja su uzimana po pojedinim fazama:

1. djelovanje pogonske sile (F_{max}) i mase koša ($m_{koša}$) bez tereta u donjem krajnjem položaju,
2. djelovanje pogonske sile, mase koša i mase donjeg užeta (F_{du}) u gornjem krajnjem položaju,
3. djelovanje mase koša i tereta u gornjem položaju.

Diskretizacija kompleksne prostorne strukture je izvršena sa 7706 konačnih elemenata tipa ploče, odnosno 8162 čvorne tačke. Granični uslovi su određeni tako da simuliraju realna ograničenja u pojedinim pravcima pri vožnji koša u smislu dobijanja adekvatnih slika naponsko-deformacionih i dinamičkih pokazatelja za ocjenu ponašanja konstrukcije. U tabeli 1 je dat prikaz fleksionih pokazatelja, polja pomjeranja, krutosti, polja napona i maksimalnih napona, te raspodjela energije deformacije, a u tabeli 2 su date detaljne vrijednosti samo za III slučaj opterećenja.

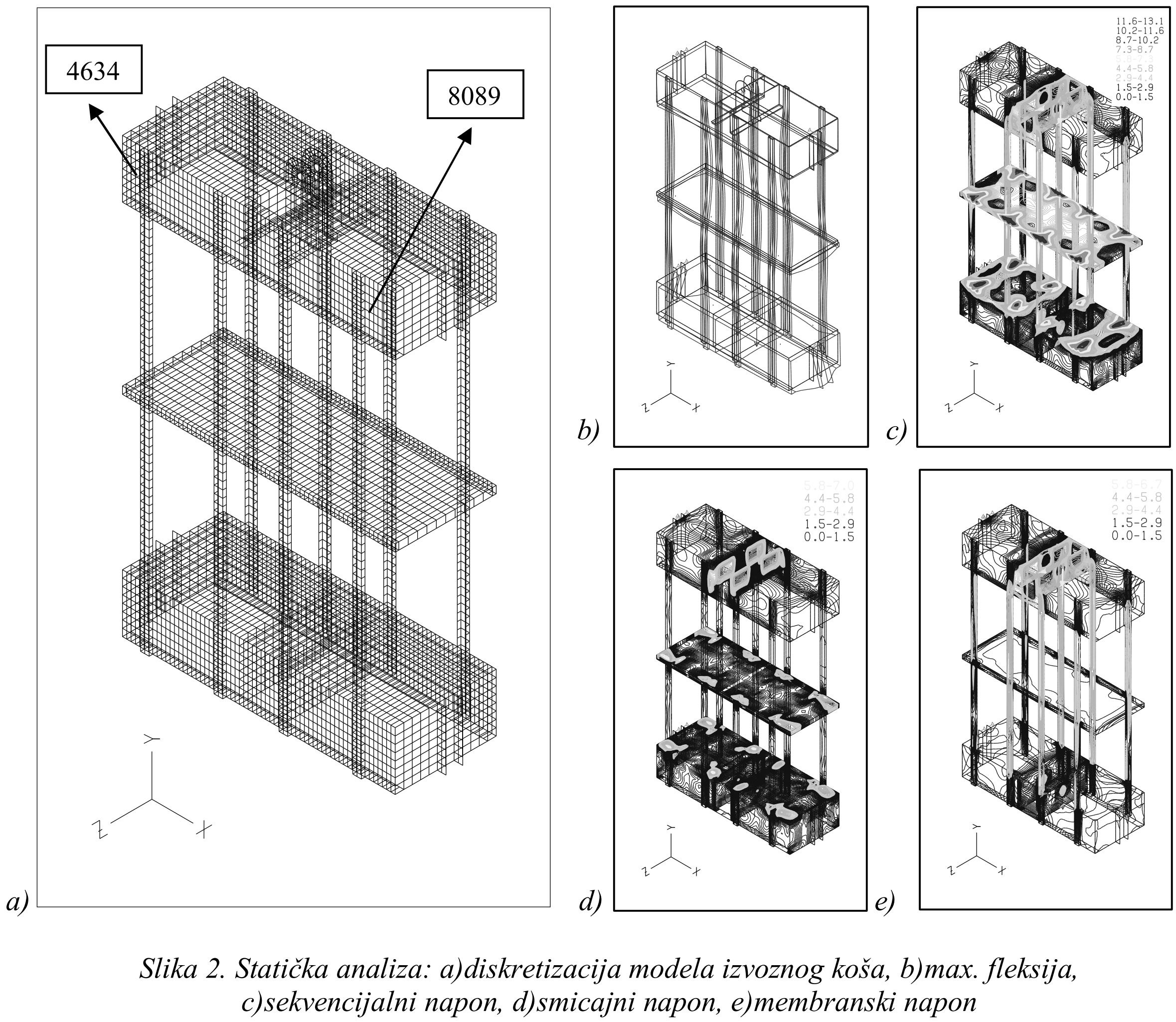
Tabela 1. Zbirni prikaz analize za sva tri slučaja opterećenja

Opterećenje	OPTEREĆENJE I F_{max} = 53,52 (kN) $m_{koša}$ = 56,65 (kN) F_{du} = 0 (kN)	OPTEREĆENJE II F_{max} = 53,52 (kN) $m_{koša}$ = 56,65 (kN) F_{du} = 51,5 (kN)	OPTEREĆENJE III F_{max} = 212 (kN) $m_{koša}$ = 56,65 (kN) F_{du} = 51,5 (kN)
Max. pomjeranje (cm)	0,031	0,061	1,25
Krutost (kN/cm)	3508,6	2623,7	256,12
Max. napon (kN/cm^2)	1,06	2,08	13,1
Vrijednosti abs. energ. deformacije	2.371E-03	9.129E-03	7.037E-02

Tabela 2. Prikaz veličina za odabrane karakteristične tačke – OPTEREĆENJE III

	POMJERANJE (cm)						
TAČKA	X			Y		Z	
4634	1.759E-02			-0.133		-1.756E-02	
8089	1.048E-02			-3.704E-02		-9.764E-03	
	NAPONI (kN/cm^2)						
TAČKA	SigEkv	Sig	Tau	Mem	Sav	AbsEn	RelEn
4634	1.20	0.378	1.15	1.09	0.145	1.106E-03	2.633E-05
TAČKA	SigEkv	Sig	Tau	Mem	Sav	AbsEn	RelEn
8089	1.33	0.386	1.29	1.26	0.127	1.455E-03	3.465E-05
MAKS.	SigEkv	Sig	Tau	Mem	Sav	AbsEn	RelEn
VRIJED.	13.1	13.0	7.03	6.66	12.6	7.037E-02	1.934E-03
ELEM. 855	NAPONI ISTEZANJA			NAPONI SAVIJANJA			EKVIVAL NAPON
	ISTX	ISTY	SMICXY	SAVX	SAVY	SMICXY	
	0.138	-6.890E-02	4.425E-02	-0.101	-0.111	5.984E-02	0.270

Procentualno učešće napona membrane (54,95%) i savijanja (45,05%), a procentualno učešće normalnih (69,20%) i smicajnih napona (30,80%). Na slici 2 je data analiza za III slučaj statičkog opterećenja: F_{max} = 212 (kN); $m_{koša}$ = 5775 (kg); F_{du} = 51,5 (kN).

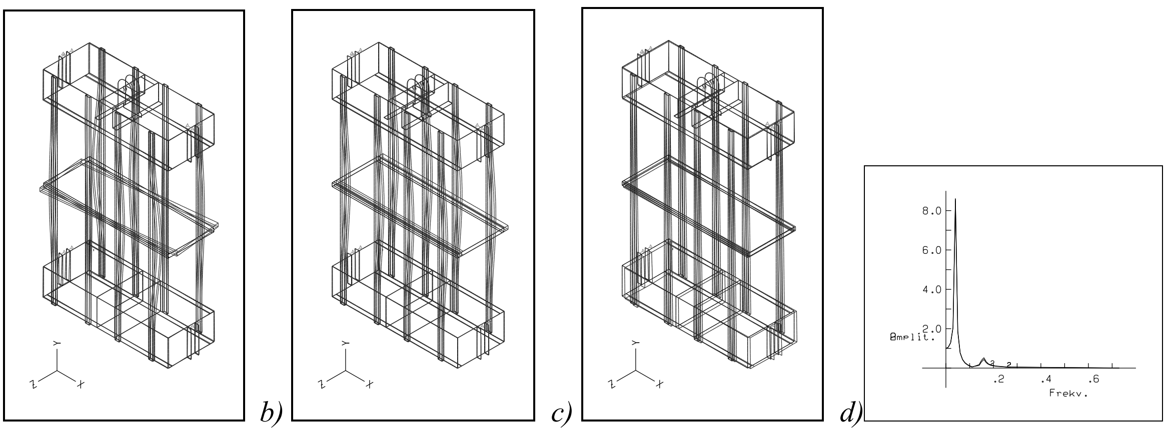


Slika 2. Statička analiza: a)diskretizacija modela izvoznog koša, b)max. fleksija, c)sekvencijalni napon, d)smicajni napon, e)membranski napon

U smislu identifikacije statičkog ponašanja konstrukcije povoljna je analiza rasporeda membranskih i savojnih napona, gdje se slabim mjestima konstrukcije smatraju ona sa većim učešćem savijanja, a povoljnim ona sa učešćem membranskih napona, odnosno sa manjim nivoom ukupnog napona. U slučaju rasporeda tangencijalnih i normalnih napona slaba su mjesta konstrukcije sa tangencijalnim naponima i povoljna mjesta sa većim učešćem normalnog napona, kao i manje vrijednosti napona. Energija deformacije, po grupama elemenata strukture ukazuje na put prolaska opterećenja i koji dijelovi strukture nose, a koji prenose opterećenje. U smislu kompleksne identifikacije dinamičkog ponašanja izvoznog koša razmatrane su sopstvene oscilacije sistema, raspored kinetičke i potencijalne energije po strukturi, te frekventni domen za karakteristične tačke.

Tabela 3. Sopstvene oscilacije konstrukcije izvoznog koša

Sopstvena oscilacija (Hz)	Max. pomjeranje (cm)	Ravan oscilovanja	Ep (%)	Ek (%)
4,12	3,7	XZ – pravac x	66,7	33,3
10,03	4,6	XZ – pravac z	82,2	17,8
15,26	7,4	XZ – pravac z	64,7	35,3
15,64	25,3	XZ – pravac x	41,4	58,6
15,75	24,4	XZ – pravac x	42,1	57,9



a) b) c) d)

Slika 3. Dinamička analiza – sopstvene oscilacije: a) f_{01} = 4,12 (Hz), b) f_{02} = 10,03 (Hz), c) f_{03} = 15,26 (Hz), d) frekventna analiza

3. ANALIZA REZULTATA I ZAKLJUČNA RAZMATRANJA

Za slučaj statičke analize maksimalna fleksija je dobijena u srednjoj zoni donjeg dijela konstrukcije, a ukupno ekvivalentno naponsko stanje pokazuje maksimalnu vrijednost u srednjoj zoni dva gornja potporna lima blizu uške. Očekivani tok sile kroz konstrukciju je u smislu opterećenja dva gornja i donja srednja pojasa, kao i srednje četiri vertikalne ukrute. Posmatranjem glavnih oblika oscilovanja očekuje se obično da kombinacija pobude i odziva osciluje najviše na prvoj frekvenci. Osnovni uticaj na ponašanje sistema imaju glavne sopstvene oscilacije i vektori, te raspored kinetičke i potencijalne energije. Frekventni domen pokazuje dominantan uticaj prve sopstvene frekvence, te uobičajeni faktor dinamičkog ponašanja. Glavni oblici oscilovanja ukazuju na to da konstrukcija ima manju krutost u horizontalnoj ravni čemu su uzrok vertikalne spojne grede. Također, mogu se primjetiti male vrijednosti sopstvenih frekvenci na svih 5 oblika oscilovanja, te bliskost frekvenci (pogotovo u zadnja 3 oblika).

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

COMPUTATIONAL FLOW ANALYSIS OF A SUBMARINE

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ABSTRACT
In this paper, flow analysis around a submarine has been performed computationally. The hydrostatic calculations and design of the submarine with block coefficient C_B=0.583, prismatic coefficient C_P=0.822, C_M=0.785 and C_{WP}=0.821 have been done by means of Maxsurf and Solidworks before analysis process. During the computational fluid dynamics analysis, finite volume method has been chosen. Flow around the submarine has been investigated in three—dimensional.

Flow around the submarine has been shown for different service speeds. It is obvious that the submersion depth of a submarine depends on various parameters such as structural resistance, material, design of the hull etc. In this study, the hydrostatic pressure loads on the submarine with different depth have been calculated.
Keywords: computational fluid dynamics, submarine, fluid flow, turbulence, hydrostatics

1. INTRODUCTION
Computational fluid dynamics (CFD) is based on numerical techniques and computer modeling of fluid flow. It can be used for wide range of problems including three-dimensional behavior of flow in and around an object. Comparing to the experimental analysis it is cheaper and faster solution techniques. Therefore, CFD become very popular within academic world and industry due to not only its cheapness but also robustness with advances in electronics recently. CFD has been used worldwide in various sectors such as piping systems, automotive industry, chemical sector, power generation, environmental analysis, etc. Design process in naval architecture can be done by means of computationally and/or experimentally. It can be selected in accordance with degree of accuracy and available money and time. In this paper, flow around a submarine has been calculated by means CFD techniques. One of the work related the design of a submarine can be found in [1]. From the related literature survey it is seen that most of the studies are on the hydrodynamic performance of the submarine, [2], [3], [4]. It is very important in the design stage of submarine. That is why it has been investigated in many different aspects such as hull lines, speed, power requirements, appendage positioning, propulsion systems, wake field anaylsis, and so many experimental works.

In this paper flow around a submarine has been calculated by means of computational fluid dynamics techniques for two different depths. Analyses give the flow fields, hydrostatics forces on the shell of the submarine. It is important especially in the initial calculations of a submarine design process.

2. COMPUTATIONAL MODEL

As reported by [5] one of the most important factor that affect the hydrodynamic performance of a submarine is the length (L) to beam (B) ratio. In this paper L/B=7.22 which is near the optimum ratio of 7.723 as proposed in [5]. Other specific information can be found in Table 1.

Table 1. Submarine information.

Parameters	Value	Unit
CB	0.583	-
CP	0.822	-
CM	0.785	-
Displacement	2642	tonne

Submarine is located in a rectangular working domain as shown in Fig.1. Submarine is located between the boundary of z/L=1.33, y/L=1.33 and x/L=±3.2. In this working domain submarine is moved in the x-direction and submerged in the z-direction. Left side and right sides of the domain is specified as velocity inlet and pressure outlet, respectively. Remaining sides is assumed as wall-type.

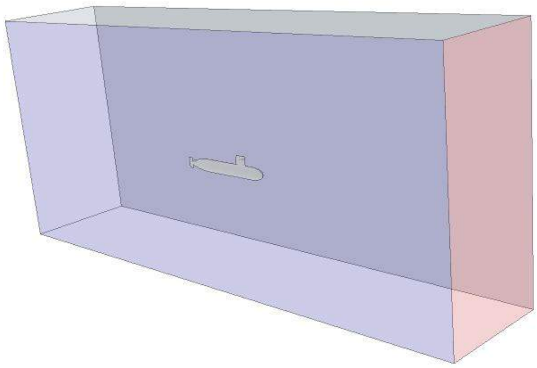
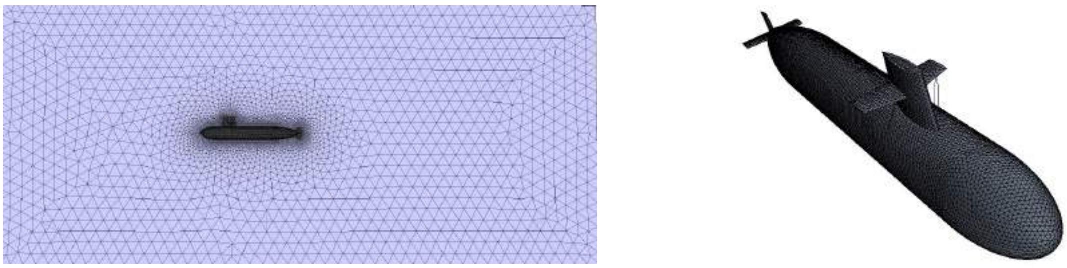


Figure 1. Working domain.

Calculated boundary layer thickness developed on the submarine shell is calculated as 0.897 m. Although it is not shown in Fig.2 mesh structure is taken into account according to this boundary layer. Totally 266184 cells and 524459 faces have been generated.



(a) (b)

Figure 2. Mesh structure of the domain (a) submarine (b).

During the simulation continuity (Eq.1), momentum equations (Eq.2) are solved iteratively:

$$\frac{\delta \rho U_i}{\delta x_i} = 0 \qquad ...(1)$$

$$-\frac{\delta P}{\delta x_i} + \frac{\delta}{\delta x_j}\left[\mu\left(\frac{\delta U_i}{\delta x_j} + \frac{\delta U_j}{\delta x_i}\right) - \rho\overline{u_i u_j}\right] = 0 \qquad ...(2)$$

Standard k-epsilon model is used as turbulence model. This model contains the turbulence kinetic energy (Eq.3) and turbulence kinetic energy dissipation rate (Eq.4):

$$\rho\frac{Dk}{Dt} = \frac{\delta}{\delta x_i}\left[\left(\mu + \frac{\mu_t}{\mu_k}\right)\frac{\delta k}{\delta x_i}\right] + G_k + G_b - \rho\varepsilon - Y_M \qquad ...(3)$$

$$\rho\frac{D\varepsilon}{Dt} = \frac{\delta}{\delta x_i}\left[\left(\mu + \frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\delta \varepsilon}{\delta x_i}\right] + C_{1\varepsilon}\frac{\varepsilon}{k}\left(G_k + C_{3\varepsilon}G_b\right) - C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} \qquad ...(4)$$

$C_{1\varepsilon}, C_{2\varepsilon}$ and $C_{3\varepsilon}$ are set to equal to 1.44, 1.92 and 0.09, respectively. $\sigma_k = 1.0$ and $\sigma_\varepsilon = 1.3$ are the turbulent Prandtl numbers for k and ε, respectively. G_k represents the generation of turbulent kinetic energy due to the mean velocity gradients. G_b is the generation of turbulent kinetic energy due to buoyancy. Y_M represents the contribution of the fluctuating dilatation in compressible turbulence to the overall dissipation rate.

3. RESULTS

One of the main purposes of the present study is to calculate hydrostatic forces on the submarine hull and the viscous flow around the body for oblique motion in a depth. Calculations have been done for two different service speeds of 10 knots and 15 knots, respectively.

Pressure contours on the hull is presented in Fig. 3. As it is expected the higher pressure values are detected on the fore of the hull which acts as stagnation point. Although it is not shown here it can be concluded that this corresponds to the lower velocity at these region. The sail of submarine is the region where the lowest pressure and higher velocity occurs.

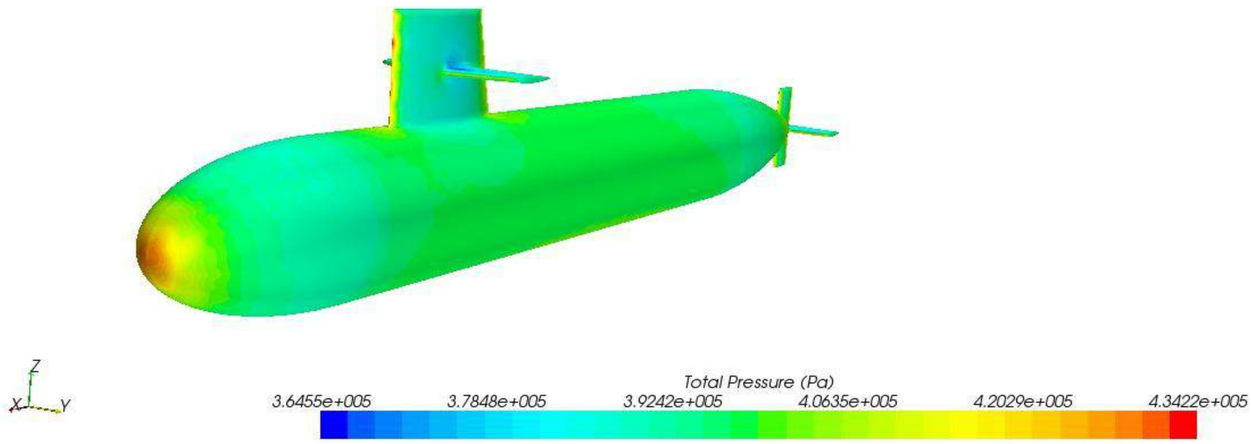


Figure 3. Pressure contours on the submarine surfaces.

Pressure distribution during service of the submarine is shown in Fig.4. Like pressure values seen in the sails, the region vicinity of the sail also has the lowest pressure. Pressure increases with the depth as one can easily predict. Such a distribution occurs due to hydrostatic forces which increase with the height of the fluid.

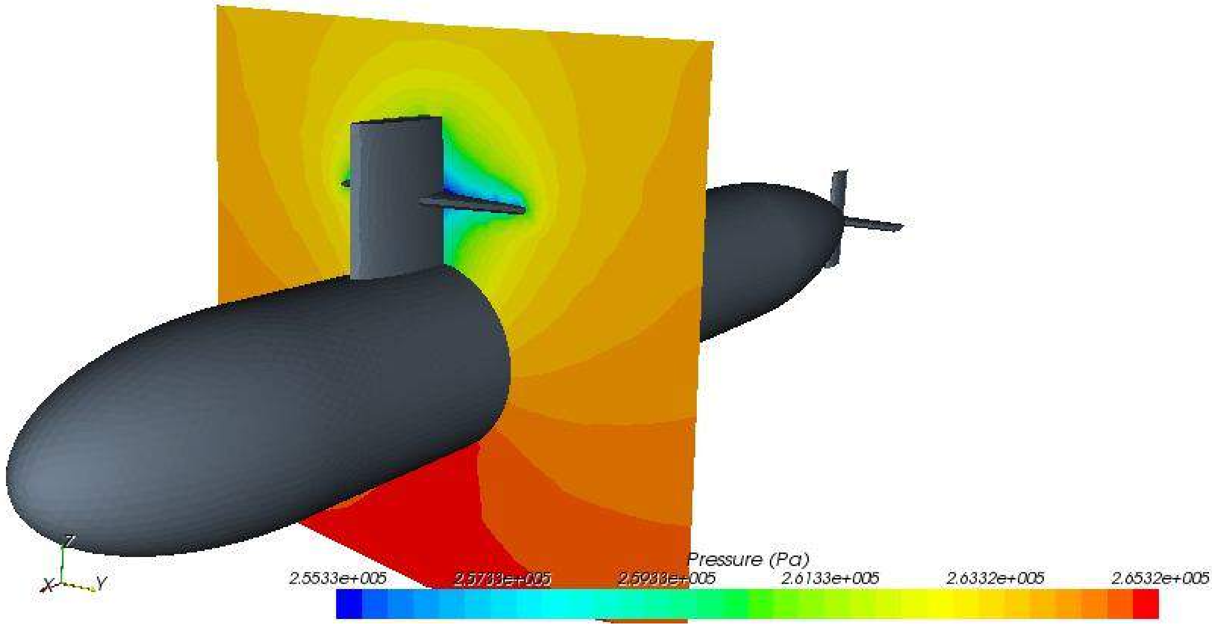


Figure 4. Pressure contours around the hull and sail of the submarine.

The close-view of the submarine sail is presented in Fig.5 for clarity. In this picture the highest pressure is seen in the foreplanes of the submarine.

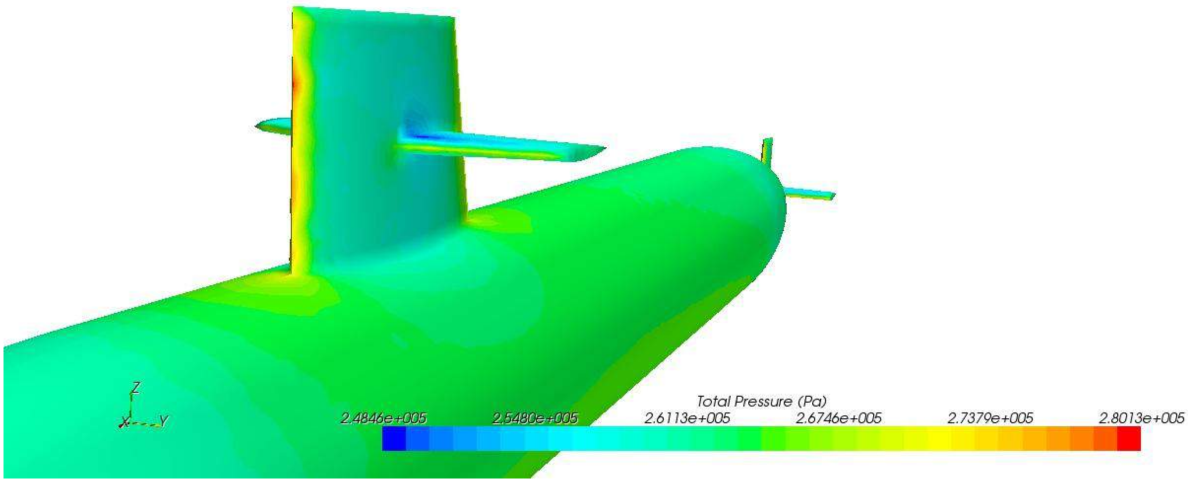


Figure 5. Pressure distribution on the sail.

Fig.6 shows the streamline comes from the bottom of the hull. Such presentations and related data can be used for calculating the wake field to use as input for propeller designs. As it can be seen the flow around the hull is so smooth and considerable flow separation is not detected. Pathlines around the sail is shown in Fig.7 which represents the separation phenomena.

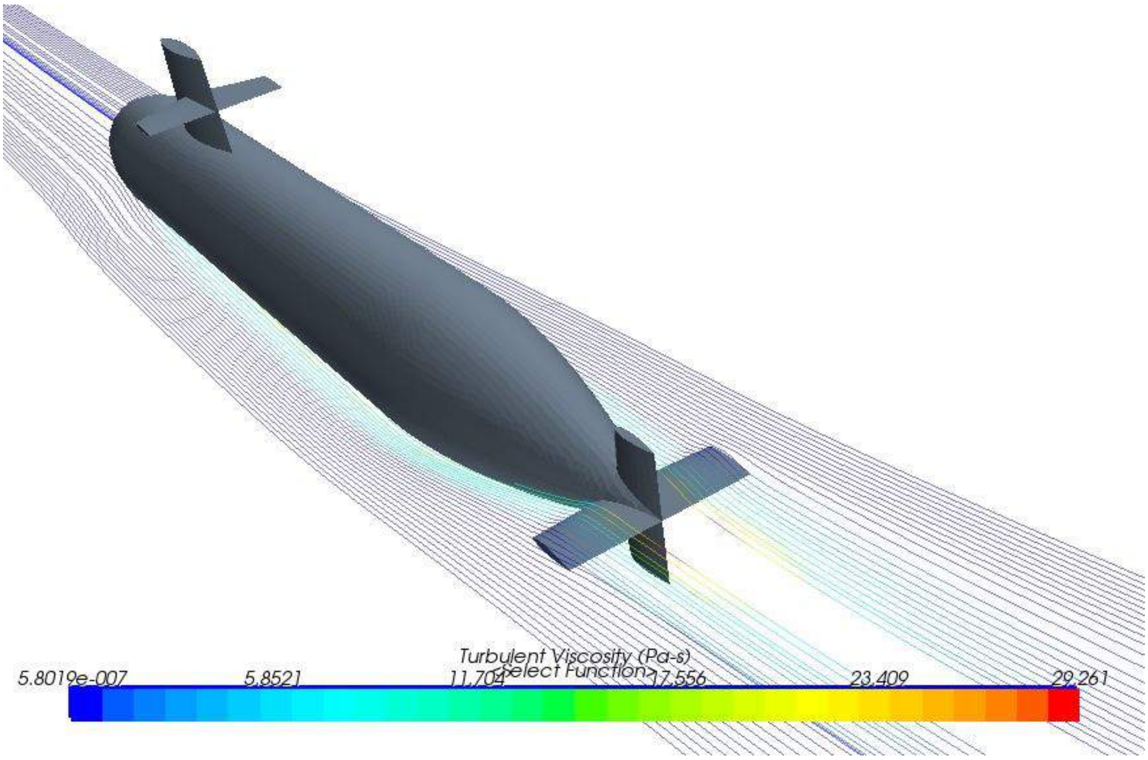


Figure 6. Pathlines from the bottom of the submarine.

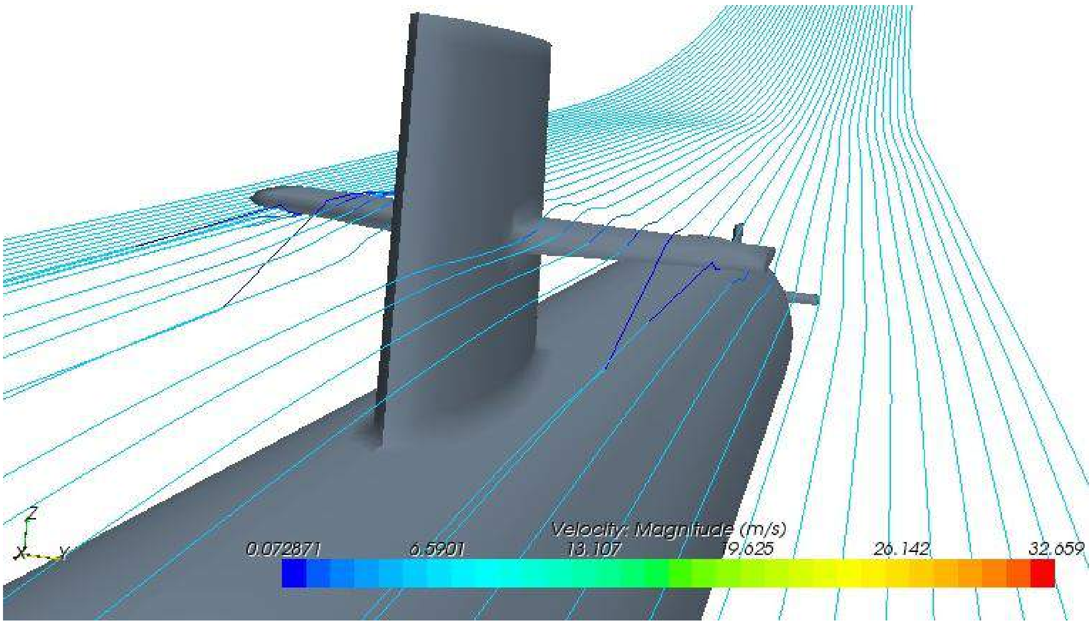


Figure 7. Pathlines around the sail of the submarine.

The drag forces on the hull are also calculated. For the depth of 100 m the drag is calculated as 144 kN for the 10 knot service speed while it increases to 310 kN for the service speed of 15 kN knots.

4. CONCLUSION

In this paper, viscous flow calculations have been done by means of computational fluid dynamics (CFD) technique which is very valuable in supplementing model tests in the design process of submarines. Drag forces for two different service speeds have also been calculated and it is seen that drag forces increases with the speed in a given depth. Flow parameters have been obtained in the vicinity of the hull for the possible design works.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 november 2010

THE TESTING OF TENSE AND BLAST CHARACTERISTICS OF THE TEST TUBES OF THE WELDED JOINT AND THE COMPONENTS OF THE WELDED JOINT OF LOW-ALLOY STEEL WITH HIGHER DENSITY AND THE ESTIMATION OT THE EFFECTS OF HETEROGENITY OF THE WELDED JOINT STRUCTURE TO THE CHANGE OF THE DEFORMITY CONDITION

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ABSTRACT

Welded joint as a complex and heterogeneous structure presents a critical point in a welded structure. Because of that in many cases, the safety of welded structures is based on characteristics of welded joint as a whole, and characteristics of all its components. Often assessment of the welded joint is based on comparing the characteristics of base metal (BM), heat affected zone (HAZ) and weld metal (WM), but in most cases the behavior of welded joints as a whole is different comparing to the behavior of weld metal, heat affected zone, and base metal.

Classic tensile testing of welded joint specimens gives information reliable only for maximal fracture force and tensile strength, but data related to stretch are unreliable since different areas suffer different strain depending on the strength level in them. That is the reason why it is so difficult to define metal yielding strength which can relate to the weld metal or the base metal, depending on their toughness ratio. In the process of tensile testing, heat affected zone behaves differently for the base metal and for the weld metal, but the complex structure of the temperature influence zone should be observed.

Considering different mechanical properties of certain areas of welded joint it is not quite simple for its behavior treated as a whole to be predicted or interpreted.

The additional data about the behaviour of the material are gotten by the blast examination (the energy of the blast of a test-tube with a notch). It represents the local behaviour of the material, conditioned by the existence of the concentration of tension in the shape of a notch. During the blast examinations, the possibility of dividing the overall energy of the blast to the energy of making and energy of spreading the crack brought about a new approach in the appraisal of the behaviour of the material. This is the most common way of examination, no matter if it is about the weld metal, when the additional material is deposited in a special way and when samples are taken out of it, or about the examinations when proper structures are welded and are to simulate the load conditions in the construction.

Keywords: welded joint, base metal, weld metal, heat affected zone, the tension firmness, .

1. INTRODUCTION

For the examination of the problem of effects of the chosen technology of welding to the tense characteristics of the components of the welded joint, we've chosen the steel Nionikral-70. Nionikral-70 belongs to a group of low-doped steels of high firmness. It has been produced in the electric stove, drained and turned into metal plates with 18 millimeters of thickness. The process of firming is the combination of the classical improvement with the grain attrition which is compatible with the chosen chemical composition, micro-doping and suitable sedimentation. The deliverer of the material is "AKRONI-

SLAVONIC RAILWAYS" JESENICE. The chemical composition of the delivered metal plates is given in table 1, and the mechanical properties in table 2.

Table 1. The chemical condition of the steel Nionikral-70

Šarža	% mass									
	C	**Si**	**Mn**	**P**	**S**	**Cr**	**Ni**	**Mo**	**V**	**Al**
180079	0,10	0,20	0,23	0,009	0,018	1,24	3,10	0,29	0,05	0,08

Table 2. The mechanical properties of the steel Nionikral-70

Šarža	The direction of examination	The density of flow, $R_{p0,2}$, MPa, min.	The tension firmness, R_m, MPa, min.	Dilatation, ε, %
180079	L - T	710	770	14

For welding the plates of 18 millimeters made of the Nionikral-70 steel, as an additional material we've chosen the basic low-hydrogen electrode TENACITO-75 with the diameter of 3,25 and 4,0 millimeters, which is defined in the catalogue of additional materials by ACRONI Jesenica. The choice of the additional material is made according to the properties and the thickness of the basic material and according to the chosen way of welding.

The chemical composition of the used electrode is given in table 3, while the mechanical characteristics are shown in table 4.

Table 3. The chemical composition of the electrode Tenacito-75

Electrode	% mass					
	C	**Mn**	**Si**	**Cr**	**Ni**	**Mo**
Tenacito-75	0,06	1,45	0,25	0,55	2,0	0,35

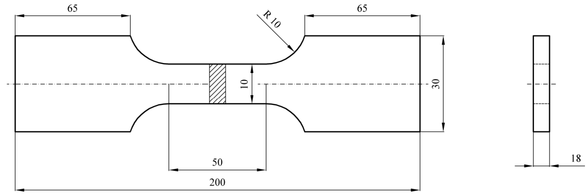
Table 4. The mechanical characteristics of the electrode Tenacito-75

Electrode	The density of flow, $R_{p0,2}$, MPa, min	The tension firmness, R_m, MPa, min.	Dilatation,ε, %	The energy of the pulse, J		
				-20°C	**-40°C**	**-60°C**
Tenacito-75	725	780	12	110-140	65-95	50-80

The welded joint is a 2/3 X-joint. The preparation of the channel is done by the standard SRPS C. T3.030.2. THE DETERMINATION OF THE TENSION CHARACTERISTICS

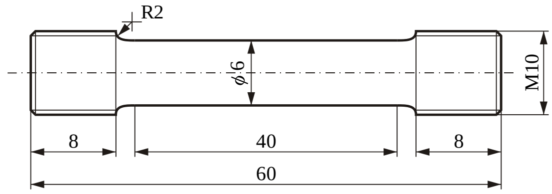
We get the basic characteristics of the firmness of the material, as well as the curve of the tension-strain which is necessary for the tension analysis of a certain construction, by the tension tests. Because we are talking about the welded joint (WJ), it is necessary to determine the tension characteristics of the whole WJ, as well as apiece BM and WM.

The examination of the welded joint at room temperature, including the shape and the dimensions of the test tubes as well as the process of examination is defined by the standard EN 895 [1]. This standard primarily defines the dilatation under the forces normally along the joint. With the dilatation of the welded joint normally along the joint, as a rule, we only determine the tension firmness of the tested sample, which shouldn't be lower than the tension firmness of the basic material. The shape and the dimensions of the test tube for determining the tension properties of the welded joint are given in graphic 1.



Graphic 1. The test tube for determining the tension properties WJ

Standard EN 895 supposes also the determination of the tension characteristics BM and WM at room temperature. The determination of the tension characteristics is defined by the standard SRPS EN 10002-1 [2], that is ASTM E8 [3]. The shape and the dimensions of the test tube of the tension characteristics of BM and WM are given in graphic 2.



Graphic 2. The test tube for determining the tension properties BM and WM

The tension tests of the test tubes are of the welded joint, BM and WM, were done at room temperature of 20 degrees. The whole testing was done with the electric-mechanic rupture machine SCHENCK TREBELL RM 400, with the ratio of 0-400 kN and the dilatation control [4].
The speed of the effect of the load was 5 millimeters per minute. The dilatation is registered thanks to the super sound extension-meter (for examining the test tubes of the welded joint) and with a double extension-meter HOTTINGER DD1 (for examining the test tubes of BM and WM). The accuracy of the measurement of both extension-meters was ±0,001 millimeters. The results of the determination of tension characteristics of the welded joint at room temperature are given in table 5 and of BM and WM in table 6 [4].

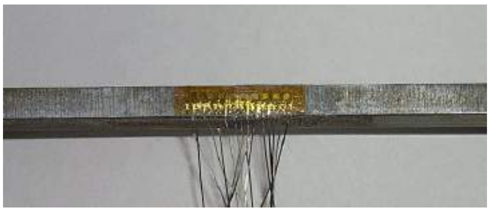
Table 5. The results of the tension tests of the welded joint

The sign of the sample	**The density of flow, $R_{p0,2}$, MPa**	**The tension firmness, R_m, MPa**	**Dilatation, ε, %**	**Ratio $R_{p0,2}/R_m$**
WJ-1	727	811	19,6	0,90
WJ-2	719	798	20,4	0,90
WJ-3	723	806	18,6	0,90

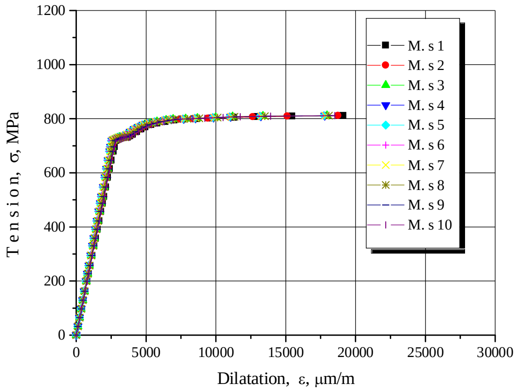
Table 6. The results of the tension tests of the test tubes BM and WM

The sign of the sample	**The density of flow, $R_{p0,2}$, MPa**	**The tension firmness, R_m, MPa**	**Dilatation, ε, %**	**Ratio $R_{p0,2}/R_m$**
BM-1	730	824	20,8	0,89
BM-2	723	821	21,5	0,88
BM-3	727	832	20,2	0,87
WM-1	749	858	15,7	0,87
WM-2	757	864	14,7	0,88
WM-3	738	846	16,5	0,87

The effect of the heterogenic structure of the welded joint to the change of the deformity condition is analyzed by the examination of the test tube with previously pasted measure stripes. The basic goal of these examinations was to determine whether the variety of certain zones of the welded joint affects the change of the module of flexibility of the tested material. Furthermore, it was important to determine whether to choose the welding technology “over matching”, where the firmness of the metal joint is higher than the firmness of the basic material, or “under matching”, where the firmness of the metal joint is lower than the firmness of the basic material. The aspect of the prepared test tube for examination is given in figure 3 (4), and the curves of the tension-dilatation dependence are given in figure 4 (4).



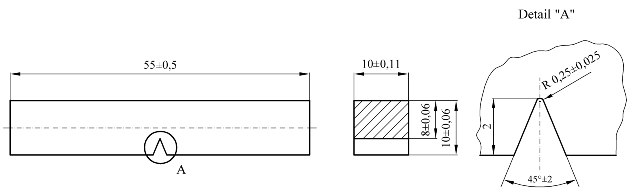
Graphic 3. The aspect of the test tube with a chain of measure stripes



Graphic 4. The dependence tension-dilatation

3. THE EXAMINATIONS OF THE BLAST

The examinations of the blast of the test tubes with notches in the base metal , weld metal and the heat affected zone were done in order to determine the overall energy of rhe blast, as well as the components, the energy of the formation of the crack and the energy of the spreading of the crack. The process of the examination, as well as the shape and dimensions of the test tubes, which are shown in graphic 5, are defined by the standard SRPS EN 10045-1 EN [5] and SRPS EN 10045-2 [6], that is ASTM E23-02 [7].



Graphic 5. The test tube for determination of the energy of the blast

The position of the notch in relation to the welded joint is defined by the standard EN 875 [8]. The examination was done on the instrumental Šarpi pendulum SCHENCK TREBEL 150 J, in the room temperature [4].

There are three groups of test tubes depending on the position of formation of the V-2 notch. These are:

- Group I - the test tubes with the V-2 notch in the base metal;
- Group II - the test tubes with the V-2 notch in the weld metal;
- Group III - the test tubes with the V-2 notch in the heat affected zone.

Because the examination was done with the instrumental Sarpijev pendulum, it was possible to see how the position of the notch affects the value of the energy of the making of crack, *Al,* and the energy of the spreading of the crack, Ap, as the integral components of the overall energy of the blast [9].
The results of the examinations of the blast are given in the table 7 for the test tubes with notches in the BM, in table 8 for the test tubes with notches in WM, table 9 with the notches in HAZ [4].

Table 7. The results of the blast examinations in the test tubes with the notch in the BM

The mark of the sample	**The temperature of the examination, °C**	**The overall energy of the blast, A_{uk}, J**	**The energy of the making of the crack, A_I, J**	**The energy of the spreading of the crack, A_P, J**
BM-1a	20	118	43	75
BM-2a		126	49	77
BM-3a		131	50	81

Table 8. The results of the blast examinations in the test tubes with the notch in the WM

The mark of the sample	**The temperature of the examination, °C**	**The overall energy of the blast, A_{uk}, J**	**The energy of the making of the crack, A_I, J**	**The energy of the spreading of the crack, A_P, J**
		Electrode Tenacito-75		
WM-1a	20	47	17	30
WM-2a		40	12	28
WM-3a		43	19	24

Table 9. The results of the blast examinations in the test tubes with the notch in the HAZ

The mark of the sample	**The temperature of the examination, °C**	**The overall energy of the blast, A_{uk}, J**	**The energy of the making of the crack, A_I, J**	**The energy of the spreading of the crack, A_P, J**
		Electrode Tenacito-75		
ZUT-1a	20	129	45	84
ZUT-2a		124	41	83
ZUT-3a		119	39	80

4. CONCLUSION

According to the given results of the examination by the dilatation of the test tubes taken out of the welded plate given in tables 5 and 6, the given diagrams of the examination, as well as the analysis of the surfaces of the test tubes, we can conclude that we have achieved a relatively high level of compatibility between the characteristics of the welded joint and the basic material. The relation between the values of the density of flowing and the tension firmness was from 0,87-0,90, which can be considered a good result, given that we have simultaneously achieved the dilatation values at the values level for the steel Nionikral-70 [4]. The character of the curve is compatible with the ductile material with approximately equal participation of both homogeneous and inhomogeneous dilatation. As a homogeneous dilatation we consider the dilatation to the maximum force, and inhomogeneous dilatation is the dilatation to the maximal force to the break, that is from the moment when a neck appears on the test tube, that is when there appears the instable growth of the initial break in the material. All the broken test tubes have cracked in the basic material, which clearly shows the character of the welded joint. This is the "over matching" which means that the firmness of the metal joint is higher than the firmness of the basic material [4]. It is noticeable that the place of the measure stripe in the chain of the measure stripes, that is whether an individual stripe in the chain is placed in MS, WJ or OM, does'n affect much the change of the deformity condition, both in the flexible and plastic area. The differences are relatively small, which is confirmed by the individual examinations of the tension characteristics of the welded joint components [4]. The effect to the value of overall energy of the blast, A_{uk}, also has the place where the test tubes have been taken out, that is the place where the V-notch is at. That means that the heterogenity of the welded joint structure, which is followed by various mechanical characteristics of the certain arears of the welded joint (base metal, weld metal and heat affected zone), has the most important effect to the blast characteristics, that is the values of the overall energy of the blast. The highest value of the overall energy of the blast have the test tubes with V-notch in the base metal (BM) and that value at room temperature is about *125 J* (4). The lowest value of the overall energy of the blast have the test tubes with V-notch in the weld metal and that value at room temperature is about *43 J* (4). The overall energy of the blast in case when the notch is in the heat affected zone (HAZ) iz about *124 J* (4). The most favourable relation between the energy of the making of the crack, A_I, and the energy of the spreading of the crack A_P, have the test tubes with the V-notch in HAZ and at room temperatutre it is *1:1,98* [4]. As for the test tubes with the notch in BM the relation between the energy of the making and spreading of the crack at room temperature is *1:1,64*, while in the test tubes with the notch in the WM this relation is *1:1,71* [4]. The highest value of the overall energy of the blast, that is the best ductility have the test tubes with the V-notch in the BM, and HAZ, and the lowest value of the overall energy of the blast, that is the worst ductility, have the test tubes with the V-notch in the WM. Thus, the heterogenity of the welded joint structure makes the weld metal have the worst ductile characteristics.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

QUALITY INVESTIGATION OF CONCRETE STEEL

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ABSTRACT
Object of research in this paper is an influence of processing of concrete steels on its mechanical properties and structure. Samples for this work were rolled at high temperature and at low temperature and they are from different manufacturers. Samples were broken on tear machine TIRA Test 2300, to analyses it's mechanical properties and for consecutive micromorphology valuation of fracture surface. There were chosen two samples for valuation of microstructure, the first was sample rolled at high temperature and second was sample rolled at low temperature, in light of appearance of impurities, cracks and micro-reglets. On the basis of our experiments, we found out, that steel, which was rolled at high temperature had higher mechanical properties in comparison with steel, which was rolled at low temperature, also despite of that in the structure of this steel were detected more impurities like sulfides, oxides, and more cracks and micro-reglets. This steel had higher mechanical properties despite of there were detected oxides in deep 0,25-0,35 mm, in regard of it refused to norm STN 42 0471. On the basis of found information, we stated that steel by rolling at high temperature allocates higher mechanical properties by ductility preservation.
Keywords: steel, concrete steel, microstructure, cold rolling, heat rolling, mechanical properties

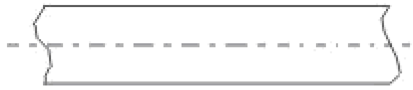
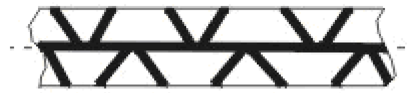
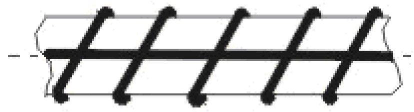
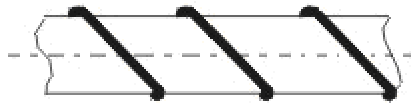
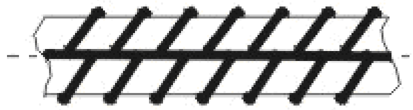
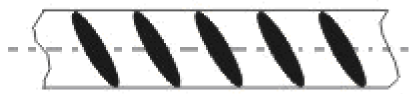
1. INTRODUCTION

Following the World Steel Association (WSA) the global steel production was decreasing on 24 % at 86 millions metric tones last January. There was occurred by global economical recession which decrease the steel production all significant producing countries except in case of China.
In February 2010 the WSA reported that the production rising on 24, 2% at 107, 5 millions metric tones. Long-term steelmaking expectations become better. The important role in steel producing plays the quality of steels. Common used steels for reinforcing material into concrete are materials by grades of steel 10. These have a low content of carbon and there is certain the tensile strength, yield strength, weldability and hot ductility. There are treated by hot working as rolled profiles, plates and wires.

Table 1. Chosen grades of steels 10

steel (STN)	Tensile strength Rm (MPa)	Usage example
10 004	〈 490	No dimensioned parts according the stress analysis
10 335	470 – 706	Reinforcing into a concrete construction, Weldability is certain
10 425	520 – 770	Reinforcing into a concrete construction
10 500	〉 490	On rails, difficult weldability
10 750	〉 750	On cross switch parts, difficult weldability

Table 2. Steels schema for concrete reinforce

Class of steel	Mode of production	Profile
10 216	Hot rolling	
10 245	Hot rolling	
10 335	Hot rolling	
10 338	Cold torsion	
10 425	Hot rolling	
10 505	Hot rolling	
“Kari” wire	Cold drawing and rolling	

Structure of concrete steel

The steel properties are on a large scale affected by structure and the quantum of present compounds besides its morphology.
The concrete steel is tried towards carbon hypoeutecoid ferrite-pearlitic steels. There are the steels with the carbon content over 0,018%. The structure is created by ferrite and pearlite.

Figure 1 illustrated the “dark meshing places” as pearlite in microscopy imagination following the eutecoid mechanical meld of ferrite and cementite. The etching solution surface etched both phases but finally there is the no planar surface and by microscopy observing is defined as the dark place.

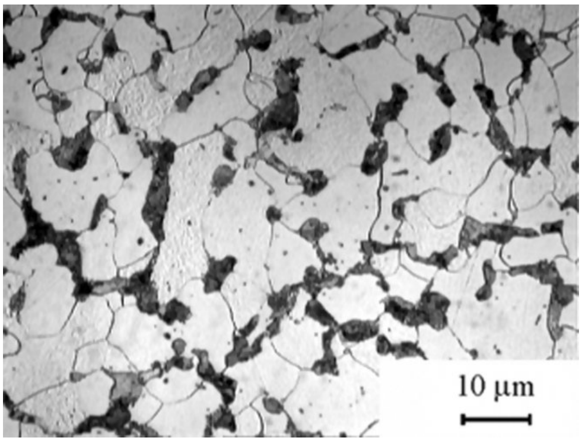


Figure 1. Ferrite-pearlite steel by 0,1% C

The steel in construction

Present steel in most constructions is basically the composite compound following the relation of steel reinforce and concrete. Concrete is the building material produced from the stoneware, cement and water. For buildings construction are used three types of concrete.

1. Common concrete – producing from comprehensive stoneware, the volume weight of 2500 kg.m^{-3}; uses for all variety constructions.
2. Cellular construction concrete - consists from porous stoneware like "expandit", blast-furnace scab, the volume weight of 1100 to 2000 kg.m^{-3}; uses for housing and urban constructions.
3. Heavy concrete - compound of heavy stoneware like basalt, granite, the volume weight of 2500 kg.m^{-3}; uses for exceptional circumstances for example the protecting shells of reactors.

2. EXPERIMENTAL

In table 3 is present the sample index which were investigated. There are different diameter samples from several producers processing by cold and hot case.

Table 3. Sample index

Sample identification	diameter	Note
	mm	
C6Z	6,00	scroll - cold processing
Z6R	6,00	straight - cold processing
E6R	6,00	straight - cold processing
C8Z	8,00	scroll - cold processing
CM8R	8,00	obscure straight - hot processing
CL8R	8,00	glossy straight - cold processing
C10Z	10,00	scroll - cold processing
B10R	10,00	straight - hot processing
T12R	12,00	straight - hot processing

After the mechanical properties testing were added the exactly identification according ČSN 42 0139, table 4. The steel identification is inseparable including of it's identify.

Table 4. Mechanical properties of steels and its identification

Provider	diameter (mm)	Average tensile strenght Rm (MPa)	Average yield strenght Re (MPa)	Average ductility (%)	Signing according to ČSN 42 0139	
					National mark	European mark
C6Z	6,00	646,96	573,75	8,8	**M 550**	**B 550 A**
Z6R	6,00	699,67	610,25	14,34	**M 550**	**B 550 A**
E6R	6,00	637,95	567,01	17,07	**M 550**	**B 550 A**
C8Z	8,00	627,42	557,34	8,4	**M 550**	**B 550 A**
CM8R	8,00	567,48	480,55	22,6	**BSt 420 S**	**B 420 B**
CL8R	8,00	493,53	415,44	12,8	**B 500 A**	**B 500 A**
C10Z	10,00	547,16	484,02	16,12	**B 500 A**	**B 500 A**
B10R	10,00	617,37	537,1	22,56	**BSt 500 S**	**B 500 B**
T12R	12,00	612,73	528,32	21,37	**BSt 500 S**	**B 500 B**

Metallographic evaluation

In case of hot processing steel were observed thermal affection of structure which drove through the decay fields into a basic material. The decay structure was appeared almost as bainite, figure 2. The structure affection was observing into a depth of 0, 85 mm.

Figure 2. Thermal affection of structure, magnification 500 xs

There were occurred the sulphides by characterized length of 2,2mm and depth of 0, 25 to 0,35 mm, figure 3. The sample refused according to STN 42 0471 – estimation of nonmetallic inclusion.

Figure 3. Sulphides, sample CM8R, hot processing, magnification 500xs

In case of cold processing sample was occurred the ferrite-pearlite structure with a gentle lamellar pearlite and grain size of ferrite G = 9 and grain size of pearlite G = 10, figure 4.

There weren't occurred no markedly defects. In the cut plane was noted sulphide presence according to STN 42 04 71.

Figure 4. Sample CL8R and ferrite – pearlite structure, magnification 500 xs

By comparison of both processing steels we can allege that the difference in structures – figure 5 and 6 was affected the processing process where occurred to material affection which was hot processing.

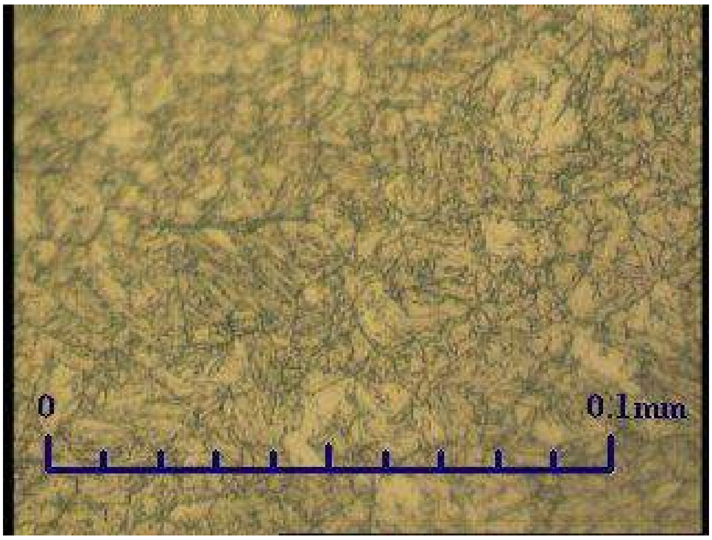


Figure 5. Steel structure of hot processing, magnification 500 xs

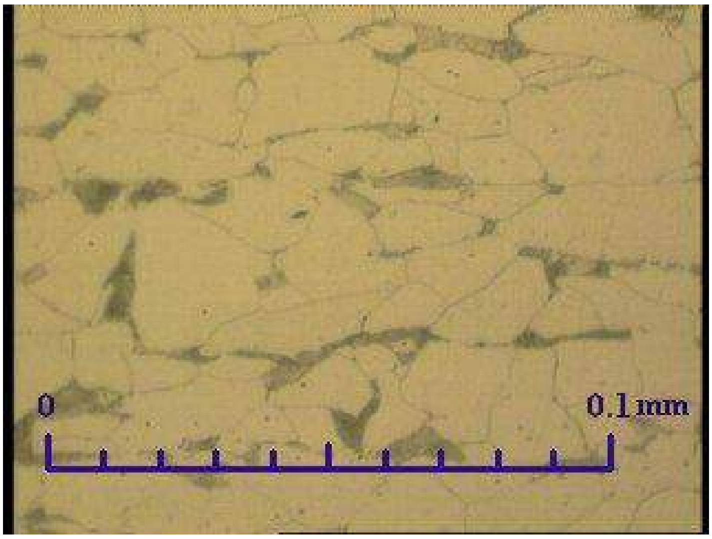


Figure 6. Steel structure of hot processing, magnification 500 xs

3. CONCLUSION

By testing of mechanical properties were estimated the tensile strength, yield strength, ductility by both types of steel. The influence of processing plays role by material testing. The hot processing steels have shining yield strength, the cold processing steels haven't.

In term of microstructure evaluation were compared the samples worked by hot and cold processing. The structure was markedly different, by sample with cold processing was noted the markedly ferrite – pearlite structure with fine lamellar pearlite.
By hot processing sample was observing the affected phase reaching into depth 0,85 mm where the affected structure drove through the decay fields into a basic material and almost appear as bainite.
The hot processed steel observing this material have much more micro-reglets, in some cases was observing crack creation and continual sulphide coat below the surface area 0,25 – 0,35 mm by length of 2,2 mm. By controlling with STN 42 0471 (the standard of estimation the nonmetallic inclusion) this material refused.

In spite of fact the hot processed sample contains much more violations and impurities, its mechanical properties were higher. We can allege, that the thermal affection rising the mechanical properties observed concrete steel besides the markedly structure defects.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

THE STUDY OF FILLER INFLUENCE ON DYNAMICAL – MECHANICAL PROPERTIES OF POLYETHYLENE

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ABSTRACT
Paper deals with the filler influence on dynamical –mechanical properties of by testing on DMA Paris Diamond. There are described samples and methodic of measurements. Dynamical mechanical properties of samples are evaluated by frequency and thermal dependencies.
Keywords: DMA, polyethylene, filler

1. INTRODUCTION
Polyethylene is a thermoplastic commodity made by the chemical industry and heavily used in consumer products. Polyethylene is a polymer consisting of long chains of the monomer ethylene. Polyethylene is created through polymerization of ethene. It can be produced through radical polymerization, anionic addition polymerization, ion coordination polymerization or cationic addition polymerization. This is because ethene does not have any substituent groups which influence the stability of the propagation head of the polymer. Each of these methods results in a different type of polyethylene [1].
Polyethylene is classified into several different categories based mostly on its density and branching. The mechanical properties of PE depend significantly on variables such as the extent and type of branching, the crystal structure, and the molecular weight. The following are types of polyethylene: UHMWPE (ultra high molecular weight PE) - because of its outstanding toughness, cut, wear and excellent chemical resistance, UHWMPE is used in a wide diversity of applications. These include can and bottle handling machine parts, moving parts on weaving machines, bearings, gears, artificial joints, edge protection on ice rinks, butchers' chopping boards., HMWPE (high molecular weight polyethylene), HDPE (high density PE) - is used in products and packaging such as milk jugs, detergent bottles, margarine tubs, garbage containers and water pipes, HDXLPE (high density cross-linked PE), PEX (cross-linked PE), MDPE (medium density PE) - is typically used in gas pipes and fittings, sacks, shrink film, packaging film, carrier bags, screw closures, LDPE (low density PE), LLDPE (linear low density PE) - is used predominantly in film applications due to its toughness, flexibility, and relative transparency., VLDPE (very low density PE) - used for hose and tubing, ice and frozen food bags, food packaging and stretch wrap.

1.1. Dynamic Mechanical Analysis
Dynamic Mechanical Analysis (DMA) is a technique used to study and characterize materials. It is most useful for studying the viscoelastic behavior of polymers. A sinusoidal stress is applied and the

strain in the material is measured, allowing one to determine the complex modulus. The temperature of the sample or the frequency of the stress are often varied, leading to variations in the complex modulus; this approach can be used to locate the glass transition temperature of the material, as well as to identify transitions corresponding to other molecular motions.

1.2. Dynamic module of polymer

The viscoelastic property of polymer is studied by dynamic mechanical analysis where a sinusoidal force (stress σ) is applied to a material and the resulting displacement (strain) is measured. For a perfectly elastic solid, the resulting strain and the stress will be perfectly in phase. For a purely viscous fluid, there will be a 90 degree phase lay of strain with respect to stress. Viscoelastic polymers have the characteristics in between where some phase lag will occur during DMA tests [2].

- Stress $$\sigma = \sigma_0 \sin(t\omega + \delta) \quad \ldots(1)$$
- Strain $$\varepsilon = \varepsilon_0 \sin(t\omega) \quad \ldots(2)$$

where

ω is period of strain oscillation,
t is time,
δ is phase lag between stress and strain [2].

The storage modulus measures the stored energy, representing the elastic portion, and the loss modulus measures the energy dissipated as heat, representing the viscous portion [2]. The tensile storage and loss module are defined as follows:

- Storage Modulus $$E' = \frac{\sigma_0}{\varepsilon_0} \cos\delta \quad \ldots(3)$$
- Loss Modulus $$E'' = \frac{\sigma_0}{\varepsilon_0} \sin\delta \quad \ldots(4)$$
- Phase angle, Tan (delta) $$\tan\delta = \frac{E''}{E'} \quad \ldots(5)$$

Similarly we can also define shear storage and loss module G' and G".
Complex variables can be used to express the module E* and G* as follows:

$$E^* = E' + iE'' \quad \ldots(6)$$

$$G^* = G' + iG'' \quad \ldots(7)$$

1.3. The principle of DMA method

The basis of device for dynamic-mechanical analysis (DMA) are two collinear arms, Arms are placed on special pivots, which are located in the middle of arms. Pivots are very exact torsion springs. The specimen is clamped in special holder between two collinear arms.
The device is situated in thermostatic environment, which enable to isothermal measure and to measure during changing of temperature, usually from 150 to 500°C. The deformations of sample are caused by two opposed moments the same size, which are impact on opposite end of sample clamped to the clamp.

By DMA we can characterize polymer material, its dependence of modulus, stupor or losing angle tan δ on temperature, possibly on time at various frequencies. So we obtain basic information about mechanical properties, which are related to processability and applicability of product.
We used the testes apparatus by PerkinElmer „PYRIS Diamond Dynamic Mechanical Analyzer (DMA) for measure dynamical-mechanic properties.
Dynamical tensile test we did during time program from 20°C to 100°C. We gradually applied frequencies 0.01 Hz, 0.05 Hz, 0.2 Hz, 0.5 Hz, 1 Hz, 5 Hz, 10 Hz, 20 Hz and 50 Hz.

2. EXPERIMENTAL PART

In presented measurements by using DMA were evaluated E´, E´´, E* and tan δ on HDPE samples. The HDPE samples were prepared in standard version and by adding of silver and gold pigment.
On figure 1-12 we evaluated our measurements.

Sample 1 – standard HDPE
Sample 2 – HDPE with silver pigment
Sample 3 – HDPE with gold pigment

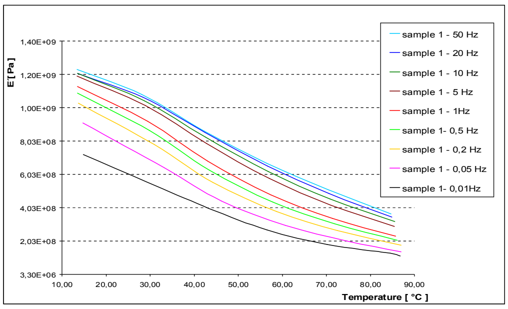

Figure 1. Comparison of dependence E´ on the temperature standard HDPE by various frequencies

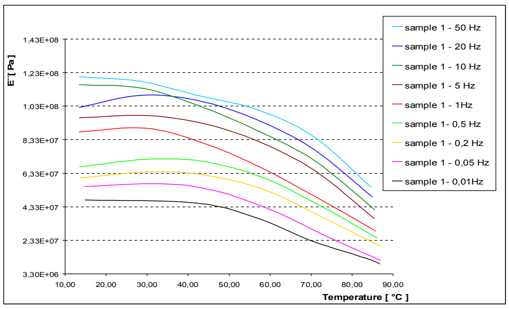

Figure 2. Comparison of dependence E´´ on the temperature standard HDPE by various frequencies

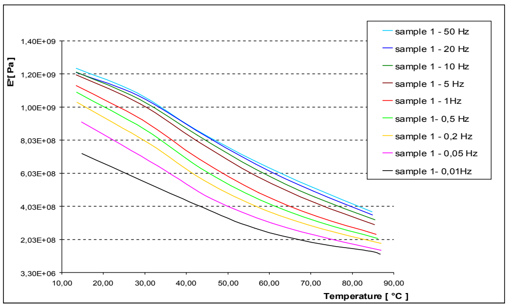

Figure 3. Comparison of dependence E on the temperature standard HDPE by various frequencies*

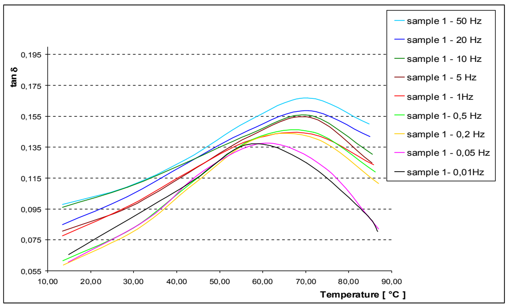

Figure 4. Comparison of dependence tan δ on the temperature standard HDPE by various frequencies

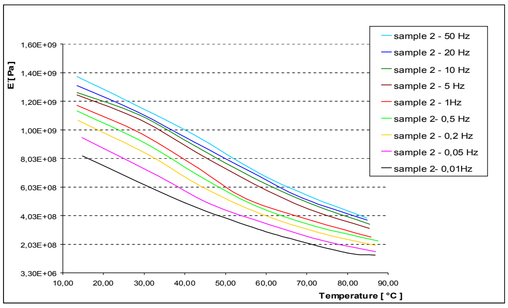

Figure 5. Comparison of dependence E´ on the temperature HDPE with silver pigment by various frequencies

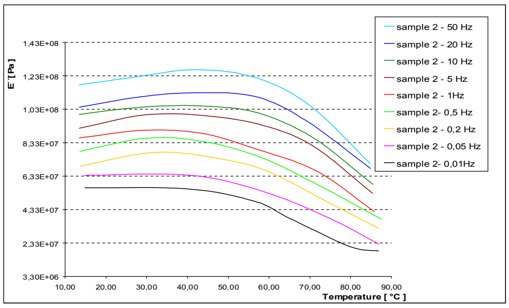

Figure 6. Comparison of dependence E´´ on the temperature HDPE with silver pigment by various frequencies

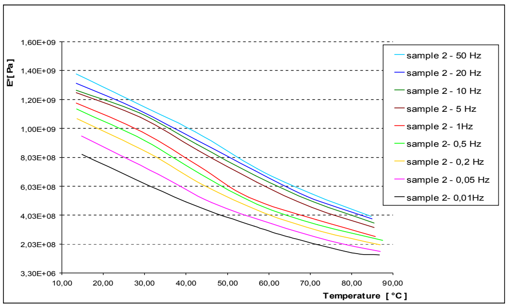

Figure 7. Comparison of dependence E on the temperature HDPE with silver pigment by various frequencies*

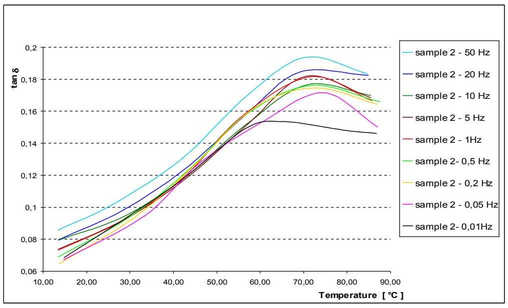

Figure 8. Comparison of dependence tan δ on the temperature HDPE with silver pigment by various frequencies

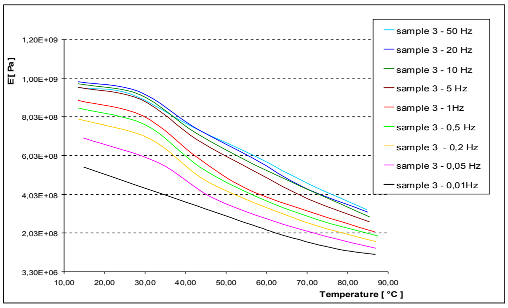

Figure 9. Comparison of dependence E´ on the temperature HDPE with gold pigment by various frequencies

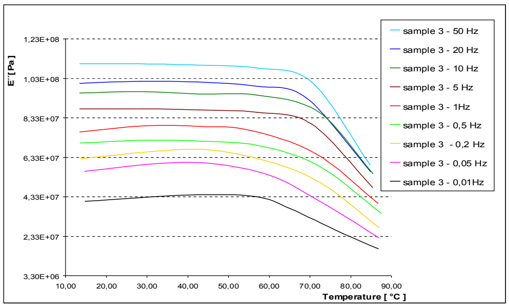

Figure 10. Comparison of dependence E´´ on the temperature HDPE with gold pigment by various frequencies

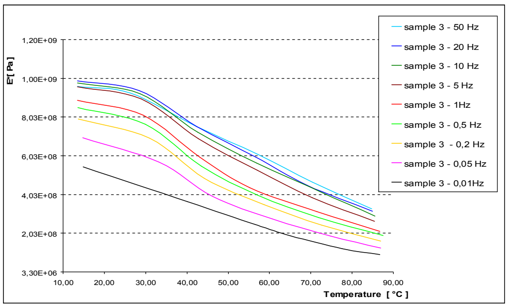

Figure 11. Comparison of dependence E on the temperature HDPE with gold pigment by various frequencies*

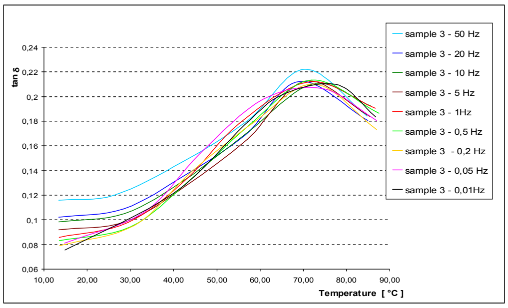

Figure 12. Comparison of dependence tan δ on the temperature HDPE with gold pigment by various frequencies

3. RESULTS

From graphical dependencies of real part the Young modulus E´(figures 1,5 and 9), imaginary part of Young modulus E´´ (figures 2,6 and 10) and the complex modulus E* (figures 3,7 and 11) is possibly to see that by increasing temperature lead to decrease of modulus, occurred to chain freeing and its twisting. There is a behavior of linear polymers, by rising frequency are increasing the modulus. This manner is characterized mark of Maxwell's environ, the present material is harden by frequency rising. The values of tan δ versus temperature (figures 4, 8 and 12) achieve the maximum by high temperatures. The temperature limit of maximums is changing in frequency dependence. By samples comparison of standard HDPE, silver and gold pigmented HDPE results that the silver pigment increase the values of complex Young modulus, the sample is harden. On the other hand the gold pigment decreases the values of complex Young modulus.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

REFLECTIONS ON MAXIMUM TOOTH ROOT STRESS LOCATION OF THIN-RIMMED GEAR

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ABSTRACT
Based upon the analysis of 3D FEM stress results, the locations of maximum tooth root stress have been determined for a spur external involute gear. The adopted gear structures with different performance of teeth foundation have included from a solid and thin-rimmed gear without web, to the gear with the rim supported by middle and offset web. The attention has been devoted to the contribution of teeth foundation geometry on maximum tooth root stress appearance related to the location at the tooth fillet, as well as along the tooth face width.
Keywords: thin-rimmed gear, stress analysis, rim, web

1. INTRODUCTION
The investigations into tooth root stress of thin-rimmed gear have underlined the complexity of stress behavior being influenced by numerous parameters. The basis for successful and reliable stress analysis has been established through the development of hardware and software with sophisticated numerical methods, and the distribution of gear teeth loading that respects actual gear structure has been enabled.
The results of early works pointed to the necessity of 3D approach for the determination of tooth root state of stress, even when a spur gear is under consideration [1,2]. The tooth root stress was calculated for thin-rimmed gear without web (fan shape hole) [3,4], as well as for more complex gear structures where web is used to connect thin rim and hub [5,6,7].
The simulation of load distribution along the tooth face width resulting from actual gear structure, has shown that the tooth root stress is not uniformly distributed along the tooth face width in relation to a solid and thin rimmed gear, regardless of its structure. Furthermore, the variation of maximum tooth root stress location at the tooth fillet has been evident.
The procedures for a tooth root stress calculation proposed by standards [8, 9] and based upon the 2D approach, don't provide the information about tooth root stress distribution along the tooth face width and the corresponding maximum stress location. For critical tooth root section defined by fixed point at the tooth fillet, the resulting stress results considerably differ in magnitude and location from the results of the 3D analysis. The introduction of rim thickness factor for the correction of nominal tooth-root stress in the cases of thin-rimmed gears is worth to be discussed, too.
The performed 3D FEM calculations enabled the determination of maximum tooth root stress in relation to both, the tooth fillet and tooth face width, going from a solid gear to the thin-rimmed gears of various structures. Through the stress calculations the geometrical parameters that define the flexibility of teeth foundation are varied. The location of maximum tooth root stress at the tooth fillet is discussed in relation to the critical tooth root section proposed by the standard ISO, method B.

2. 3D FEM GEAR MODELS
The pinion-wheel geometrical model is developed consisting of always solid pinion mating with a solid wheel, a wheel without the web (fan shape hole), and a wheel structure with middle and offset

web. The angular extension of pinion and wheel corresponds to four teeth, but three teeth are modeled above the rim. The gear pair is modeled for the engagement position at the outer point of single pair tooth contact that is indicated as critical one by the standard ISO, method B.
The geometrical parameters of pinion and wheel are the same: number of teeth z_1=z_2=20, module m=10 mm, pressure angle α_n=20°, profile shift coefficient x_1=x_2=0, and contact ratio ε_α=1,56.
The rim thickness of pinion corresponds to a solid gear, while the wheel rim thickness s_R expressed by the backup ratio is s_R/h_t =0,44; 0,64; 0,92; 1,34; and 1,78; (s_R/m=1; 1,5; 2; 3 and 4), and covers a thin-rimmed and solid gear (h_t – tooth height). Along with the backup ratio s_R/h_t, the rim thickness is expressed by very often used ratio of s_R/m. Another gear geometrical parameter of interest is the web thickness b_s that is expressed by the face width b and takes the values of b_s/b=0,1; 0,2; 0,3 and 0,4. The gear tooth is loaded by nominal load F_{bn} per face width b F_{bn}/b= 100 N/mm.
The adopted boundary conditions of numerical model enable the contact between the pinion and wheel through the middle teeth, and the simulation of load distribution along the tooth face width arising from actual performance of gear teeth foundation [10]. As regards the wheel of gear pair, its rim constraints were chosen to simulate thin-rimmed and a solid gear.
Maximum tooth root stress σ_{1max} is the highest value of calculated wheel maximum principal stress σ_1 at tensile side of the loaded tooth. Its location at the tooth fillet and along the face width is discussed.

3. MAXIMUM TOOTH ROOT STRESS AT TOOTH FILLET

The location of maximum tooth root stress at the tooth fillet is expressed by the gear radius r_x that corresponds to it. On Fig. 1, 2 the gear root radius r_f and the radius $r_{30°}$ that belongs to critical tooth root section according to the standard ISO, method B, are indicated.
The standard ISO, method B defines the range of thin rim thickness from s_R/h_t = 0,5 (s_R/m=1,13) to s_R/h_t = 1,2 (s_R/m=2,7). For this range, the rim thickness factor y_B is to be utilized for the calculation of nominal normal tooth root stress σ_{F0}.
In Fig.1 the location of maximum tooth root stress is presented going from a solid gear (s_R/h_t = 1,78; s_R/m=4 and the corresponding rim constraints) to thin-rimmed gear without web with the rim thickness that overcomes the rim thicknesses proposed by ISO.
As the rim thickness decreases and the flexibility of teeth foundation increases, the location of maximum stress moves towards the gear root, but for the considered cases doesn't reach it.
Fig.2 shows the influence of another geometrical parameter-the web thickness b_s/b, along with the influence of rim thickness. For the webbed thin-rimmed gears the location of maximum tooth root

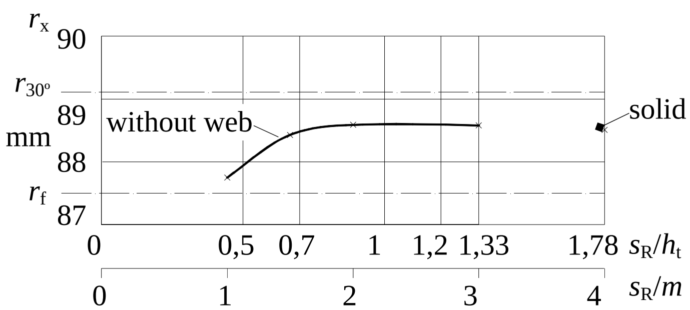

Figure1. The locations of maximum tooth root stress at the fillet for a solid gear and thin-rimmed gear without web

stress differs from the gear without web, and depends on the location of web along the face width, too.
The contribution of web to the rim rigidity is obvious and maximum tooth root stress is located more distantly from the tooth root in relation to the gear without web, regardless of web thickness, and web position, especially for the thinnest rim.
The comparison of webbed gears shows that more non uniform load distribution for offset web in relation to middle one, results with more shifted location towards the tooth root which is more expressed for the thinnest web. As the rim thickness approaches to the lowest value, the location of maximum tooth root stress becomes constant and for the thickest web the influence of web position diminishes.

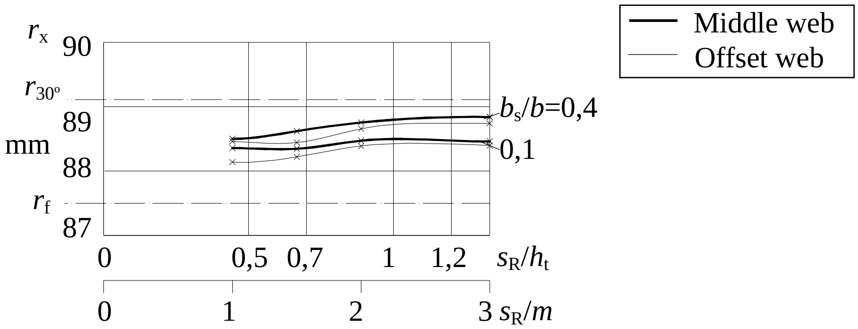

Figure 2. The locations of maximum tooth root stress at the fillet for webbed gear structures

4. MAXIMUM TOOTH ROOT STRESS ALONG TOOTH FACE WIDTH

The location of maximum tooth root stress along the face width is expressed by no dimensional coordinate b_Z/b, where b_Z is the coordinate z in axial tooth direction. For a solid gear and gear without web, the location of maximum stress is symmetrical in relation to the middle of tooth face width (Fig.3). When going from a solid (s_R/h_t = 1,78 ; s_R/m=4, and the corresponding rim constraints) to the

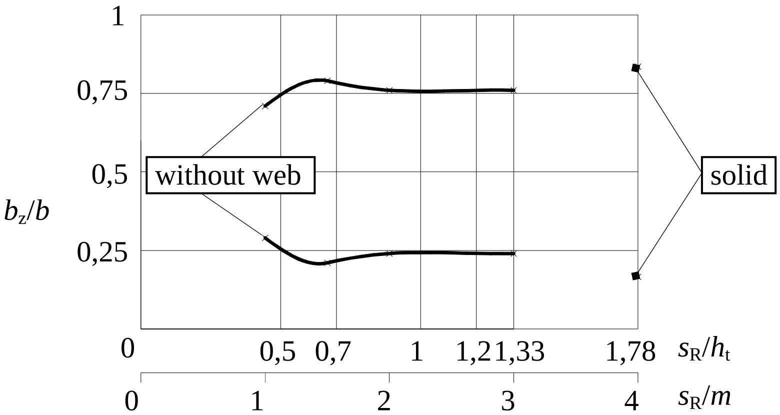

Figure 3. The locations of maximum tooth root stress along the face width for a solid and thin-rimmed gear without web

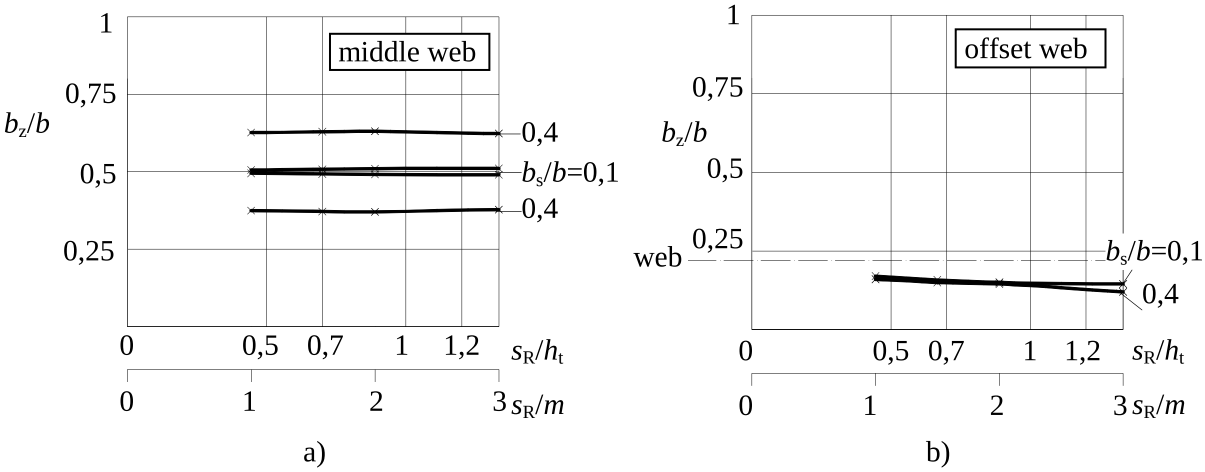

Figure 4. The locations of maximum tooth root stress along the face width for webbed gear structure

thin-rimmed gear, the stress location moves from the tooth edges towards the middle of the tooth. This location shift is especially obvious for the thinnest rim.

From Fig. 4a can be concluded that the rim thickness has practically no influence on the location of maximum stress along the face width, and in the case of gear with narrow middle web, maximum stress appears above the web. But as the web thickness increases the location of maximum stress is moved from the middle of tooth face towards the ends.

The decrease of rim thickness more affects maximum tooth root stress location in the case of offset web, when this location is shifted towards the web end that is closer to the tooth edge (Fig. 4b), regardless of web thickness.

5. CONCLUSIONS

The results of investigation into maximum tooth root stress location at the tooth fillet pointed to the obvious disagreement with the definition of critical tooth root section according to the standard ISO, method B, regardless of gear structure under consideration. The calculated maximum tooth root stress locations are achieved always closer to the loaded tooth root i.e. for the fillet tangent angle greater than the proposed of 30º. The increment and decrease of maximum tooth root stress for gear without web is accompanied clearly by the movement of stress location towards to and away from the loaded tooth root, respectively. As regards the webbed gear structures, maximum tooth root stress at the fillet is located more distantly from the tooth root than for the gear without web, regardless of web thickness and web position. The location of maximum stress for offset web gear structure with the thinnest web is mostly shifted towards the tooth bottom, but for the calculations under conditions adopted in this work, the stress location never leaves the tooth fillet. The location of maximum tooth root stress is symmetrically positioned in relation to the middle of tooth face for a solid and thin-rimmed gear without web, and for the thinnest rims this location moves towards the middle of tooth face width. By adding the web to a gear structure, characteristic distribution of maximum tooth root stress along the tooth face width is achieved depending on the position of web. Symmetrical location of maximum stress of thin-rimmed gear with middle web is considerably influenced by the web thickness, while the rim thickness has practically no influence. As the web thickness increases, the location of maximum stress is shifted from the middle towards the tooth edges. When the web is positioned asymmetrically, the location of maximum stress slightly moves from the tooth edge towards the web edge that is closer to the tooth edge, and the web thickness has no influence as the rim thickness decreases.

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ANALYSIS OF STRESS IN TORISPHERICAL HEAD OF PRESSURE VESSELS

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ABSTRACT
In this paper, it would be shown an experimental analysis of stress at torispherical head of pressure vessels and compared with results gathered from standard expressions. Also, those results would be compared with evaluated results obtained using finite element method. For experimental analysis it would use multiple strain gages in order to obtain real stress in observed area. Ansys software would be used for FEM analysis. In practice is shown that standard expressions and FEM could have deviations from actual value of stress.
Keywords: stress, vessel pressure, strain gages, FEM

1. INTRODUCTION
Design of pressure vessels by different criteria is usual engineering problem. There is a standard procedure in calculating dimensions of pressure vessels for wanted criteria which are usually maximum working conditions [1]. Also, there are standard equations for calculating maximum stress in torispherical heads of pressure vessel [2]. Results gathered by standard equations could have some divergence from real stress condition. Real stress condition is measured on pressure vessel with torispherical heads on three measuring points by strain gages. Results are compared and dilatation of results is determined.

2. GOVERNING EQUATIONS
Torispherical heads have a meridian formed of two circular arcs (fig.1.) [3], a knuckle section with radius *r* and a spherical crown with radius *L* [2].

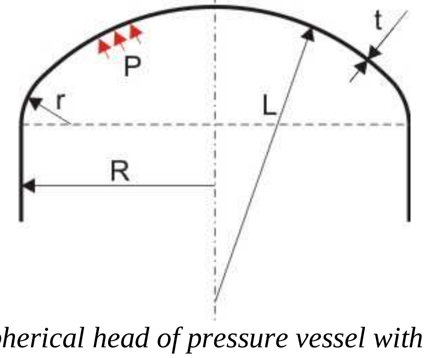

Figure 1. Torispherical head of pressure vessel with inside pressure.

Both stresses in the spherical cap are on tension, and could be calculated by following equation[2]:

$$\sigma_L = \sigma_t = \frac{P \cdot L}{2 \cdot t} \quad \text{... (1)}$$

Where:

- -P – inside pressure
- -L – radius of spherical crown
- -t - thickness

Longitudinal stress at beginning of knuckle of torispherical head could be calculated as follows:

$$\sigma_L = \frac{P \cdot r}{2 \cdot t} \quad \text{... (2)}$$

Where *r* represents knuckle radius. Tangent and longitudinal stress in knuckle are not equal.

3. EXPERIMENTAL RESEARCH

Strain gages are used for measuring strain of torispherical head in longitudinal direction (parallel with axis of rotation). Two measuring points are used with gauges connected in a halfbridge with one compesating gage. Third used chanell is pressure sensor P8AP100 from HBM. For signal conditioning, SPIDER 8 by Hottinger Mess Technik is used. Software which is used for recording and results analysis is CATMAN 5 (HBM). Measuring equipment is shown on Fig.2.

Figure 2. Equipment used for measuring

For experimental research pressure vessel with dimensions: R=191,3mm, L=260mm, r=67,75mm, t=1,2mm is loaded with inside pressure [4] with values in increasement form 0 to 3 bars. Dimensions of torispherical head is measured by apropriate sliding scale, and thickness is measured by ultrasonic device. Measuring points of strain gauges are shown on Figure 3.

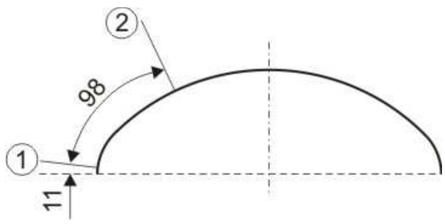

Figure 3. Position of measuring points

Measured strain on measuring points 1 and 2 are shown on figure 4.

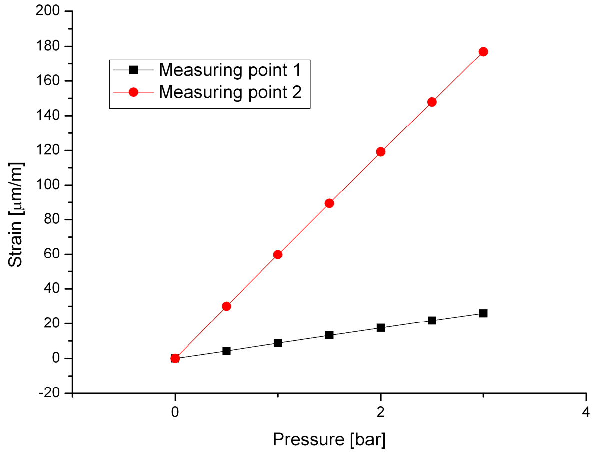

Figure 4. Measured strain by strain gages

4. FEM ANALYSIS

For showing real spectrum of stress, stress condition of pressure vessel is analysed by finite element method in software ANSYS12. Spectrum of stress in pressure vessel is shown on Fig.5. For analysis apropriate shell elements [5] elastic4 node are used.

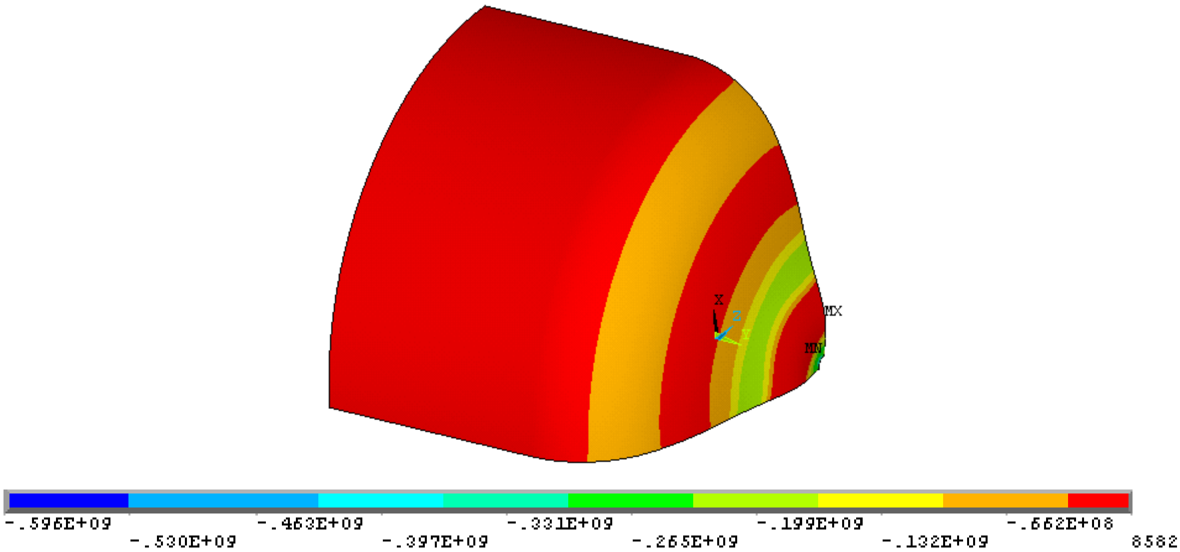

Figure 5. Stress distribution in pressure vessel

5. RESULTS COMPARISON

Two measuring points are used (Figure 3). Results of a measurement are shown in table 1. Measured strain is recalculated in stress and compared with stress gathered by equation (1) and (2).

Table 1. Calculated and measured results

Pressure [bar]	Measured stress [MPa]		Calculated stress [MPa]		Error [%]	
	M1	M2	M1	M2	M1	M2
0,50	0,90	6,30	1,40	5,93	35,52	6,21
1,00	1,83	12,54	2,79	11,86	34,45	5,70
1,50	2,77	18,74	4,19	17,80	33,85	5,31
2,00	3,67	24,99	5,58	23,73	34,27	5,32
2,50	4,56	31,04	6,98	29,66	34,66	4,66
3,00	5,44	37,14	8,38	35,59	35,04	4,35

As could be noticed, there is difference in results gained by experiment and results gained by standard calculation for stresses in pressure vessels. This could be discussed in fact that calculation of stress in pressure vessel head is defined as reference stress for designing od pressure vessels. Measured stress is stress which represents one point, and it could vary from point to point.

Results from FEM analysis on same spots as measured in experiment are extracted. While gathering results from FEM analysis, extreme increasement of stress value is noticed in some areas of shell in neighbouring nodes. That is possible reason that extracted results form FEM, and theoretical calculated values of stress have dilation of about 35% on measuring point 2 for pressure of 3 bars (Fig.6.). FEM result on point 1 have dilation for about 15% for pressure value of 3 bars. Comparison of FEM and theoretical results are compared for reason that both of them does not take into account amount of real conditions.

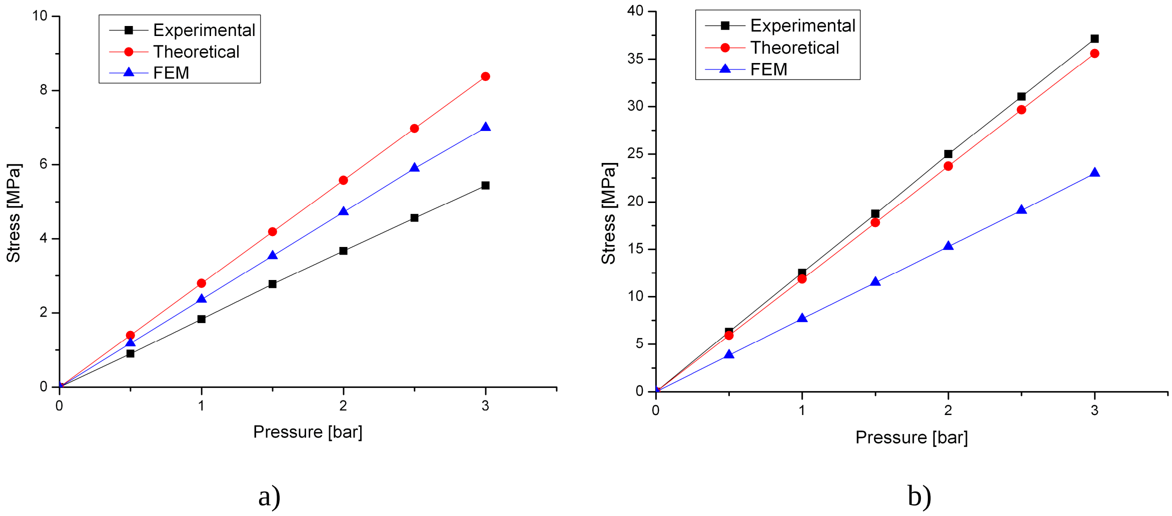

Figure 6. Comparison of results gained by different methods at a)measuring point 1 and b)measuring point 2

6. CONCLUSION

In this paper is shown comparision of three methods of stress analysis in pressure vessels. It is shown that there are a significant deviations between results obtained by this three methods. Imperfection in material and shape, corrosion and other similar factor can be reason for this deviations in stress values obtained using these three methods. Standard expressions as also as FEM analyses do not take into account mentioned factors that signifficaly influence on stress value in pressure vessels and could only be used as reference values for overviewing stress condition in pressure vessels. On the other side, measuring stress by experimental methods could only be in one point, so it requires much more measuring points to have complete spectrum of stress distribution on surface of pressure vessels. Nonexperimental methods are quite appropriate to use in design process as contiguous tools but they must not be used as reference for calculation of final product without an experimental aprovement of analyses results.

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EVALUATION OF CHARACTERISTICS FSW JOINTS OF FORGED PANELS MADE OF HIGH STRENGTH ALUMINIUM ALLOYS Al-Zn-Mg-Cu IN A T652 TEMPER

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ABSTRACT
Retention of high strength in aluminium alloys by methods of design and processing while retaining satisfactory hardness in the presence of welded joint formed by FSW process with adequate tools, is impossible to accomplish without more complete insight and analyses of its microstructure, insight in values and hardness distribution in the central level of cross section and without mechanical testing of a welded sample. In papers published so far on this innovative technology of welding in a solid phase, there is no data about welding capacities of alloy EN AW 7049A, although it is the representative indicator of the phase alloy system Al-Zn-Mg-Cu. These multi-component aluminium alloys, recognized by the highly expressed strength value, possess reduced plasticity, low resistance to wearing and high sensitivity to the influence of stress corrosion.This paper defines a procedure of experimental welding of two forged panels made of named alloy in a T652 temper. We determined the process parameters and the tool geometry. By methods without destruction we classified the quality of welded joint, described and showed metallographic specimens and structural content of welded joint. Categorisation of mechanic features is carried out by means of static testing of test tubes. On the basis of the obtained results, we concluded that welding in a solid phase, by means of mechanical deformations in the friction generated heat, has opened ways for much bigger application of these alloys even in the complex loaded structures.

Keywords: friction stir welding, process parameters, metallography, mechanical test

1. INTRODUCTION

The occurrence of errors in forms of cracks in welded joints made by processes of melting of high strength aluminium alloys is a very serious technological problem. It is particularly pronounced for alloys series EN AW 7 XXX (Al-Zn-Mg-CU). This limitation had significantly reduced their area of application up to introduction in mass production FSW (friction stir welding) at the end of last century. From that time to these days , number of applications of various welded components made with FSW has been increased , even in very demanding elements in aerospace industry and military production. For alloy EN AW 7049A , as multi-component alloy of quadruple phase composition, high strength is accomplished with zinc and magnesium mechanism for strengthening with thermal precipitation. Beside improvement of hardness with solid solution and precipitation, copper improves plasticity, resistance to fatigue and stress corrosion [1]. Until the research published in this paper, it was unknown what is the reaction of this alloy to processing by deformation with help of tool that makes welded joint forgings of hyper high strength.

2. PROCEDURE OF EXPERIMENTAL FSW

Friction stir welding is made on thermally processed and machine prepared forged elements whose dimension are 180 mm x 65 mm x 5 mm, from domestic alloy produced in commercial industrial conditions. Specimen for sample making was a panel dimensions 680 mm x 580 mm x 13 mm, hardness 175 HB, made of raw aluminium where alloying elements were added as a clean metal or, master alloys. It passed all phases technological procedure of making and thermo-mechanical processing casting of raw billet, two-level homogenisation, cutting and processing to measures for forging, free forging and forging in tool, hardening, pressing of 1% and 3% and artificial ageing [2].

2.1. Analysis of chemical composition of samples

Determination of chemical elements content in samples for welding is made on samples in temper T652 using OE quant metre ARL with electronic samples “Pechiney”. Results are given in table 1.

Table 1. Chemical composition of parent material EN AW 7049A T652 [3]

Alloy type	Content of element, wt %											
	Zn	Mg	Cu	Mn	Cr	Zr	Ti	V	B	Fe	Si	Al
ENAW7049A	7.20	2.15	1.45	0.27	0.13	0.13	0.015	0.004	0.003	0.23	0.10	bal.

In order to eliminate potential heat influence on experimental results, panels had been prepared by cutting with water jet and afterwards by skimming of saw chips made in named measures with intensive cooling of treated surface. Mechanical testing of parent material showed good results, given in Table 2.

Table 2. Mechanic characteristics of parent material EN AW 7049A[3]

Alloy type	Mechanical properties		
	0,2% Yield strength $R_{0,2}$, MPa	Tensile strength R_m, MPa	Elongantion A, %
ENAW7049A	562	628	7.5

2.2. Equipment for procedure implementation, tools and process parameters

Experimental welding had been performed on adapted machine tool –universal vertical milling machine whose power of electromotor for accomplishment of main movement of vertical milling machine arbour was 18 kW, with gradual setting of number of revolutions from 80 min(-1) up to 1450 min(-1) and traverse speed from 12.4mm/min up to 175 mm/min. Image of machine is given in Figure 1.

The backing plate with dimensions of 300 mm x 200 mm x 25 mm, made of steel for the improvement of 42 Cr M0 4, thermally processed on 850 MPa and surface tempered on 44 $\pm$ 2 HRc was fastened to workbench with improvised machine for FSW. In fastening head of main milling machine arbour a tool for welding was inserted and it is presented in figure 2 and chemical composition is given at table 3. The tool was thermally treated up to surface hardness of 61±1 HRc.

Figure 2. Tool for friction stir welding with backing plate on water desk

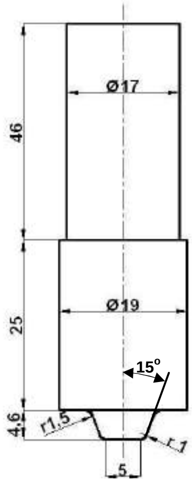

Figure 2. Tool for friction stir welding aluminium alloy EN AW 7049A in condition T 652

Table 3. Chemical composition of welding tool [4]

Steel type	Content of element , wt %						
	C	Mn	Si	Cr	Mo	V	Fe
ENx155CrVMo121	1,55	0,32	0,34	11,81	0,82	0,95	bal.

The pieces were fastened to backing plate without turning down of edges and after that vertical head of milling machine with inserted tool in tapered elastic capsule, was put in contact position on central line of joined pieces. The tool is moved from normal axle for 3º at welding direction. All process parameters were held constant during the welding. After that, main milling machine arbour rotation was switched on up to contact of fore of tool body and welded piece. After some time working desk applied traverse of element and welding process started. Its parameters are given in the following table.

Table 4. Parameters for sample welding

Alloy type	State TMO	Welding parameters		
		Tool rotaring speed n, min^{-1}	Welding speed v_z, mm/min	Penetration depth of tool pin h_p, mm
EN AW7049A	T652	1000	31.5	0.3

Welded experimental panel, whose appearance after welding is presented in Figure 3, was tested on hypersonic device with flat probe and with beam transmission direction from bottom side towards the face of metal weld in order to found possible existence of metal discontinuity in the sample.

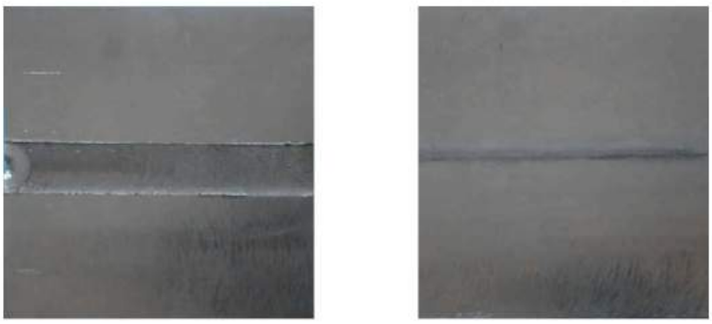

Figure 4. Photographic presentation face and obverse of welded joint

3. TEST RESULTS

3.1. Metallographic analysis

After welding, the sample was prepared for testing on standard prescribed way. By etching in Keller reagent macrostructure of ground element was clearly differentiated, figure 5.

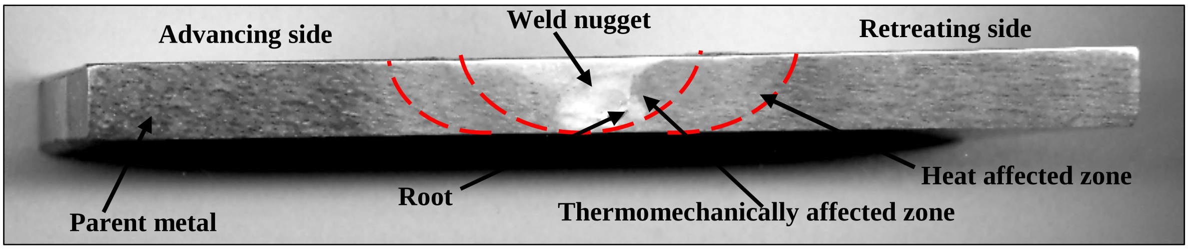

Figure 5. Makrostruktura zavarenog spoja [5]

On this image we can see advancing and retreating side of two regions, right and left from the centre of welded joint. The side where the directions of tool rotation vector and welding speed vector overlap, and side where they have opposite directions. Macrostructure consists of zone of thermo mechanical impact, zone of heat impact and parent metal zone, Figure 4. Thermomechanically affected zone (TMAZ) has two recognizable areas; weld nugget and weld root although there are authors that consider nugget zone to be separate zone of welded joint, including the root as its part.
Metallographic analysis of sample was done on light microscope NEOPHOT 21 with magnifications of 100 and 1000x.
Thermomechanically affected zone in nugget and root region is situated at the place of pin tool traverse and immediately underneath its top. This is fine recrystalized grained zone, little moved toward back side, figure 5.a and b. Transition region of this areas into remained zone of thermomechanical influence is clearly visible even if with small magnifications, Figure 5c. Remaining of this TMAZ zone has plenty of deformed grains and its structure consists of bigger grains, figure 5d. Neighbour zone, heat affected zone (HAZ), is characterised by elongated grains with little recrystalised grains and with series of intermetallic phases, Figure 5e. It is little different from the zone of parent material, Figure 5f.

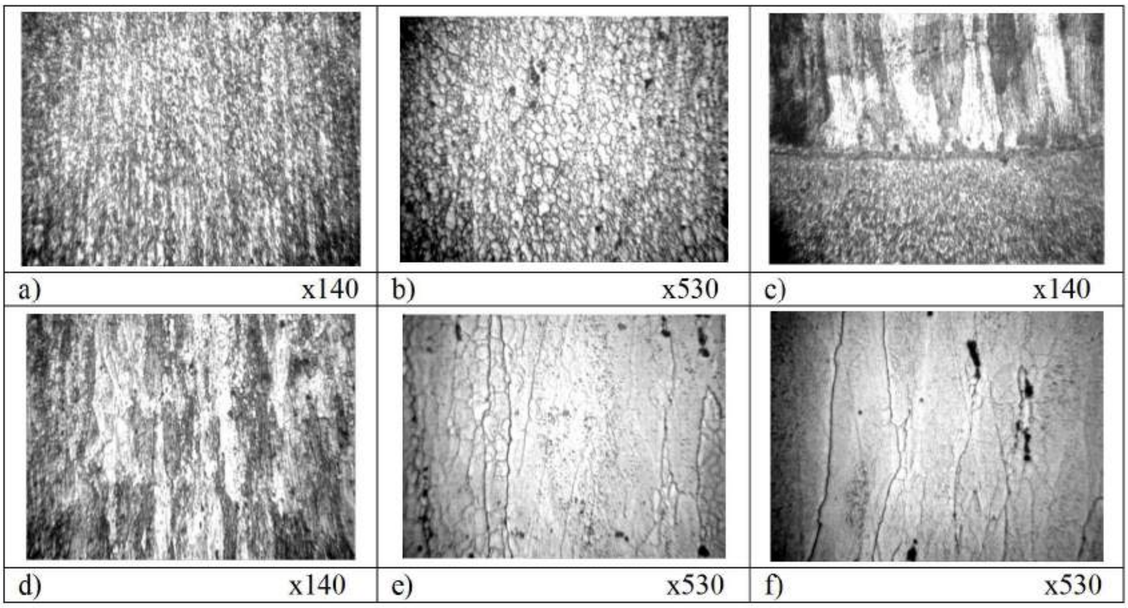

Figure 5. Presentation of weld microstructure for EN AW 7049A in T 652 condition (a-weld root, b-nugget, transition zone between nugget area and thermo mechanical influence , d-thermo mechanic affected zone , e-heat affected zone and f-parent material zone)

3.2. Mechanic testing of welded joint EN AW 7094A T 652

Tensile test is conducted according to standard MEST EN 10002-1:2008 on machine INSTRON 105. Test results are given in table 5 and they purports to specimen taken normally on welding direction

Table 5. . Mechanic characteristics of welded joint ENAW 7049AT 652 [5]

Trial number	Mechanical properties		
	0,2% Yield strength $R_{0,2}$, MPa	Tensile strength R_m, MPa	Elongantion A, %
1	384	522	9.5

3.3. Values and microhardness distribution

Microhardness test is conducted on mean line of cross section. Microhardness is measured with the load of 1000 g and magnification of 100x. Values are given in table 6. and distribution graph in Figure 6.

Tabela 6. Microhardness values (HV) on mean line of cross section [5]

Microhardness (HV)							
Advancing side				Retreating side			
PM	HAZ	TMAZ	WN	WN	TMAZ	HAZ	PM
192	157	142	158	159	143	156	191
191	158	144	156	159	146	157	192

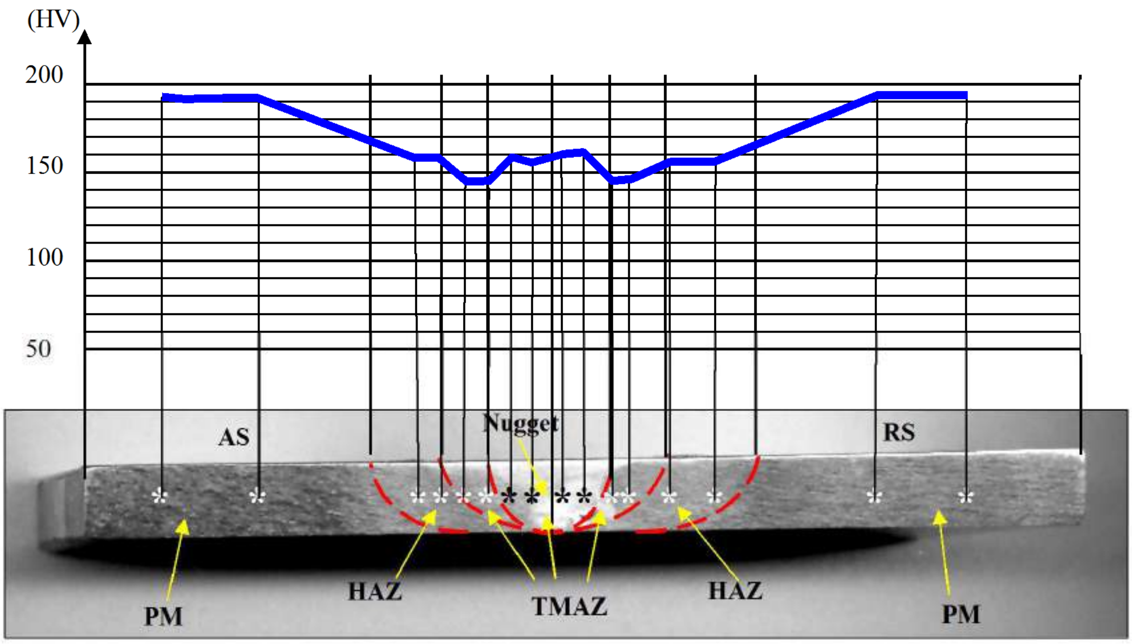

Figure 5. Microardness distribution in various welded joint contents and in parent material

4. DISCUSSION ABOUT RESULTS

Analysis of experimental welding forged panels of alloy EN AW 7049A in state of maximal hardness values (T652) showed that the elongation of welded joint is bigger than that of parent material, which can be explained by forming structure with small grains in mixed zone. Microhardness profile has a sign of slightly expressed letter “W” that is identical to other alloys form 7XXX series. Tensile strength of welded joint is about 20% lower than for parent material and flowing stress is almost one third bigger in parent material than in welded joint. Crack location of specimen on tension test is situated in transition zone from nugget to remaining zone of thermomechanically affected zone, figure 7.

Figure 7. Pulled specimen after failure [5]

5. CONCLUSION

Microstructural development in welded joint zones formed by FSW process and with tool in proper high strength aluminium alloys has a very complex nature. First of all, this depends on their chemical composition, state of thermomechanical processing and process parameters. What and how big is the influence of some factors is not possible simply define without additional testing. Although welded joint was without defects, fracture seen in transition zone is the consequence of important difference in nugget microstructure and other regions of thermomechanically affected zone and the area that passed through intensive mechanic deformation form tools with bare pin and generated heat because of contact surfaces friction. Improvement of plasticity in welded joint, with retaining of high tension parameters, represent the beginning of much wider application of this complex alloy in many industrial branches.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

INVESTIGATION OF IMPACT TOUGHNESS AND FRACTURE MECHANICS PARAMETERS OF HIGH-STRENGH STEEL WELDS

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ABSTRACT
This paper outlines brief results of conventional testing of high-strength steel welded joints, as well as detailed testing of impact toughness and fracture mechanics parameters. Specimens where taken from the base metal, weld metal and heat-affected zone. The impact toughness characteristics were tested and evaluated using the instrumented Charpy pendulum, in accordance to EN 10045-1, down to -100°C to found transition temperature of 27J impact energy. The fracture mechanics parameters, both the crack growth resistance curves and corresponding critical values, are tested and evaluated for base and weld metal, in accordance to ASTM E1820 and BS 7448-2, on room temperature only, using single-specimen technique.
Obtained results for typical zones, such as base metal, heat affected zone and weld metal, have provided so called toughness distribution of welded joint. In this way, the essentially range of weld joint fracture resistance have been obtained. This approach should provide more reliability and confidence in assessment of high-strength steel welded structures, especially while considering novel integrity assessment procedures.
Keywords: impact toughness, fracture mechanics parameters, high-strength steel, welds

1. INTRODUCTION
There are number of affirmative reasons to use high-strength structural steels in various welded structures. Most beneficial of them are significant savings in weight and total cost of transportation, manufacturing and inspection. However, those steels have some particular welding requirements due to the increased sensitivity to cold cracking and toughness degradation. In addition, unfavourable yield stress to tensile strength ratio may present limitation for use, as stipulated in design codes [9]. Also, while considering typical weld joint heterogeneity, further assessment of high-strength steel welded structure become more complicated. Therefore, conventional testing of welded joints should be followed with detailed testing of impact and quasi-static fracture resistance. While considering experimental approach, it is beneficial to perform characterisation of welded joint impact and quasi-static toughness, or generally fracture mechanics parameters.

This approach becomes particularly important if we consider novel structural integrity procedures, such as international FITNET. Therefore even conventional approach using design codes for various steel structures, such as tanks, pressure vessels, pipelines, penstocks, bridges, cranes, etc., may prohibit use of high-strength steels, it may be found quite reliable and safe to apply them when structural integrity assessment based on fracture mechanics is employed [8].

In accordance to those novel procedures, the main material property is fracture resistance, represented in various types of characteristics due to the considered type of loading. However, the most used one is impact toughness, KV [J], followed with quasi-static toughness, i.e. critical fracture mechanics parameters, fracture toughness, K_c [$MPam^{0,5}$], J-integral, J_c [kJ/m^2] or crack tip opening displacement $CTOD_c$ [mm].

While welded joints are considered as typical structural joints with material properties heterogeneity, it is of particular importance to determine its range of properties, e.g. in this case the distribution of fracture resistance. In addition, welded joints are well known structural joints which contain various micro and macro faults (in fracture mechanics considered as cracks). Here, application of fracture mechanics becomes particularly important.

2. EXPERIMENT

As base metals, two high-strength structural steels are selected, S690QL and S890QL in accordance to EN 10025-6. The steels are characterized by typical microalloying composition, tempered martensitic microstructure, and good combination of mechanical properties. The main standard properties as well as properties of selected commercial grades of both steels are presented in Tab. 1.

Table 1. The main standard properties of base metals

Steel	Strength				Ductility, elongation a.f. A [%]		Impact toughness, KV [J] at -40°C		Carbon equivalent, CE	
	Yield stress, $R_{p0,2}$ [MPa]		Tensile strength, R_m [MPa]							
	avg. com.	std. min. req.	avg. com.	std. req. rng.	avg. com.	std. min. req.	avg. com.	std. min. req.	avg. com.	std. max. all.
S690QL	762	690	867	770-940	15,9	14	115	27	0,46	0,65
S890QL	948	890	1020	940-1100	13,1	11	46	27	0,55	0,72

Note:
avg. com. – average commercial grades properties or average obtained by mechanical destructive test
std. – standard required values, given as required range (req. rng.), as minimum required (min. req.) or as maximum allowable (max. all.)

Therefore, while fracture mechanics parameters are not defined or requested by the material delivery standard, e.g. EN 10025-6, the specified impact toughness, KV=27J at -40°C, was taken as the main reference fracture resistance [1].

A pairs of X-type joints, with 30mm thickness of base metal for S690QL, and 20mm for S890QL, are welded using GMAW process and welding parameters selected in accordance to recommendation set in EN 1011-2. Thus, welding of both steels is characterized with application of preheating, T_p=150-200°C, heat input, Q=1,4-2,8 kJ/mm, and quite low cooling time, $t_{8/5}$=6-8s, which is in the recommended range of $t_{8/5}$=5-15s, in accordance to EN 1011-2 and manufacturers specifications. It is well known that sampling of specimens from heat affected zone, within the welded joints, may present complicated task, especially from the X-type joints. Thus an additional set of specimens prepared by welding thermo-cycle simulation were prepared as a representatives of coarse-grain heat affected zone, CG-HAZ. Theoretically, this zone presents the critical HAZ zone. In this manner, it was possible to obtain the lower (weakest) bound of weld joint resistance.

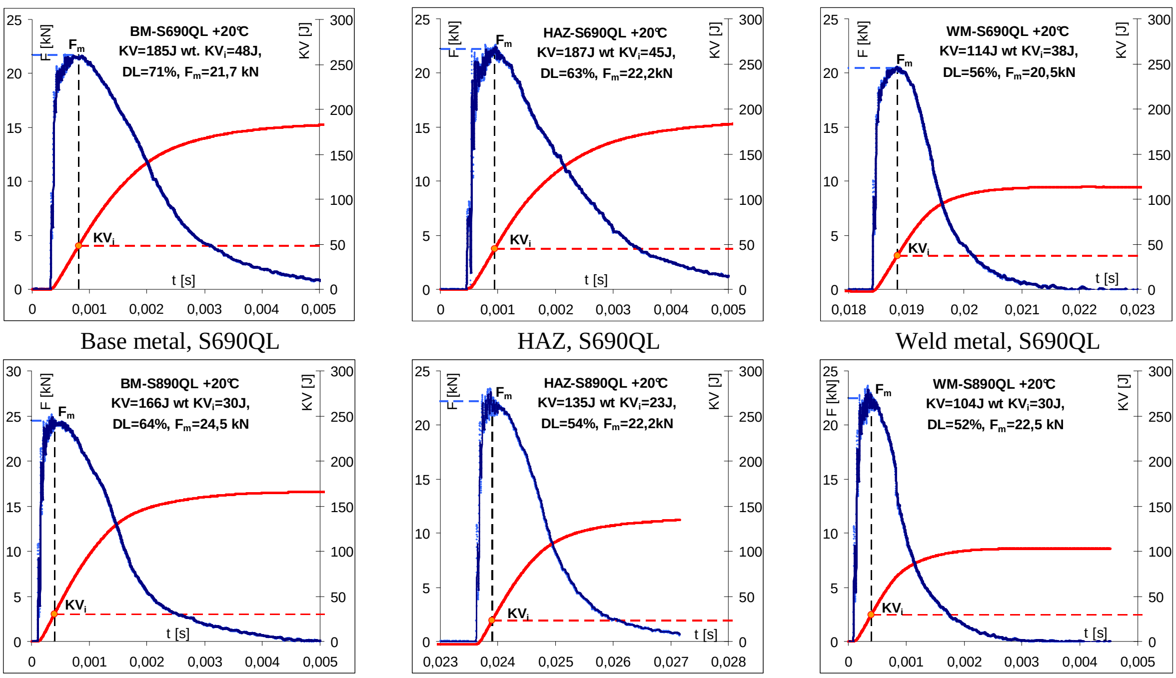
In addition to major research, as outlined in this paper, the conventional testing required for welding procedure qualification, in accordance to EN ISO 15614-1 were performed. Also, for evaluation of fracture mechanics parameters, tensile properties are required. Thus, those tests have included, tensile testing of base and weld metal in accordance to EN 10002-1, hardness distribution testing in accordance to EN 1043-1. Results of tensile testing are presented as for commercial grade in Tab. 1.

Testing of impact toughness was performed on instrumented Charpy pendulum in accordance to EN 10045-2. Using instrumented Charpy pendulum it was possible to evaluate both, crack initiation energy, KV_i [J] and crack propagation energy, KV_p [J], as well as total energy which is the sum of KV_i and KV_p, or impact toughness, KV [J]. Of course, crack initiation and propagation energies, were evaluated from corresponding force-time diagrams, F-t, while they were acquired with high acquisition frequencies of 1 kHz. For acquired F-t diagram, and characteristic force values the percentage of shear or ductile fracture, DL [%], was calculated for each specimen. To assess the complete welded joints, the specimens were taken from base and weld metal, designated as BM and WM respectively, from real HAZ, as well as previously explained CG-HAZ specimens.

Quasi-static toughness or fracture mechanics parameters were evaluated from base and weld metal only. Conventionally, this approach is mostly found as reasonable, due to the fact that fracture mechanics parameters testing are more demanding, and therefore more expensive [7]. Testing of specimens with initial crack within the base metal was performed in accordance to ASTM E1820, and for specimens with initial crack within the weld metal in accordance to BS 7448-2. However, both standards provides calculation of corresponding crack growth elasto-plastic resistance curves, from which, it is possible to evaluate critical fracture mechanics parameters, K_{Ic} [$MPam^{0,5}$], J_{Ic} [kJ/m^2] and $CTOD_{Ic}$ [mm]. Mark “I” in index of all three critical parameters means that specimens were loaded in first type of loading, with crack growth employed by specimens bending. More exactly, direct results of testing are corresponding force-crack opening displacement curves, F-COD. After an appropriate calculation procedure, as required by ASTM E1820, the corresponding crack growth resistance curves are obtained, J-Δa and CTOD-Δa, for both elasto-plastic fracture mechanics, EPFM, parameters, J-integral and crack tip opening displacement, where Δa [mm] is crack growth. Further, for crack growth Δa=0,2mm, the critical EPFM parameters, J_{Ic} and $CTOD_{Ic}$, were evaluated. For most structural steels with good toughness and crack growth in elasto-plastic regime, the linear-elastic fracture mechanics parameter, LEFM, fracture toughness, K_{Ic}, may be only evaluated for known a qualified critical J-integral, J_{Ic} [3,4,7].

3. RESULTS AND COMMENTS

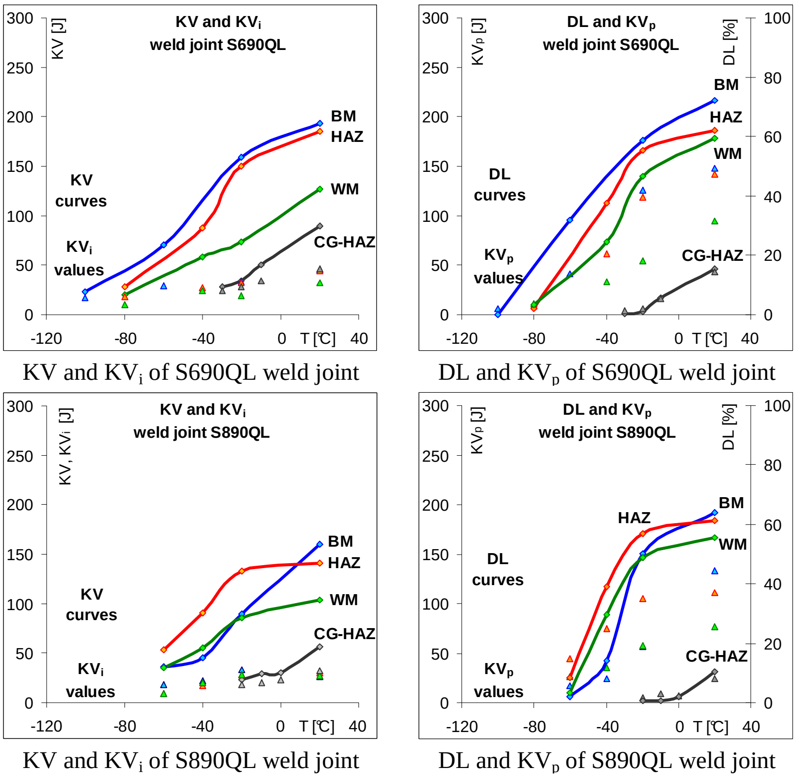
Typical results of impact toughness testing, and corresponding force-time curves, F-t, are shown on Fig. 1.



Base metal, S890QL HAZ, S890QL Weld metal, S890QL

Figure 1. Typical results of impact toughness testing presented as force-time curves for base metal, BM, weld metal, WM, and heat affected zone, HAZ, at room temperature

For once determined characteristic values of impact toughness properties, from F-t curves, on testing temperatures in a range of -100°C to +20°C, it was possible to determine variation of KV, KV_i, KV_p, DL versus temperature, T [°C], as it shown on Fig. 2.



KV and KV$_i$ of S690QL weld joint — DL and KV$_p$ of S690QL weld joint

KV and KV$_i$ of S890QL weld joint — DL and KV$_p$ of S890QL weld joint

Figure 2. Variation of impact toughness characteristics versus testing temperature

Triangle marks on Fig. 2. presents crack initiation and propagation energies, KV$_i$ and KV$_p$, respectively.

Typical results of fracture mechanics parameters testing of steel S690QL weld joint are shown on Fig. 3, while summarized results of evaluation of critical fracture mechanics parameters are shown on Tab. 2.

Once, the experimentally obtained impact toughness, KV, and critical fracture mechanics parameters, J_{Ic}, $CTOD_{Ic}$, K_{JIc}, were obtained, it was possible to evaluate approximation terms, which is a case in similar researches and proposed by novel structural integrity procedures [8,10]. Approximation terms are derived upon regression analysis as shown on Fig. 4.

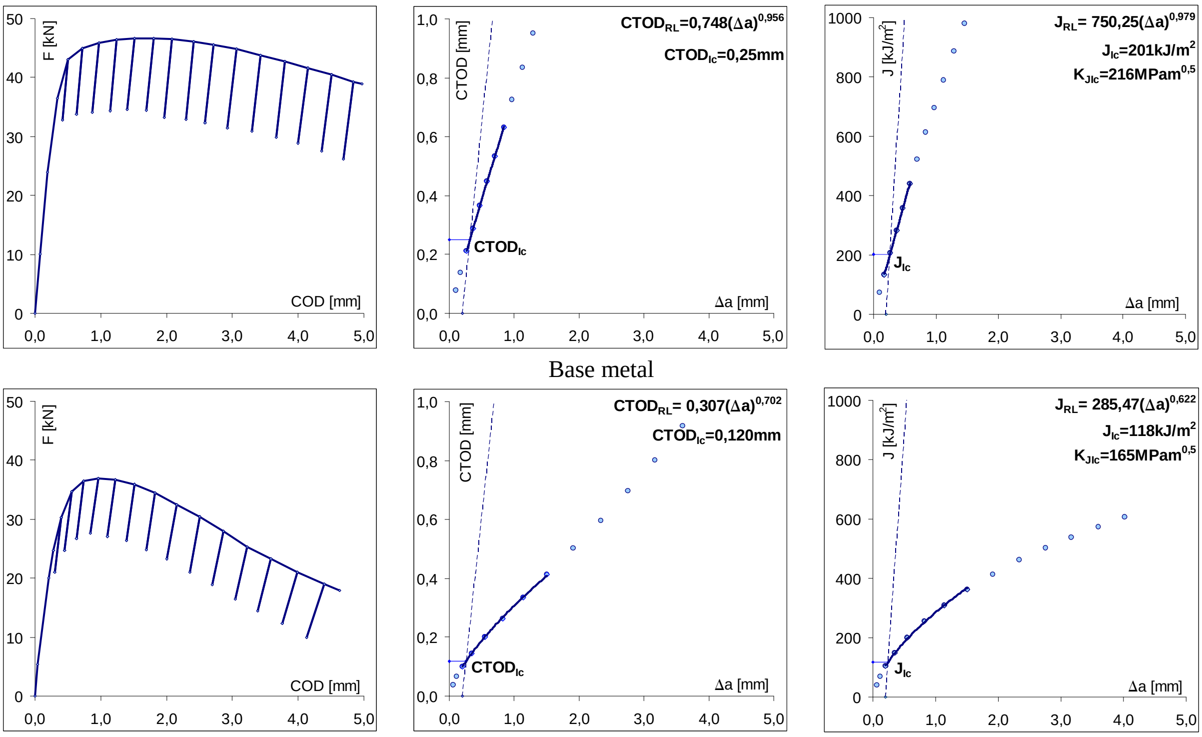
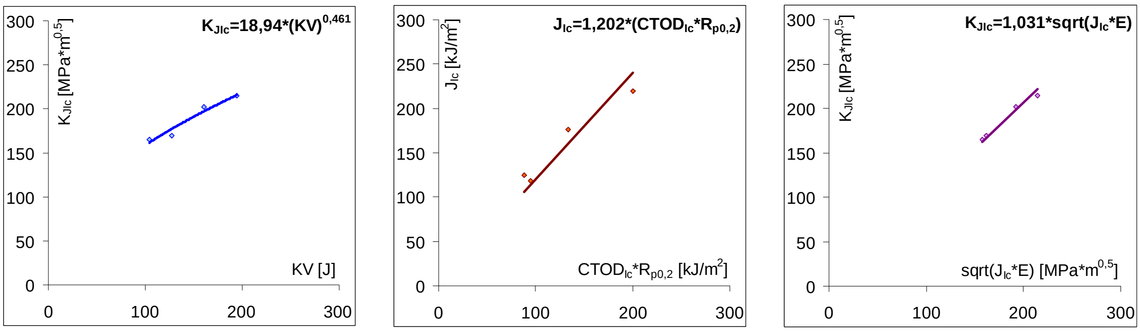


Figure 3. Typical results of fracture mechanics parameters testing for weld joint on steel S690QL

Finally, for known experimentally obtained impact toughness, KV, of HAZ and CG-HAZ, the corresponding critical fracture mechanics parameters, J_{Ic}, $CTOD_{Ic}$, K_{JIc}, were calculated in accordance to approximation terms (shown on Fig. 4). Thus, it was possible to present distribution of impact toughness and fracture toughness of complete weld joints, on both steels (Fig. 5).

Table 2. Summarized results of evaluated critical fracture mechanics parameters

Initial crack in	EPFM parameters		LEFM parameters
	J_{Ic} [kJ/m^2]	$CTOD_{Ic}$ [mm]	K_{JIc} [MPam^{0,5}]
Base metal - S690QL	201-238	0,250-0,275	216-235
Weld metal - S690QL	118-132	0,119-0,146	164-175
Base metal - S890QL	173-180	0,136-0,146	200-204
Weld metal - S890QL	111-126	0,102-0,109	160-170



K_{JIc}=f(KV) J_{Ic}=f($CTOD_{Ic}$, $R_{p0,2}$) K_{JIc}=f(J_{Ic}, E)

Figure 4. Approximation terms from regression analysis of experimentally obtained results

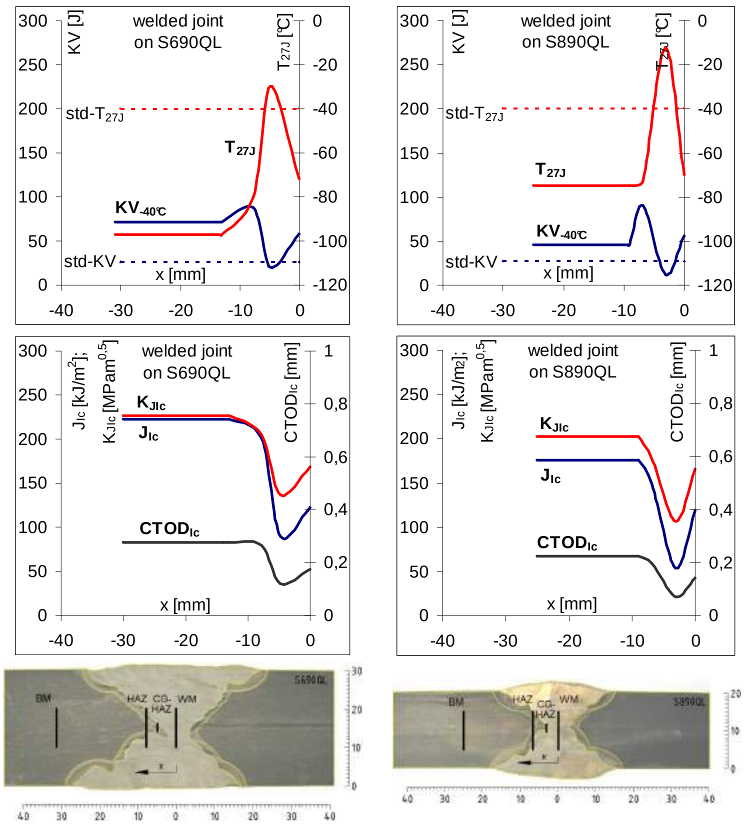


Figure 5. Distribution of impact toughness and critical fracture mechanics parameters at room temperature for high-strength steel weld joints

Fig. 5 presents quite detailed distribution of fracture resistance of weld joints on both high-strength structural steels. As can be seen, for both steels, the weakest part of weld joints is CG-HAZ. Accordingly, as it graphically illustrated from distribution on Fig. 5, the zone of 2-3mm wide has impact toughness lesser than required for base metal (minimum KV=27J at -40°C, or T_{27J}<-40°C), when base metal has thickness in a range of 20-30mm. Other zones of welded joints, from weld metal trough to the base metal have quite acceptable fracture resistance (much higher than required for base metal in accordance to EN 10025-6).

In this way, the quite reliable presentation of complete weld joint fracture resistance is obtained.

However, approximation terms shown on Fig. 4, are obtained for limited number of experimental results, and they may be further refined. In addition, weld joints are executed with GMAW, and provided results and approximation terms should be treated with this process in consideration.

4. REMARKS AND CONCLUSIONS

Use of high-strength steels in various welded structures may present a challenging task. Even, some major design codes does not allow use of such high-strength steels, this research provides more confidence in complete weld joint fracture resistance. This is particularly important if novel structural integrity procedures, such as international FITNET, are used already in design phase.

The weakest part of weld joint, which is practically and theoretically well known, is coarse-grained heat affected zone, CG-HAZ. Therefore, even this zone has decreased fracture resistance it does not mean that such weld joints or welding procedure should be rejected. It is rather a fact which design engineer should take carefully into consideration. With once defined critical fault (crack type) size and position, it is possible to determine allowable stress level, to make complete welded structure save and reliably operational, and vice versa. However, weld joint fracture resistance must be known [8].

While novel structural integrity assessment procedures provide various levels of confidence, it is of particular importance to use more detailed data about material resistance. Here, the approximation terms provided in this paper (Fig. 4), for GMAW executed weld joints, on high-strength structural steels S690QL and S890QL become particularly helpful.

However, a design engineer should take carefully into consideration all type of loading on subject welded steel structure, particularly those related to fatigue and corrosion type of material degradation, which are not considered in this research.

Results of this research, as well as researches of structural integrity assessment of exact welded steel structures, may be helpful for definition of new acceptance criteria based on fracture mechanics parameters.

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"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

KORIŠTENJE PARAMETARA MEHANIKE LOMA U OCJENI KVALITETA ZAVARENIH SPOJEVA KOD VERTIKALNIH VIŠEKOMORNIH POSUDA ZA TEČNA GORIVA

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REZIME
U radu su prikazani rezultati eksperimentalnog određivanja parametara mehanike loma kod zavarenog spoja čelika Č.0361. Analizirano je kako heterogenost strukture i mehaničkih svojstava MZ i ZUT utiče na parametre mehanike loma, odnosno kako parametre mehanike loma možemo koristiti u ocjeni kvaliteta zavarenih spojeva kod vertikalnih stacionarnih cilindričnih višekomornih posuda za tečna goriva.
Ključne riječi: osnovni metal (OM), zona uticaja toplote (ZUT), metal zavara (MZ), zavarivanje, tehnologija zavarivanja, mehanika loma, prslina, J-integral, kritični faktor intenziteta napona - K_{Ic}.

1. UVOD
Višekomorni rezervoari za tečna goriva predstavljaju rezultat sve izraženijih zahtjeva distributera goriva, za rekonstrukciju jednokomornih u višekomorne rezervoare u cilju skladištenja više vrsta goriva na jednom mjestu. Iako postoje domaći i međunarodni standardi koji okvirno regulišu ovu problematiku još uvijek ne postoji jedinstveno postavljen i pouzdan algoritam za izradu višekomornih posuda potkrijepljen naučnim i istraživačkim saznanjima, odnosno projektovanje i izrada višekomornih rezervoara još uvijek nije standardizovana. Znači, osnovni problem koji se nameće, odnosi se na projektovanje i izradu višekomornih rezervoara sa nedefinisanim naponskim stanjima u zonama zavara, posebno u zoni "čvornih mjesta zavara".
S obzirom na heterogenost strukturnih, mehaničkih i eksploatacijskih osobina pojedinih područja zavarenih spojeva, ponašanje posude velikih dimenzija kao cjeline nije jednostavno predvidjeti i protumačiti. Iako vertikalni cilindrični rezervoari sa ravnim dnom spadaju u tankozidne posude čiji se proračun po membranskoj teoriji znatno pojednostavljuje, ovom prilikom želim ukazati i na konstrukcioni aspekt koji se ne može zanemariti. U području prelaznih spojeva između plašta i pregrade, zatim prelaza između dna i plašta, zatim u području spajanja glavnih nosača ova teorija raspodjele naponskih stanja nije potpuno pouzdana, odnosno prisutna su enormno visoka naponska stanja. Ocjena sklonosti ka krtom lomu je analizirana ispitivanjem epruveta sa zamornom prslinom u OM, ZUT i MZ. Kao parametri mehanike loma u analizi su korišteni faktor intenziteta napona, otvaranje prsline i J integral. Analizom dobijenih rezultata ocjenjena je sklonost ka krtom lomu konstituenata zavarenog spoja, što se uspješno može primjeniti i za ocjenu sigurnosti zavarene konstrukcije [1].

2. MATERIJAL
Za proučavanje uticaja heterogenosti strukture na parametre mehanike loma je izabran čelik Č.0361, odnosno materijal od koga je napravljen predmetni rezervoar od 5.000m^3. Isporučilac materijala je "US STEEL SARTID". Materijal je isporučen u obliku ploča dimenzija 1000x1000x12mm, koje su poslije toga sječene na dimenzije 500x200x12mm i onda zavarivane. Hemijski sastav dostavljenih ploča je dat u tabeli 1, a mehanička svojstva isporučenog čelika Č.0361 su data u tabeli 2.

Tabela 1. Hemijski sastav d ostavljenih ploča

Šarža	% mas.					
	C	Si	Mn	P	S	N
234-349	0,16	0,23	1,12	0,028	0,021	0,009

Tabela 2. Mehanička svojstva čelika Č.0361 u stanju isporuke

Šarža	Napon tečenja $R_{p0,2}$, MPa	Zatezna čvrstoća, R_m, MPa	Izduženje A, %	Energija udara KU3, J
234-349	247	398	24	55

Pri zavarivanju opštih konstrukcionih čelika najvažnije je odabrati korektan termički ciklus zavarivanja koji neće imati izrazito negativan uticaj na osobine čelika dobijene usitnjavanjem zrna i procesima izlučivanja.

Za zavarivanje ispitnih uzoraka je primjenjen REL postupak sa elektrodom EVB 50 i MAG postupak sa žicom VAC 60. Za obje vrste dodatnog materijala u jednom slučaju su pripremljeni limovi odmah zavarivani (bez predgrijavanja), a u drugom slučaju je urađeno predgrijavanje pripremljenih limova prije zavarivanja na temperaturu 50°C.

Dakle, primjenjene su četiri tehnologije zavarivanja:

1. Tehnologija A – REL postupak sa elektrodom EVB 50 bez predgrijavanja,
2. Tehnologija B – REL postupak sa elektrodom EVB 50 sa predgrijavanjem,
3. Tehnologija C – MAG postupak sa žicom VAC 60 bez predgrijavanja,
4. Tehnologija D – MAG postupak sa žicom VAC 60 sa predgrijavanjem.

3. REZULTATI ISPITIVANJA

3.1. Određivanje zateznih svojstava

Ispitivanje zatezanjem sučeono zavarenih spojeva, uključujući oblik i dimenzije epruveta kao i sam postupak ispitivanja je definisan standardom EN 895 - Sučeono zavareni spojevi na metalnim materijalima - ispitivanje poprečnim zatezanjem (Welded butt joints in metallic materials - Transverse tensile test) [2]. Ovaj standard prije svega definiše samo poprečno zatezanje, odnosno uvođenje opterećenja poprečno na zavareni spoj. Ispitivanje je izvedeno na elektromehaničkoj kidalici SCHENCK-TREBEL RM 100 u kontroli deformacije. Brzina uvođenja opterećenja je bila 5 mm/min. Izduženje je registrovano pomoću dvostrukog ekstenzomjera HOTTINGER DD1. Tačnost mjerenja ekstenzomjera je ±0,001 mm.

Rezultati određivanja zateznih svojstava epruveta osnovnog materijala čelika Č.0361 su dati u tabeli 3, a epruveta sučeono zavarenog spoja poprečnim zatezanjem su dati u tabeli 4. Prikazani rezultati u tabelama 3 i 4 predstavljaju srednju vrijednost tri mjerenja.

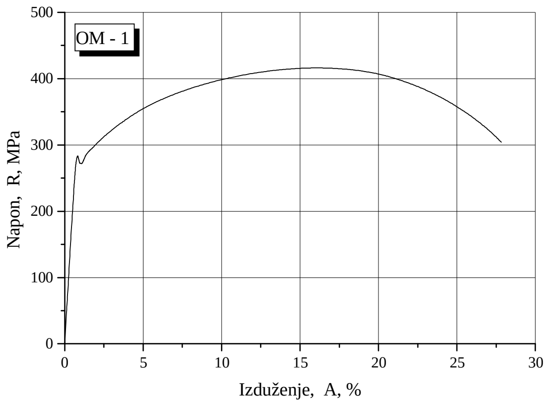
Tabela 3. Rezultati zateznih ispitivanja epruveta osnovnog materijala

Oznaka uzorka	Gornji napon tečenja, R_{eH}, MPa	Donji napon tečenja, R_{eL}, MPa	Zatezna čvrstoća R_m, MPa	Izduženje A, %
OM	282	273	420	27.8

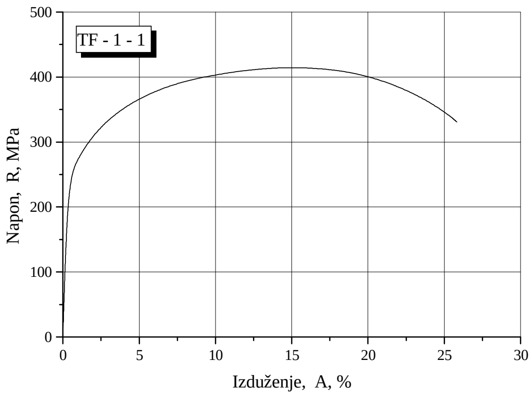
Tabela 4. Rezultati zateznih ispitivanja epruveta sučeono zavarenog spoja

Oznaka uzorka	Tehnologija zavarivanja	Napon tečenja $R_{p0,2}$, MPa	Zatezna čvrstoća R_m, MPa	Izduženje A, %
TF -1-3	I	249	416	25.4
TF -2-3	II	247	404	26.8
TF -3-3	III	253	417	25.8
TF -4-3	IV	259	409	28.1

Tipična kriva zatezanja za epruvetu izvađenu iz osnovnog metala je data na slici 1, a za epruvetu iz sučeono zavarenog spoja oznake TF – 1 - 1 je data na slici 2.



Slika 1. Dijagram napon - izduženje epruvete oznake OM - 1



Slika 2. Dijagram napon - izduženje epruvete oznake TF – 1 - 1

Na osnovu prezentiranih rezultata ispitivanja zatezanjem epruveta izvađenih iz osnovnog metala datih u tab. 3, dobijenih dijagrama ispitivanja, kao i analize prelomnih površina epruveta, može se konstatovati da su rezultati u granicama standardom propisanih vrijednosti za taj materijal, odnosno vrijednosti koje je dao proizvođač u atestnoj dokumentaciji. Kada su u pitanju rezultati ispitivanja epruveta izvađenih iz zavarenog spoja sa metalom zavara u sredini radnog dijela može se konstatovati velika sličnost sa rezultatima ispitivanja epruveta osnovnog metala. Naime, sve polomljene epruvete su pukle u osnovnom metalu, što jasno ukazuje na karakter zavarenog spoja. U pitanju je "over-matching" što znači da je čvrstoća metala zavara viša od čvrstoće osnovnog materijala.
Međutim, kada je u pitanju analiza karaktera krive zatezanja može se konstatovati da je predgrijavanje u postupku zavarivanja, dovelo do povećanja izduženja. Isto tako, analizirajući dijagrame napon - izduženje uočavamo fenomen izraženog napona tečenja kod epruveta izvađenih iz osnovnog metala i gubljenje pojave donjeg i gornjeg napona tečenja kod epruveta sučeono zavarenog spoja.

3.2. Ispitivanja mehanike loma

Analizom krtog ponašanja tijela sa prslinom mehanika loma je otvorila nove mogućnosti u obezbjeđenju sigurnosti zavarenih konstrukcija. Standardom ASTM E399 za određivanje žilavosti loma pri ravnoj deformaciji, K_{Ic}, proces razvoja linearno-elastične mehanike loma (LEML) je zaokružen do njene primjene na realne konstrukcije, izrađene od materijala visoke čvrstoće, kod kojih se u prisustvu prsline ostvaruje ravno stanje deformacije. Uslov važenja tih ispitivanja je da plastična deformacija zahvata samo zanemarljivo malo područje oko vrha prsline prije nego što dođe do razvoja prsline i loma. Kako se kod većine konstrukcijskih materijala i zavarenih spojeva oko vrha prsline razvija veliko područje plastične deformacije, to direktno određivanje parametra K_{Ic} nije mogućno, i njegova je primjena u realnim uslovima ograničena. Analiza plastičnog ponašanja materijala, kojom se bavi elasto-plastična mehanika loma dovela je do definisanja dva slijedeća parametra: konturnog J integrala, i pomjeranja otvora na vrhu prsline - δ(CTOD).
Ispitivanje epruveta sa prslinom pokazuje lokalno ponašanje materijala oko vrha prsline i polazi od pretpostavke da je materijal epruvete dovoljno homogen, što znači da se rezultati lokalnog ponašanja mogu tretirati globalno, odnosno da se mogu neposredno prenijeti na odgovarajuću konstrukciju. Imajući u vidu u strukturu zavarenog spoja, ovaj postupak ispitivanja se pokazuje nedovoljno pouzdanim, jer vrh prsline pri razvoju loma može da prolazi kroz područja različitih struktura i mehaničkih osobina zavarenog spoja. Zbog toga je potrebna detaljna analiza zavarenog spoja sa aspekta primjene mehanike loma. Uticaj heterogenosti strukture i mehaničkih osobina zavarenog spoja se prije svega ogleda kroz položaj vrha zamorne prsline i osobina područja kroz koje se lom razvija. Žilavost loma pri ravnoj deformaciji, epruveta izvađenih iz zavarenih ploča, rađena je u cilju određivanja kritičnog faktora intenziteta napona, K_{Ic}. Za ispitivanje su korištene epruvete za savijanje u tri tačke (SEB) čija geometrija je definisana standardom ASTM E1737 [3]. Epruveta za savijanje u tri tačke se pokazala veoma prikladnom za praksu, pa se i najviše koristi. Samo ispitivanje je rađeno

na sobnoj temperaturi na elektromehaničkoj kidalici. Otvaranje vrha prsline je registrovano pomoću specijalnog induktivnog davača DD1, čija je tačnost mjerenja ±0,01 mm.
Rađene su tri grupe epruveta u zavisnosti od mjesta urezivanja zareza. i to:
I grupa - epruvete sa zarezom u osnovnom metalu (OM),
II grupa - epruvete sa zarezom u metalu zavara (MZ), i
III grupa - epruvete sa zarezom u zoni uticaja toplote (ZUT).
Kako je definisao standard ASTM E1820, prvo se pristupilo pripremanju epruvete, odnosno stvaranju zamorne prsline na epruvetama za savijanje u tri tačke. Zamorna prslina je potrebna da bi se stvorili uslovi ravne deformacije, jer se oko vrha zamorne prsline može ostvariti željeno polje napona na reproduktivan način, ali pod uslovom da je zamorna prslina obezbjedila odgovarajuće uslove. Određivanje nazivne granične sile, F_L, odnosno maksimalne sile početka zamaranja je definisano formulom:

$$F_L = \frac{B \cdot b^2 \cdot R_T}{2 \cdot L} \qquad ..(1)$$

gdje je: B - širina epruvete,
b - ligament,
L - raspon između oslonaca, i
R_T - efektivni napon tečenja, koji se određuje po formuli

$$R_T = \frac{R_{p0,2} + R_m}{2} \qquad ...(2)$$

Približno 50% završne dužine zamorne prsline je izvedeno pri maksimalnoj sili zamaranja $F_{max}=0,4 \cdot F_L$. U oba slučaja je minimalna sila bila $F_{min} = 0,1 \cdot F_{max}$.

Kako zahtjevi za ispunjenje uslova ravnog stanja deformacije:

$$B \geq 2,5 \cdot \left(\frac{K_{Ic}}{R_{p0,2}} \right)^2 \qquad ... (3)$$

nisu zadovoljeni, umjesto primjene linearno-elastične mehanike loma, pristupilo se korištenju elasto-plastične mehanike loma. Cilj korištenja elasto-plastične mehanike loma je da se vrijednost kritičnog faktora intenziteta napona, K_{Ic}, odredi posredno preko kritičnog J integrala, J_{Ic}, odnosno da se prati razvoj prsline u uslovima izražene plastičnosti. Postupak ispitivanja se ogleda u dobijanju R-krive, odnosno J - Δa krive, koja se sastoji od vrijednosti J integrala za ravnomjerne priraštaje prsline Δa. Eksperimenti su izvedeni metodom ispitivanja jedne epruvete sukcesivnim parcijalnim rasterećenjem, odnosno metodom popustljivosti jedne epruvete, kako je to definisano standardom BS 7448 Part II [4]. Cilj metode popustljivosti sa rasterećenjem je da se registruje veličina razvoja prsline, Δa, koja nastaje tokom ispitivanja. Po pravilu. do razvoja prsline dolazi kada se prekorači maksimalna sila u dijagramu F - δ. Ovdje treba napomenuti da je osnovni dijagram izveden u koordinatnom sistemu sila F - pomjeranje otvora prsline δ, a ne u sistemu sila F - pomjeranje napadne tačke sile δ, kako to zahtjevaju standardi ASTM E813, i ASTM E1152.
Iz dobijenih dijagrama sila F - pomjeranje otvora prsline δ, mjerenjem i izračunavanjem su dobijena dva niza podataka, i to:
1. Utrošeni rad po pojedinim fazama ciklusa (površina ispod krive), i
2. Promjena popustljivosti (promjena nagiba linije elastičnog rasterećenja).
Uočljiva rasterećenja na krivoj sila F - pomjeranje otvora prsline δ, služe za određivanje popustljivosti epruvete za savijanje u tri tačke pri trenutnoj dužini prsline a. Iz popustljivosti, koja je predstavljena odnosom priraštaja δ i priraštaja F na liniji rasterećenja, moguće je odrediti dužinu prsline preko izraza:

$$\Delta a_i = \Delta a_{i-1} + \left(\frac{b_{i-1}}{2} \right) \cdot \left(\frac{C_{i-1} - C_i}{C_i} \right) \qquad ... (4)$$

gdje je: a_{i-1} - prethodna dužina prsline.

$C_i = tg\alpha_i$ - nagib posmatrane linije rasterećenja.

$C_{i-1} = tg\alpha_{i-1}$ - nagib prethodne linije rasterećenja.

Dijagrami sila F - pomjeranje otvora prsline δ su direktno registrovani u toku eksprimenta na analogno-digitalnom ploteru HP 7090A, i bili su podloga za izračunavanje svih relevantnih parametara potrebnih za konstrukciju J - Δa krive. Integral J je izračunavan iz slijedeće zavisnosti:

$$J_i = \left[J_{i-1} + \left(\frac{2}{b}\right) \cdot \frac{A_i - A_{i-1}}{B} \right] \cdot \left[1 - \frac{a_i - a_{i-1}}{b_i} \right] \qquad ...(5)$$

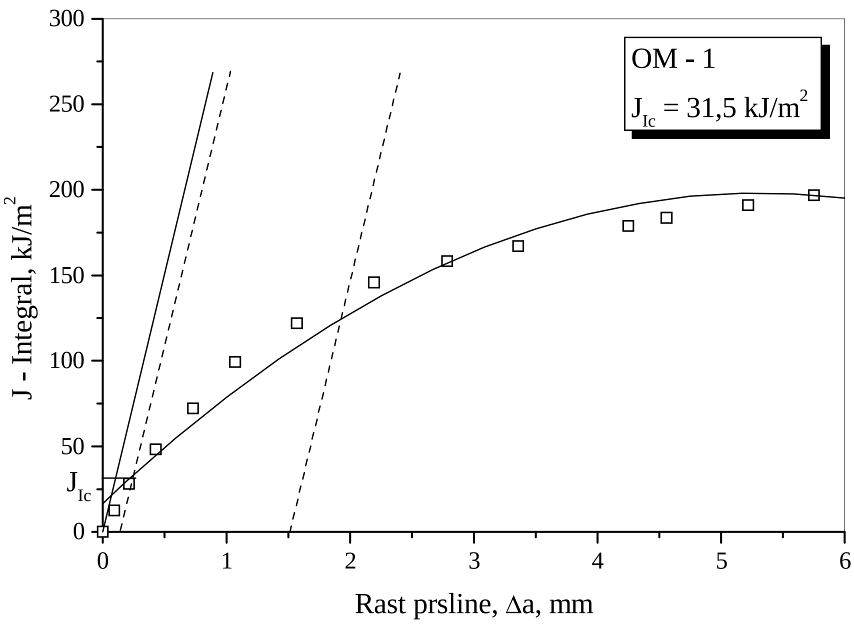
gdje je: A - površina ispod krive.

B - debljina epruvete.

b - dužina ligamenta.

Opšte je prihvaćeno gledanje da je u realno zavarenim konstrukcijama prisustvo prslina i drugih grešaka moguće, čak i vrlo vjerovatno. Odatle i potiče veliki interes da se parametri mehanike loma adekvatno primjene i na zavarene konstrukcije.

Na osnovu dobijenih podataka konstruiše se J - Δa kriva na kojoj se konstruiše regresiona linija prema ASTM E813. Iz dobijene regresione linije dobija se kritični J integral, J_{Ic}. Tipičan primjer krivih J - Δa dobijen ispitivanjem epruveta sa zarezom u osnovnom metalu je dat na slici 3.



Slika 3. Dijagram J - Δa epruvete OM-1

Poznavajući vrijednosti kritičnog J_{Ic} integrala može se izračunati vrijednost kritičnog faktora intenziteta napona ili žilavost loma pri ravnoj deformaciji, K_{Ic}, pomoću slijedeće zavisnosti:

$$K_{Ic} = \sqrt{\frac{J_{Ic} \cdot E}{1 - \nu^2}} \qquad ...(6)$$

Izračunate vrijednosti žilavosti loma pri ravnoj deformaciji, K_{Ic}, su date u tabeli 5.

Tabela 5. Vrijednosti parametara mehanike loma

Oznaka epruvete	Kritični J-integral, J_{Ic}, kJ/m^2	Kritični faktor intenziteta napona, K_{Ic}, $MPa\sqrt{m}$
OM-1	31,5	83,6
OM-2	29,4	80,8
OM-3	30,7	82,6
MZ-1	33,7	86,5
MZ-2	34,6	87,6
MZ-3	34,2	87,1
ZUT-1	24,8	74,2
ZUT-2	25,2	74,8
ZUT-3	23,6	72,4

4. ZAKLJUČAK

Na osnovu dobijenih rezultata ispitivanja ocjene sklonosti ka krtom lomu zavarenog spoja čelika Č.0361, može se zaključiti slijedeće:

Rezultati zateznih ispitivanja ukazuju na kvalitetno izabranu tehnologiju zavarivanja. Naime, sve epruvete su pukle u osnovnom materijalu, odnosno radi se o OVERMATCHING-u gdje je čvrstoća metala zavara viša od čvrstoće osnovnog metala.

Dobijene vrijednosti žilavosti loma pri ravnoj deformaciji K_{Ic}, koje su u granicama vrijednosti za ovu grupu čelika i izabrane tehnologije zavarivanja, predmetni čelik svrstavaju u kategoriju relativno otpornih na prisustvo greške tipa prsline.

Primjenom osnovne formule mehanike loma:

$$K_{Ic} = \sigma \cdot \sqrt{\pi \cdot a_c} \qquad ...(7)$$

te unošenjem vrijednosti konvencionalnog napona tečenja, $R_{p0,2} = \sigma$, uz pretpostavku da je faktor oblika jednak jedinici, mogu da se izračunaju i vrijednosti za kritičnu dužinu prsline, a_c.

Primjena ispitivanja mehanike loma na zavarene spojeve otvara put propisivanju standarda za određivanje odgovarajućih parametara. Veći uspjeh u primjeni ovih ispitivanja ograničen je velikim brojem problema, koji su posljedica osnovnih osobina zavarenog spoja i njegovih pojedinačnih područja, sa jedne strane, i posljedica složenosti ispitivanja mehanike lome i tumačenja rezultata, sa druge strane. Potpunije razumijevanje ponašanja zavarenog spoja sa prslinom na osnovu ispitivanja epruveta sa prslinom i tumačenja dobijenih rezultata će omogućiti proizvodnju ekonomičnijih, a sigurnijih i pouzdanijih zavarenih konstrukcija.

Ostaje da se istakne da je ovdje mogao biti obrađen samo jedan dio problema. Na ponašanje zavarenih spojeva pri ispitivanju epruveta sa prslinom utiču još i brojni drugi faktori, ali njihova analiza zahtjeva mnogo više vremena i prostora.

5. LITERATURA

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[3] *ASTM E1737 – 96 (1996), Standards Test Method for J–Integral Characterization of Fracture Toughness.*

[4] *BS 7448 Part 2 (1997), Fracture mechanics toughness tests – Method for determination of K_{Ic}, critical CTOD and critical J values of welds in metallic materials, BSI standards.*

1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

STRESS ANALYSIS, LIFE AND RELIABILITY EVALUATION FOR THE ECCENTRIC PRESS SHAFT

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ABSTRACT
In this study, the effecting forces on the shaft of eccentric press used in industry frequently have been analyzed by considering different working conditions. Then, life time calculations of the shaft have been realized. In a certain period of time, for various metal sheets, statistical data such as hole diameters, sheet thickness have been collected for the purpose of using at the calculations. Since, the shaft of eccentric press machine has been exposed to different kind of strains due to different thickness, diameter, and metal sheets. For each cutting position, cumulative damage occurs on eccentric press shaft. By considering of tensions and effect periods, equivalent stresses on shaft and shaft life have been calculated by using Palmgren Miner Cumulative Damage Theory. Moreover, the level reliability of life time values has been presented due to normal dispersion function.
Keywords: Eccentric shaft, life time, reliability

1. INTRODUCTION
Press machines are so important in series production due to the fast performance. The forces acting on machine cause fatigue of crank rod. In this paper, for the analysis of force, the related size belonging to the machine is given. The press shaft designed for cutting of metal sheets with different thickness has been constrained by various stresses for each cutting position. The connecting rod forces changing due to cutting force and bending moment are analyzed for each position. Then, the resultant stresses on the shaft are obtained. Additionally, the effecting time of the stresses should be noted. In analysis of an equivalent stress, corresponding the considered stresses, Palmgren-Miner cumulative damage theory will be used. The acting order of the stresses is unimportant for this theory. That is why it provides simplicity for the solution. Finally, life analysis and reliability evaluation of the shaft are performed.

2. ECCENTRIC SHAFT OF THE PRESS MACHINE
Eccentricity of the shaft is required for transforming the circular motion to rectilinear motion. The amount of the eccentricity affects the press force due to the cut angle. The bearing of the shaft and the eccentricity (e) is shown in Figure 1.

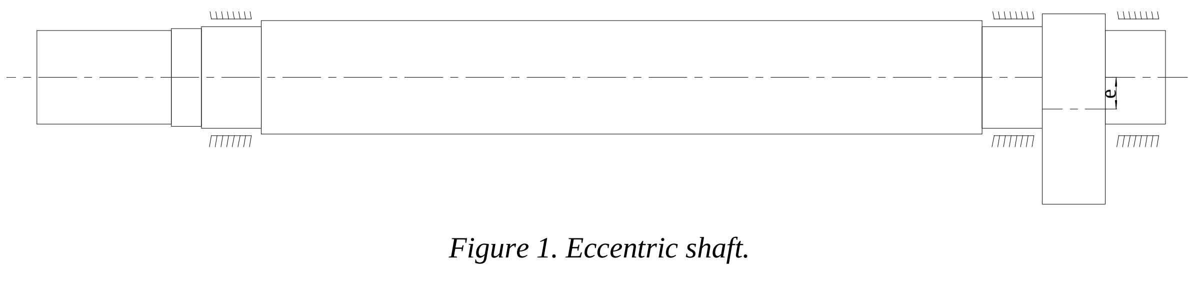


Figure 1. Eccentric shaft.

2.1. Forces Occurring in Cutting Process

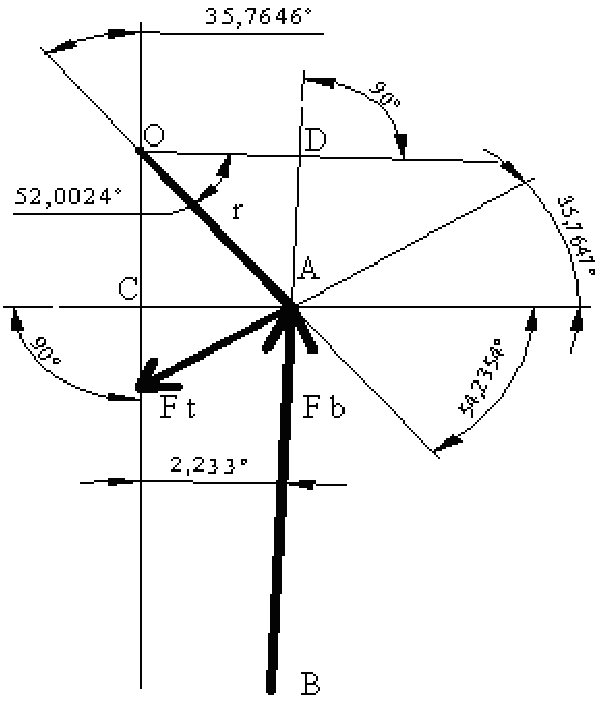


Figure 2. The relation between tangential force (Ft) and the force on connecting rod (Fb).

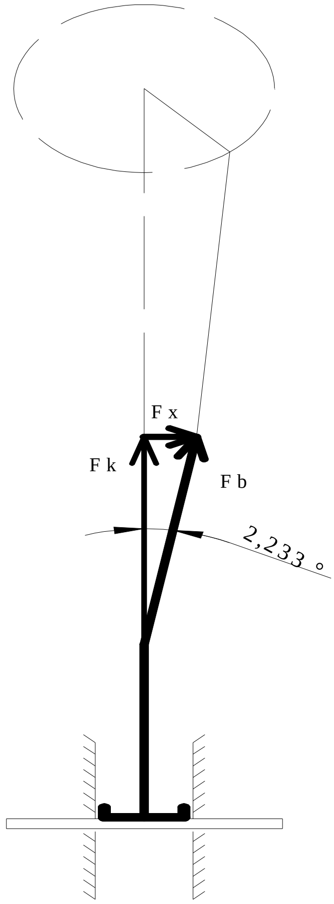


Figure 3. The components of Fb.

It is possible to obtain relation of Ft as given in equation (1) by the help of Figure 2. Also, the components of force Fb as cutting force Fk (equation (2)) and lateral force Fx (equation (3)) are given in below.

$$F_t = F_b \times Sin 37,9976 \quad \ldots(1)$$

$$F_k = F_b \times Cos 2,233 \quad \ldots(2)$$

$$F_x = F_b \times Sin 2,233 \quad \ldots(3)$$

2.2. Stress Analyses of Eccentric Shaft

Cutting force is as given in equation (4);

$$F_k = \pi \times d \times s \times z \times \tau_k \quad \ldots(4)$$

where;

F_k = perimeter x thickness x number of punch x cutting strength

Forces formed by perforated of metal sheets and moments obtained by analyzing the data of first experimental group [1] are presented in Figures 4, 5 and 6.

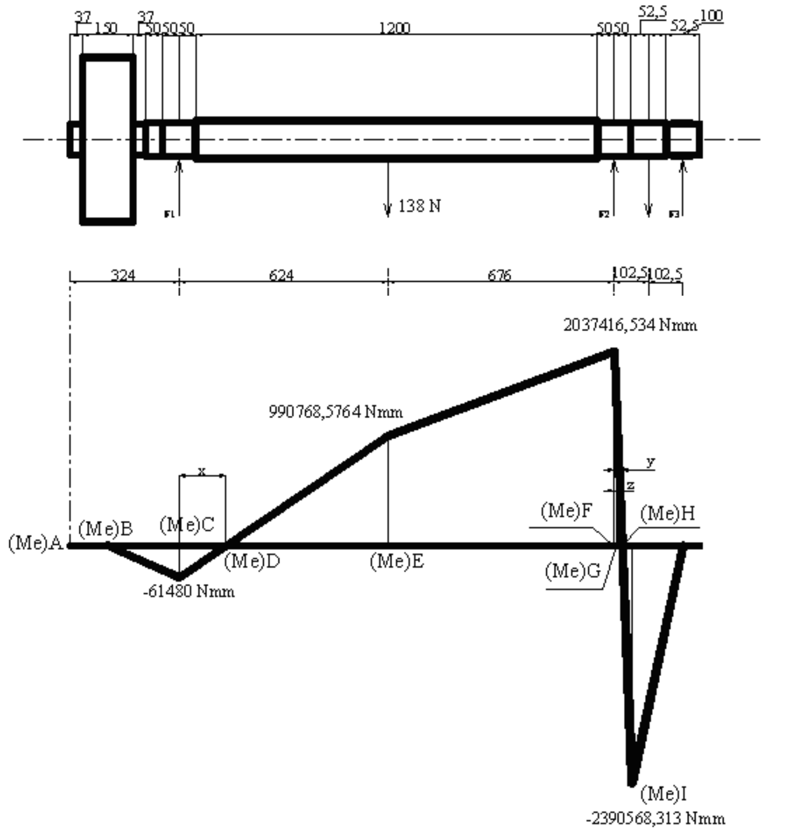


Figure 4. Bending moments due to F_{ry} and bearing forces.

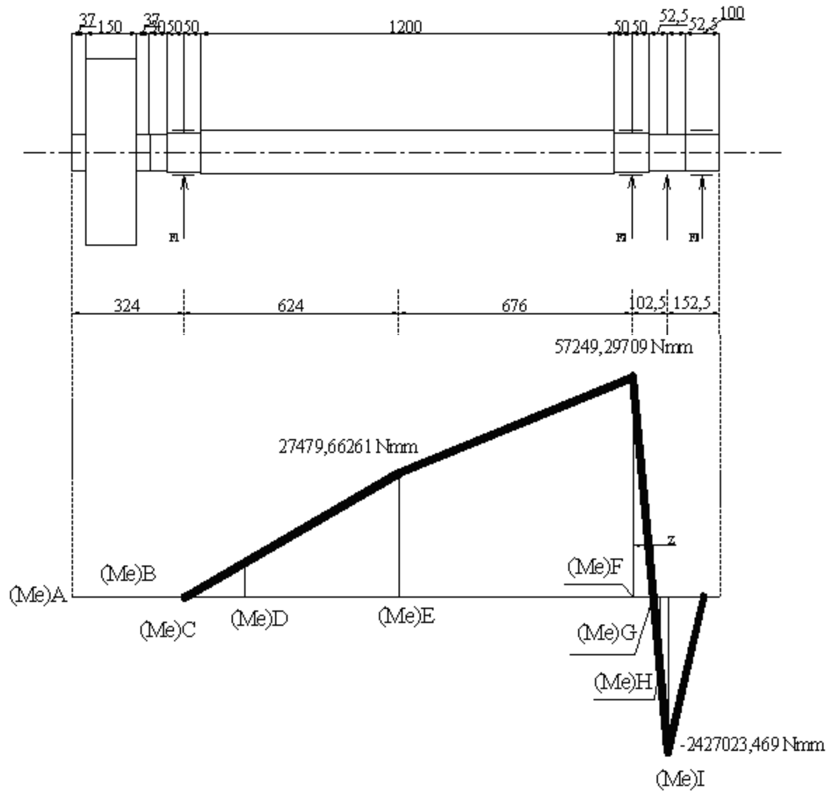


Figure 5. Bending moments due to F_{rx} and bearing forces.

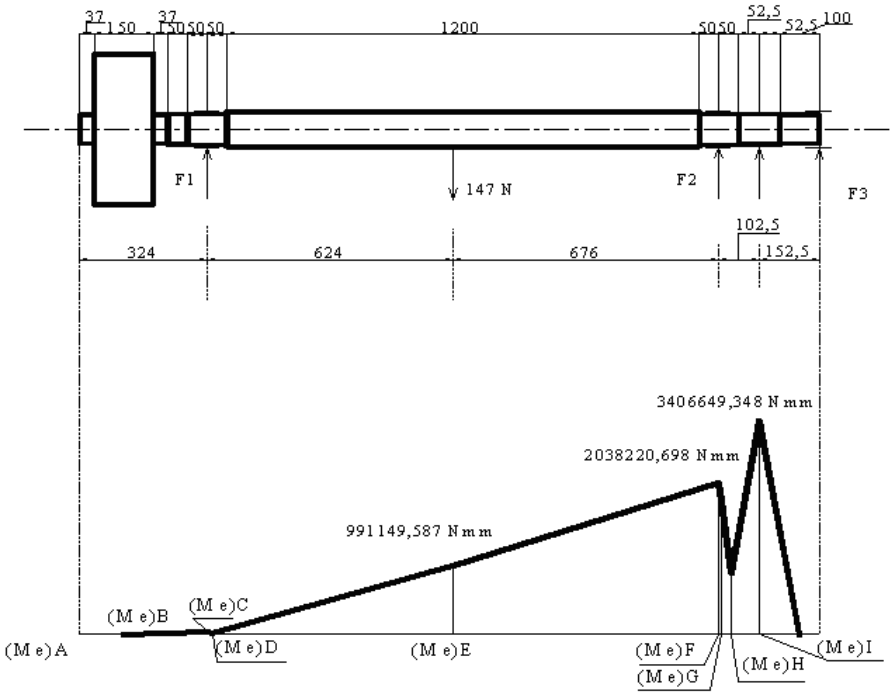


Figure 6. Total moment due to F_{rx} ve F_{ry} forces.

Figure 7. Sections of eccentric shaft.

Moment values are calculated for each section mentioned in Figure 7. By using the Soderberg equation given in equation (5), σ_e (bending stress) is focused on.

$$\sigma_e = \sigma_g + \frac{\sigma_{ak} \times \sigma_g}{\sigma_D *} \quad [N/mm^2] \qquad ...(5)$$

In the light of first experimental group, to calculate the resultant stress on the shaft, it is necessary to obtain both bending stress and torsion stress. It is known that the torsion moment results from force Ft.

By means of equations $M_b = F_t \times r$ and $\tau_b = M_b / W_b$ the resultant stress is obtained as $\sigma_B = \sqrt{\sigma_e^2 + 3 \times \tau_b^2}$.

All these steps performed for the first experimental group, are repeated for the other experimental groups. At the end of this process, it is clear that for all different cases, sections 4, 5, 6 and 7 (see Figure 7) have the maximum stress values. Life analysis will be performed by using these values related to sections.

3. LIFE ANALYSIS

3.1. Palmgren Miner Cumulative Damage Theory

The failure formed by any stress on material is proportional to the load cycle of the stress. So, to obtain periodical or continual regions of Wohler diagrams of machine elements working under different stresses, cumulative failure should be considered. In the case of cumulative failure, continual strength value (σ_D or τ_D) is smaller than the continual strength value without cumulative failure. For this reason, Wohler diagrams should be revised [2].

$$\frac{C_1}{\sigma_1}+\frac{C_2}{\sigma_2}+...+\frac{C_i}{\sigma_i}=\frac{1}{\sigma_{eq}} \quad \text{…(6)}$$

$$\frac{C_1}{N_1}+\frac{C_2}{N_2}+...+\frac{C_i}{N_i}=\frac{1}{N_{eq}} \quad \text{…(7)}$$

N: Total life of machine element

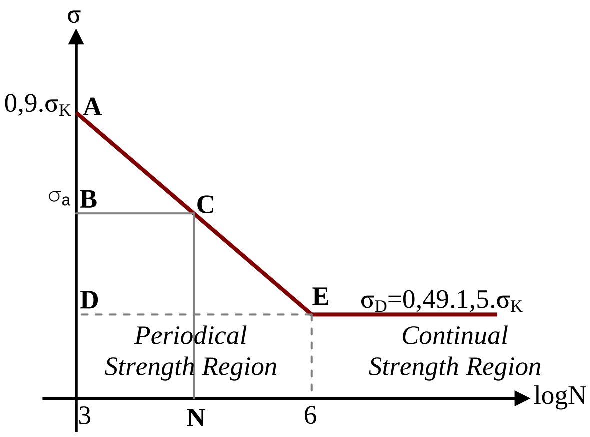
C: Working percent under a known stress; if the element works *h* hour with stress σ, then, C is the proportion of *h* to total working time;

$$C_i=\frac{h_i}{\sum h} \quad \text{…(8)}$$

In order to get more information about the usage of theory in machine elements such as railway axle, it is possible to see [3, 4, 5].

3.2. Analytical Calculation of Life Analysis in Continual Strength Region

For general manufacturing steels and in the case of ($\sigma_{\min}=0;\sigma_{\max}=2\times\sigma_{\text{amplitude}}$), the Wohler diagram could be plotted as shown in Figure 8. In general, for bending; σ_{DT} = 0,49 x 1,5 x σ_K .



$$\frac{\overline{AB}}{\overline{AD}}=\frac{\overline{BC}}{\overline{DE}}$$

$$\log N=\left(\frac{0{,}9\times\sigma_k-\sigma_g}{0{,}165\times\sigma_k}\times 3\right)+3 \quad \text{…(9)}$$

where σ_K is tensile strength of the material.

Figure 8. Wohler diagram in the case of bending.

Equation (9) is given as its general form and it gives the life value in periodical region for bending. For each resultant stress, by using equation (9), the life value under considered stress can be obtained. Therefore;

σ_{eq} = 39,75 N/mm^2 , $N_{eq} = 1{,}44231 \times 10^{18}$ or $N_{eq} = 10^{18{,}159}$. The life values calculated for other sections are also presented in Table 1.

Table 1. Equivalent life values

Section 4	Neq=1,44231x10^{18}
Section 5	Neq=2,74556x10^{18}
Section 6	Neq=3,73532x10^{18}
Section 7	Neq=1,38477x10^{18}

4. RELIABILTY (R) EVALUATION

In this part, the reliability of obtained resultant stress values due to bending moment will be presented.

Table 2. Average stress, standard diversion and Zα

$\overline{\sigma} = \sum_{i=1}^{n}\left(\frac{c_i \times \sigma_i}{n}\right)$ =1,13	$S_\sigma = \sqrt{[(\frac{\sum_{i=1}^{n}(\sigma_i - \overline{\sigma})^2}{n-1})]}$ =39,31	$Z_\alpha = \frac{\sigma - \overline{\sigma}}{S_\sigma}$ =0,16

σ_{eq}= 39,75 [N/mm2], Z=0,98 and Zα=0,1629709 (normal dispersion function [2]).Then; If R=1-Zα, then R=0,837 . Also, reliability values of sections are given in Table 3.

Table 3. Reliability values

	σ(R)	**Neq(R)**
Section 4	R=0,837	R=0,8369
Section 5	R=0,8326	R=0,8145
Section 6	R=0,8347	R=0,7486
Section 7	R=0,8482	R=0,61336

5. RESULTS

In this study, the stress analysis of eccentric press shaft has been performed and shaft life has been examined by considering cumulative damage theory. For this aim, Wohler diagram has been plotted for general manufacturing steel. It is supposed that for the considered shaft, for the result of 0,9xσ_K, life value will be 10^3 life cycles and for the transition from periodically region to continual region, it will be 10^6. In theoretically, the machine element constrained with a stress under fatigue strength will have infinite life. Also, it is clear that the result obtained by Palmgren Miner theory is 10^{18} as explained above.

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1st International Scientific Conference on Engineering
”Manufacturing and Advanced Technologies”
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

RESIDUAL LIFE AND INTEGRITY OF HIGH-TEMPERATURE BOILER COMPONENTS

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ABSTRACT
Boiler components of thermal power plant are exposed to elevated temperatures, aggressive environment, creep, fatigue, and other damage mechanisms that can cause degradation, deformation or cracking of components. The reliability of power plant has become a growing concern of electric utilities as existing equipment ages. Elevated-temperature failure mechanisms and metallurgical instabilities reduce life or cause loss of function or operating time of high-temperature components. Boiler steamlines, heaters and superheaters often require condition assessment after the boiler has been in operation. Because questions concerning remaining life, fitness-for-service, inspection intervals, and reliability of boiler structural components and equipment, it is necessary to be aware of life assessment methodologies. The paper focuses on critical boiler components operating at elevated temperatures in boiler and pipeline areas. Particular attention is given to the importance of condition assessment.
Keywords: power plant boiler, high-temperature, residual life

1. INTRODUCTION
Thermal power plants around the world are aging and need to be assessed to ensure continued safe operation. Replacement is frequently not an option because of high capital costs, and the much lower cost of continuing the operation of the older plant [1]. However, reliability and safety are issues that have become much more important in recent years, so the assessment of damage and of the risk associated with failure have become increasingly important.
Boilers and other types of steam power plant equipment are subjected to a wide variety of failures involving one or more of several mechanisms. Most prominent among these mechanisms are corrosion, including pitting and erosion; mechanical-environmental processes, including stress-corrosion cracking and hydrogen damage; fracture, including fatigue fracture, thermal fatigue fracture, and stress rupture; and distortion, especially distortion involving thermal-expansion effects of creep.
Most steam-generator failures occur in pressurized components, that is, the tubing, piping, and pressure vessels that constitute the steam-generating portion of system, [2].
Microstructural degradation is also a damage mechanism that can lead to failure by some other process such as creep, fatigue or more rapid fracture. It is important that it is recognized as a mechanism of damage as it can result in a significant loss in strength in a material. It is appropriate to discuss this following directly upon the discussion of creep damage, because the two mechanisms are closely bound together and, indeed, are difficult to separate.
Figures 1. and 2. shows typical failures of high-temperature boiler components caused by creep and fatigue.

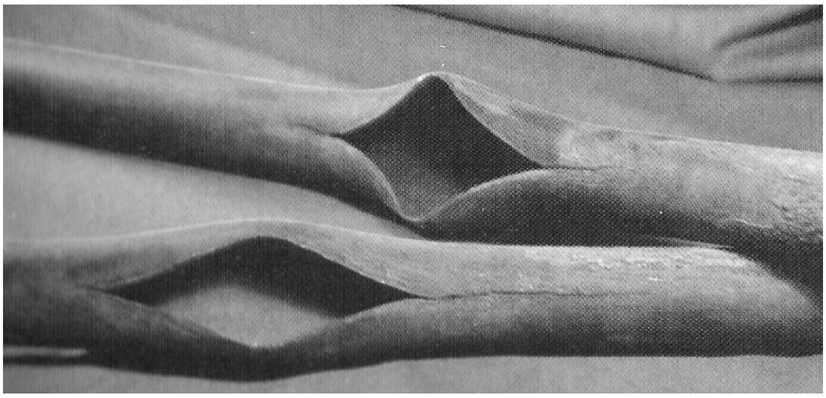

Figure 1. Two superheater tubes from a utility boiler (9,7MPa), failed by creep, [3]

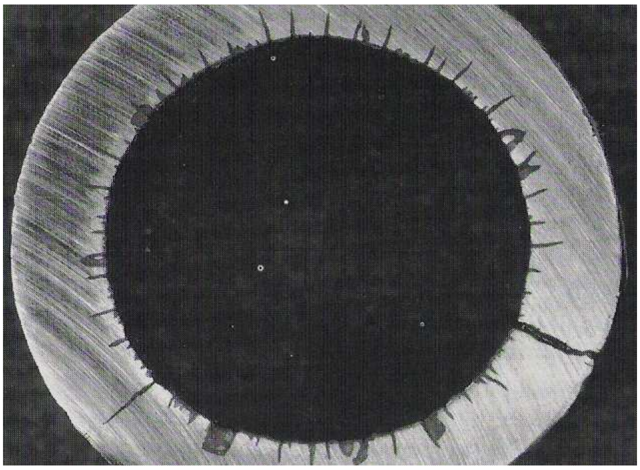

Figure 2. A family of longitudinal cracks resulting from fluctuation in internal pressure, [3]

2. HIGH-TEMPERATURE LIFE ASSESSMENT

Most power-plant operators maintain relatively complete records. Records of operating conditions and preventive maintenance for a component that has failed, and for the system as a whole, are relatively good sources of background information.

These records can provide valuable information, such as operating temperature and pressure, normal power output, fluctuation in steel demand, composition of fuel, amount of excess combustion air, type and amount of water-conditioning chemical added, type and amount of contaminants in condensate and make-up feedwater, frequency and methods of cleaning fire-side and water-side surfaces of steam generators, materials specified as to alloy requirements and dimensions, frequency and location of any previous failures, length of service, and any unusual operating history, [2].

In the absence of documented plant history data the validity of accuracy of remanent life assessment must suffer. Plant data management plays a crucial role and involves the collection, storage and manipulation of data associated with operating and maintenance histories, inspection and monitoring, failure analysis, life assessment, resources, schedules, etc.

The substantial amount of data can only be effectively dealt with using computer based systems, [4]. A finding from most life extension programs is that is necessary to focus the data gathering and evaluations. By dividing the plant into major systems and subsequently into components within those systems, an ordered evaluation of component condition can proceed logically.

Evaluations have further enabled identification of critical components, Table 1.

Table 1. Critical components and remanent life assessment, [4]

A critical component can be defined by the following characteristics:
• Failure forces the unit out for an extended outage, or • Failure endangers the safety of plant personnel, or • Long lead times and high costs for repair or replacement.
Remanent life assessment relies upon determining three kind of information:
• The degree of damage currently in the component, • The rate of damage accumulation, • The degree of damage required to cause failure.

Since damage is dependent upon factors specific to a given generating unit (design, operating modes) it is necessary to treat each unit and its components individually in order to obtain realistic life assessments. This process is made more manageable by a staged approach in which simple assessments are conducted until the need for more complicated procedures is indicated. For the initial evaluation, only design or overall service parameters need to be examined to ascertain if, on the basis of the most conservative considerations, the component has residual life greater than the anticipated extended-service period.

The two activities recommended prior the initial assessments are to assemble elementary service factors and to answer the following key questions for the component that is to be analyzed:

- Has operation exceeded the design parameters (temperature and/or pressure) for significant times or extents?
- Will the service during the extended life exceed the pertinent design parameters?
- Have the design philosophy or materials choices been shown to be non-conservative since the unit went into operation?
- Has the failure history been significant?
- Are steam-temperature records inadequate or not available for assessment of those components that function at elevated temperature?

A “yes” answer to any of these key questions suggests that the evaluation procedure should be entered with a combination of calculation and inspection, together. In any case, if the component fails the minimum-life criterion in initial evaluation (calculation), inspection method of assessment should be performed. Information for this evaluation is obtained from operating records and from measurements taken in an initial inspection.

Calculation and inspection methods are intended to identify problem components that could reach end of life before the extended service is complete. These are the components that require more detailed analysis for confident life prediction.

If the remaining life determined in calculation and inspection is too short or has an unacceptable level or uncertainty in relation to operational targets, then the more precise evaluation should be implemented. In that case, information requirements include component surveillance and sampling followed by post-exposure tests.

3. LIFE ASSESSMENT METHODS FOR POWER PLANT PIPING AND TUBING

Piping and tubing in steamlines, heaters, boilers, and superheaters are subjected to elevated temperatures that can cause degradation, deformation or cracking. Thus, it is possible for the life expectancy to be reduced. Therefore, it is often necessary that piping and tube life assessment be conducted.

Some methods can be applied for plant piping and tubing exposed to elevated temperatures, like following [5]:

- Hardness testing,
- Microstructural evaluation,
- Creep cavitations damage assessment,
- Stress-rupture tests (life fraction),
- Oxide-scale-based life prediction,
- High-temperature crack growth methods.

In history-based methods, plant records and the time-temperature history of the component is reviewed.The most common approach to calculation of cumulative creep damage is to compute the amount of life expended by using time or strain fractions as measures of damage. The most prominent rules are as follows:

- Life fraction rule: $\sum t_i / t_{ri} = 1$,
- Strain fraction rule: $\sum \varepsilon_i / \varepsilon_{ri} = 1$,

where t_i and ε_i are the time spent and strain occured at condition *i*, and t_{ri} and ε_{ri} are the rupture life and rupture strain under the same condition. The life-fraction procedure usually is inaccurate because of errors in assumed history, in material properties, and in the life-fraction rule itself, [6].
Direct postservice evaluation represents an improvement over history-based methods, because no assumptions regarding material properties and past history are made. Unfortunately, direct examinations are expensive and time consuming.
The best strategy is to combine the two approaches. A history-based method is used to determine if more detailed evaluations are justified and to identify the critical locations and this is followed by judicious postservice evaluation.
In any component, the failure criteria need to be defined and established. Failure does not always involve fracture or rupture. Progressive damage of high-temperature components under operating conditions leads to exhaustion of life, thus leading to failure.
Damage may be defined as a "progressive and cumulative change acting to degrade the structural performance of the load-bearing component or components that make up the plant". Life may be defined as the "period during which a component can perform its intended function safely, reliably, and economically", [5].

4. BOILER AND PRESSURE VESSEL CODES

Boiler and pressure vessel codes and standards provide methods and rules that can be used to evaluate remaining life of boiler components. Annex I of the Pressure Equipment Directive 97/23/EC (PED) requires that the design must take appropriate account of all foreseeable degradation mechanism such as fatigue [7].
For other degradation mechanism, such as creep interaction with fatigue there are very few methods available. The methods used to evaluate fatigue vary from exemption calculations, to simplified methods, to detailed methods.

4.1. Fatigue evaluation

Many boiler and pressure vessel codes and standards provide provisions to exempt fatigue evaluations, [8]. Exemptions are based on the components meeting the code design rules and details. Fatigue exemption rules are also a function of construction details. If fatigue evaluations cannot be exempted, the next step would be to use simplified fatigue evaluation methods. Once again these methods are based on the components meeting the code design rules and details.
Simplified fatigue analysis rules may be conservative with respect to determining stresses used in fatigue life evaluations. More detailed methods for determining stresses such as finite element analysis may be used to obtain more exact fatigue evaluation.
For detailed fatigue evaluations, detailed stress analyses are normally used, but not always necessary. These stress analyses are all based on determining stresses and involve either classical plate and shell

theory or finite element analysis. Codes and standards evaluate calculated stresses differently in their fatigue assessment procedures.

Table 2. Codes and standards for fatigue evaluation methods, [9]

1.	ASME Section VIII Division 2, (ASME VIII-2)
2.	British Standard, PD 5500
3.	German Technical Rules for Steam Boilers, TRD
4.	European Standards for Water-Tube Boilers, EN 12952
5.	European Standard for Unfired Pressure Vessels, EN 13345

4.2. Creep and fatigue interaction methods

Creep occurs in components that are stressed at elevated temperatures for long periods of time, such as superheaters and reheaters. The creep damage is based on the length of time the components stressed at a particular magnitude and temperature.

Therefore, the creep damage at a particular stress and temperature is the ratio of time of operation to allowable time for creep. The total creep usage fraction is the summation of the individual creep damage ratios.

The TRD 508 and EN 12952-4 method for creep life determination is simplified but an effective method for creep consideration and for creep-fatigue interaction, [8]. These rules are for in-service monitoring of creep and creep-fatigue life of water tube boilers, but are used for creep and creep-fatigue evaluations. For detailed creep and creep-fatigue evaluation ASME Section III can be used. Subsection NH was written for nuclear component design and is very complicated, time consuming, and is not considered useful for every day designs of power plant boilers.

Table 3. Codes and standards for creep and fatigue interaction evaluation methods, [9]

1.	German Technical Rules for Steam Boilers, TRD
2.	European Standards for Water-Tube Boilers, EN 12952
3.	ASME Section III, Subsection NH

5. FINAL REMARKS

With the current emphasis on extended operation, condition assessment is probably one of the most important activities in today aging fossil plant.

Valid run/retire/replace decisions cannot be made in the absence of assessment of the effects of creep, fatigue, corrosion, erosion and other mechanisms of material aging and wear. Condition assessment techniques developed over the last 20 years are now being applied to remanent life estimation with proven cost benefits at both inspection and engineering planning levels.

Significant resources are currently being directed to strive for new, consolidated or refined methods to enable improvements in both the accuracy and user-friendly nature of the technique application. Life assessment method advances and changes in technologies for structural components and equipment will require the investigator to adapt to the need of the industry.

Furthermore, the failure investigator role has expanded from providing accurate identification of life-limiting failure mechanisms and degradation phenomena to also providing the time for degradation or damage, and crack growth rate to be used in life assessment estimates.

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1st International Scientific Conference on Engineering
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MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

MAIN SHAFT OPTIMIZATION OF WINCH HAULAGE

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ABSTRACT
In this paper the loads of the main shaft of winch haulage based on stability and stiffness criteria are analyzed in order to optimize the shaft's parameters.
In the optimization model the shaft's volume has defined objective function subjected to the angle of torsion, safety coefficient, deflection and displacement, and shaft geometry as constraints.
The 'optimal solution' of the adopted model for the main rotating shaft found by Matlab software is compared with existed dimension bringing to satisfactory results.
Key words: Winch Haulage, Stability Criteria, Stiffness Criteria, Optimization Model, Rotating Shaft, Deflection and Displacement.

1. INTRODUCTION
Design parameters of shaft that must be fulfilled in order to complete the working criteria are: shaft sizes, rotation moment, safety coefficient, angle of torsion, displacement of shaft and critical number of rotation.
The selection of the optimum shaft model should also fulfill constraints in order that: the shaft must be in function of winch haulage, and its installation must provide given functions.
Shaft as a part of winch haulage should also execute technical conditions towards: the other parts of winch haulage, exploitation rate and the safety rate.
Methodology of shaft optimization is presented in four stages:

- The identification of constructive parameters is in the first stage, respectively the definition of vector variable,
- In the second stage constraint (geometric and constructive) are determined,
- In the third stage objective function (volume of shaft) is defined,
- In the fourth stage "the best" selection from all possible alternatives is valued, considering installation conditions and exploitation.

The analysis of an adopted model of shaft optimization are explained based on the Winch Haulages's shaft model shown in fig.1.1.

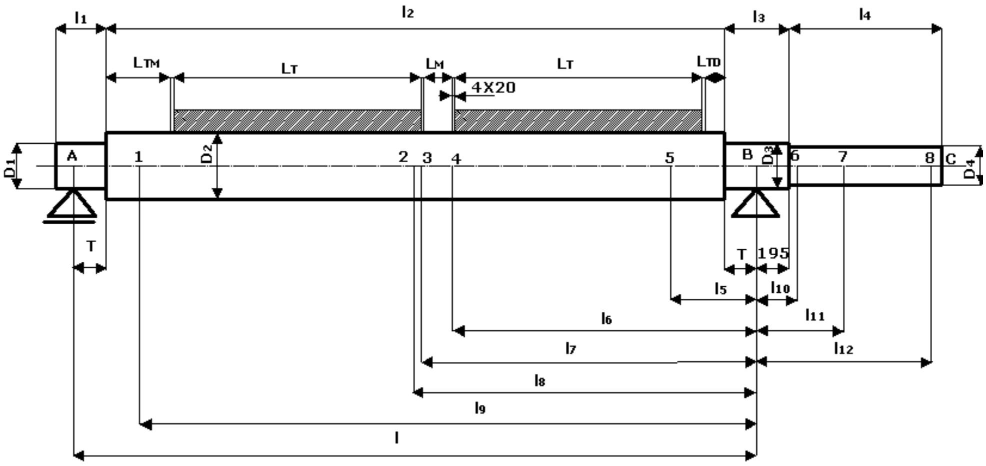

Figure 1.1. Winch Haulage's shaft model

The shaft constructive data:

$T = 200mm$

$L_{TM} = 397.5mm$

$L_M = 170mm$

$L_{TD} = 120mm$

$L_T = 1510mm$

$X = 110mm$

$l_1 = T + X = 310mm$

$l_2 = L_{TM} + 2L_T + L_{TD} + 80 + L_M = 3787.5mm$

$l_3 = 395mm$

$l_4 = 938mm$

$l_5 = T + L_{TD} + 10 = 330mm$

$l_6 = T + L_{TD} + L_T + 30 = 1860mm$

$l_7 = T + L_{TD} + L_T + L_M + 50 = 2050mm$

$l_8 = \frac{l_2}{2} + T = 2093.75mm$

$l_9 = T + L_{TD} + 2L_T + L_M + 70 = 3580mm$

$l = 2T + l_2 = 4187.5mm$

$l_{10} = l_3 - T = 245mm$

$l_{11} = l_3 - T + 334 = 529mm$

$l_{12} = l_3 - T + 877 = 1072mm$

2. OPTIMIZATION MODEL OF THE SHAFT

For the concrete case of optimization as objective function the volume of shaft is taken.

$$f(x) = \frac{\pi \cdot D_1^2}{4} \cdot l_1 + \frac{\pi \cdot D_2^2}{4} \cdot l_2 + \frac{\pi \cdot D_3^2}{4} \cdot l_3 + \frac{\pi \cdot D_4^2}{4} \cdot l_4 \qquad \text{... (2.1.)}$$

If in the expression (2.1) we substitute expression for: $x_1 = D_1, x_2 = D_2, x_3 = D_3, x_4 = D_4$, the expression for objective function – volume of shaft is obtained.

$$f(x) = \frac{\pi \cdot x_1^2}{4} \cdot l_1 + \frac{\pi \cdot x_2^2}{4} \cdot l_2 + \frac{\pi \cdot x_3^2}{4} \cdot l_3 + \frac{\pi \cdot x_4^2}{4} \cdot l_4 \qquad \text{… (2.2.)}$$

Except this, in the model of optimization the constraints must be involved in the form of inequality from aspect of:

-the torsion angel of shaft:

$$g_1(x) \equiv 0.004 - \varphi \le 0;\ 0.004 - \frac{32}{\pi} \cdot \frac{T_B}{G}\left(\frac{l_1}{x_1^4} + \frac{l_2}{x_2^4} + \frac{l_3}{x_3^4} + \frac{l_4}{x_4^4}\right) \le 0 \qquad \text{…(2.3)}$$

$$g_2(x) \equiv \varphi - 0.009 \le 0 \ ; \quad \frac{32}{\pi} \cdot \frac{T_B}{G}\left(\frac{l_1}{x_1^4} + \frac{l_2}{x_2^4} + \frac{l_3}{x_3^4} + \frac{l_4}{x_4^4}\right) - 0.009 \le 0 \qquad \ldots(2.4)$$

- the safety factor of shaft:

$$g_3(x) \equiv S - 2.5 \le 0 \, ; \quad \frac{\pi \cdot d_2^3 \cdot \xi_f \cdot \xi_t \cdot \sigma_{Daf} \cdot \tau_{Dnjt}}{16\sqrt{\xi_f^2 \cdot \sigma_{Daf}^2 \cdot \beta_{kt} T_B + 4 \cdot \xi_t \cdot \tau_{Dnjt}{}^2 \cdot M_f^2 \cdot \beta_{kf}^2}} - 2.5 \le 0 \qquad \ldots(2.5)$$

$$g_4(x) \equiv 1.5 - S \le 0 \, ; \quad 1.5 - \frac{\pi \cdot d_2^3 \cdot \xi_f \cdot \xi_t \cdot \sigma_{Daf} \cdot \tau_{Dnjt}}{16\sqrt{\xi_f^2 \cdot \sigma_{Daf}^2 \cdot \beta_{kt} T_B + 4 \cdot \xi_t \cdot \tau_{Dnjt}{}^2 \cdot M_f^2 \cdot \beta_{kf}^2}} \le 0 \qquad \ldots(2.6)$$

- the displacement of shaft

The displacement of shaft is calculated in two flats and to scrutinize the point 4 is taken as most critical.

$$g_5(x) \equiv 0.3 \cdot 10^{-3} \cdot l - f_4 \le 0$$

$$0.03 \cdot 10^{-3} \cdot l - \\ - \sqrt{\left(\frac{2081976948.7677 d_1^4 + 19546992074.189 d_2^4}{d_1^8}\right)^2 + \left(\frac{356690056189 d_4^4 + 9877702906.034 d_2^4 + 1031604732466 d_3^4}{d_4^8}\right)} \le 0$$

$$\ldots(2.7)$$

$$g_6(x) \equiv f_4 - 0.5 \cdot 10^{-3} \cdot l \le 0$$

$$\sqrt{\left(\frac{2081976948.7677 d_1^4 + 19546992074.189 d_2^4}{d_1^8}\right)^2 + \left(\frac{356690056189 d_4^4 + 9877702906.034 d_2^4 + 1031604732466 d_3^4}{d_4^8}\right)} - \\ - 0.5 \cdot 10^{-3} \cdot l \le 0$$

$$\ldots(2.8)$$

At the end, the mathematical problem as most important step for optimization is solved through defining:

- the objective function-volume of shaft,
- the six constraints, which are sufficient to minimize the objective function.

In continuance, the objective function and constraints will be given as M-files in MatLab software to realize the shaft optimization of Winch Haulage respectively to obtain the smallest shaft volume that fulfill all confirmed criteria mentioned before.

3. THE ANALYSIS OF THE RESULTS

From the results is recognized that the minimal value of the objective function-volume of shaft, is obtained through these optimal parameters of constructive vector.

x= (279,65; 334,639; 279,654; 240,274; 3729,867) …(3.1)

From the constructive vector it is recognized that the absorbed optimal values of diameters **D** and lengths l_2 are:

$D_1 = 280mm$; $D_2 = 335mm$; $D_3 = 280mm$; $D_4 = 240mm$; $l_2 = 3730mm$,

and the value of the objective function-volume of shaft is:

$$f = (414611729.7)mm^3 \qquad \ldots(3.2)$$

The difference between the values of the model, the optimal values and absorption values of the

Winch Haulage shaft are presented at the end of this paper on Table 3.1.

Table 3.1.Difference between the values of the model, optimal values and absorption values

Values of	D_1	D_2	D_3	D_4	l_2	S	φ	f	Objective function - volume
model	280	360	280	240	3787.5	1.866794	0.007934	17.57546	471365190.1
optimal	279.65	334.639	279.654	240.274	3729.867	1.499404	0.008841	13.11552	413880335.4
adopted	280	335	280	240	3730	1.504262	0.008834	13.22399	414611729.7

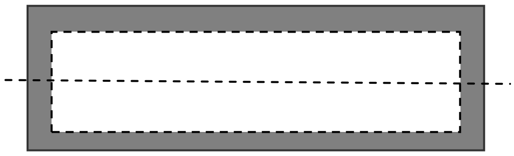

Figure. 3.2. Current Shaft with black color, and optimal Shaft with white color

The shaft as pre-fabricated is shown in this form:

- the white color shaft is the shaft obtained after optimization - $D_2 = 335mm$,
- the black color shaft is the existed shaft - $D_2 = 360mm$.

4. CONCLUSION

Based on the shaft calculations criteria, optimal construction, analysis of optimization method, and the optimization of shaft parameters with MatLab software we can conclude that:

- the optimal construction process opposite conventional process present the most important process during the optimization of parts and machinery systems.
- the shaft optimization is realized through MatLab software, where the objective function and constraints are defined.
- the realized results on the optimal parameters of the Winch Haulage show that the objective given in this paper is achieved, because optimal sizes are achieved through preliminary sizes.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

PROCJENA SIGURNOSTI ZAVARENIH SPOJEVA U PRISUSTVU GREŠKE TIPA PRSLINA

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REZIME

Veliki broj lomova zavarenih konstrukcija, do kojih dolazi u toku eksploatacije pri nivou napona nižem od dozvoljenog, ukazuje na opasnost od pojave krtog loma. Zbog toga je pri projektovanju konstrukcija neophodno definisati kriterijume na osnovu kojih se može postići sigurnost konstrukcije od krtog loma. Korišćenje energije udara, kao mjere otpornosti, i prelazne temperature, kao kriterijuma sigurnosti od loma, sadrži niz nedostataka, koje se prevazilaze projektovanjem konstrukcija na bazi mehanike loma.

Ocjena sklonosti ka krtom lomu je analizirana ispitivanjem Sharpy i SEB epruveta, a kao parametri u analizi su korišteni ukupna energija udara, komponente ukupne energije udara (energija stvaranja i energija širenja prsline), kao i parametri mehanike loma, faktor intenziteta napona, KIc, i kritični J integral, JIc. Poznavanjem ovih parametara može se uspješno ocjeniti sigurnost zavarenog spoja, a time i cijele konstrukcije.

Ključne riječi: *zavareni spoj, dužina prslina, žilavost loma*

1. UVOD

Ono što je za zavarene konstrukcije od posebnog značaja, a čime se bavi i mehanika loma jesu prsline svih vrsta, problemi neprovarenih mjesta, prisustvo uključaka, itd. Potpuna karakterizacija zavarenih spojeva sa aspekta eksploatacijskih svojstava, podrazumjeva i sagledavanje njihovog ponašanja u prisustvu greški, tj ocjenu njihove otpornosti prema iniciranju i razvoju prsline kao najopasnije vrste greške.

Polazeći od toga da su greške neizbježna pojava u konstrukcijama i u zavarenim spojevima potrebno je da se konstrukcije obezbjede od mogućih štetnih posljedica postojanja greški. Važan pravac istraživanja greški je ocjena značaja greške u konstrukciji, koja je zasnovana na teorijskim i eksperimentalnim pristupima mehanike loma. Objašnjavajući naponsko stanje na vrhu prsline kao greške najoštrijeg oblika, mehanika loma je omogućila uvođenje eksperimentalnih postupaka za određivanje parametara koji opisuju opasnost od razvoja prsline u lom. Njihovom primjenom je moguće tačnije procijeniti ponašanje materijala i zavarenog spoja sa greškom, što omogućava projektovanje sa manjom masom materijala i pouzdanije predviđanje ponašanja opterećene konstrukcije.

2. EKSPERIMENTALNA ISTRAŽIVANJA [1]

2.1. Materijal i tehnologija zavarivanja

Za eksperimentalna istraživanja korišten je čelik Č.4730, proizveden u "Slovenske Železarne" Jesenice. Hemijski sastav materijala je dat u tabeli 1, a mehanička svojstva u tabeli 2.

Tabela 1. Hemijski sastav dostavljenih ploča

Šarža	**% mas.**						
	C	**Si**	**Mn**	**P**	**S**	**Cr**	**Mo**
14-9245	0,25	0,26	0,63	0,015	0,004	0,97	0,16

Tabela .2. Mehanička svojstva čelika Č .4730 u stanju isporuke

Šarža	**Napon tečenja $R_{p0,2}$, MPa**	**Zatezna čvrstoća, R_m, MPa**	**Izduženje A, %**	**Kontrakcija Z, %**	**Energija udara KU3, J**
14-9245	420	565	25,6	60,3	60

Za zavarivanje ploča debljine 16 mm od čelika Č.4730 izabran je MAG (CO_2) poluautomatski postupak zavarivanja. Kao dodatni materijal korišćena je čelična žica prečnika ∅1,20 mm koju proizvodi "ŽICA" Sarajevo.. Zavareni spoj je sučeoni sa pravilnim simetričnim X- žljebom, a. priprema žljeba izvršena je prema standardu JUS C. T3.030 .

Tabela 3. Parametri zavarivanja

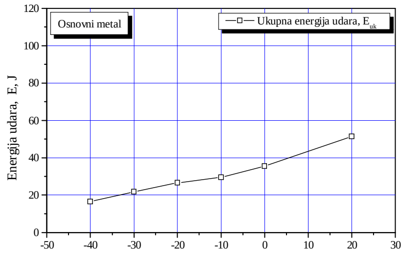
Aktivnost	**Proba X**	**Proba XX**
Broj prolaza u zavaru	8	8
Temp. predgrijvanja, T_p [°C]	170	170
Srednja jačina struje, I [A]	160	220
Srednji napon, U [V]	24	28
Brzina zavarivanja, v[cm/min]	22,5	23,7
Stepen toplotnog iskorišćenja, η	0,7	0,7
Količina unešene toplote, Q [J/cm]	7680	11696

2.2. Udarna ispitivanja

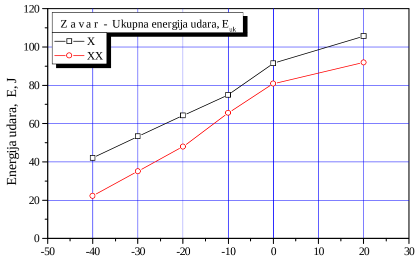
Udarna ispitivanja uzoraka izvađenih iz zavarenih ploča Č. 4730 rađena su u cilju određivanja energije udara (udarne žilavosti). Postupak ispitivanja je definisan prema standardu ASTM E23 na standardnim epruvetama Ispitivanje je izvedeno na 20°C, 0°C, -10°C, -20°C, -30°C i -40°C. Kao rashladno sredstvo za postizanje niskih temperatura korišćen je tečni vazduh u alkoholu, odnosno petroletru. Ispitivanje je izvedeno na instrumentiranom Šarpi klatnu SCHENCK TREBEL 150 J.

Rađene su tri grupe epruveta u zavisnosti od mjesta urezivanja V-2 zareza, , i to: I grupa - epruvete sa V-2 zarezom u osnovnom metalu (OM), II grupa - epruvete sa V-2 zarezom u metalu zavara (MZ) i III grupa - epruvete sa V-2 zarezom u zoni uticaja toplote (ZUT), i

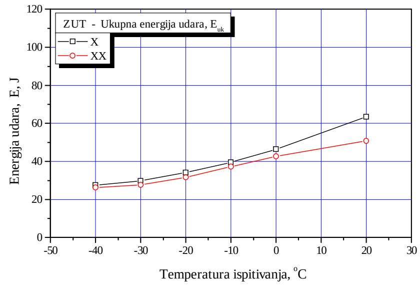
Zavisnost ukupne energije udara, E_{uk}, od temperature ispitivanja i mjesta postavljanja V-zareza je data i dijagramski na sl. 1 do 3 za sve grupe ispitivanih epruveta. Isto tako na sl. 2 i sl.3 je dat i uticaj količine unešene toplote u postupku zavarivanja na vrijednosti ukupne energije udara.



Slika 1. Uticaj temperature ispitivanja na E_{uk} epruveta sa V-zarezom u OM



Slika 2. Uticaj temperature ispitivanja na E_{uk} epruveta sa V-zarezom u MŠ

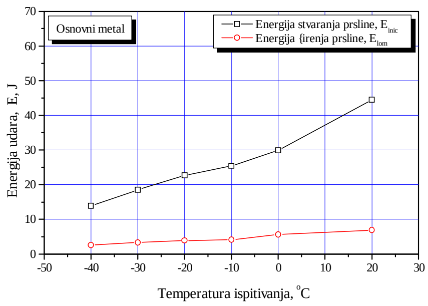


Slika 3. Uticaj temperature ispitivanja na E_{uk} epruveta sa V-zarezom u ZUT

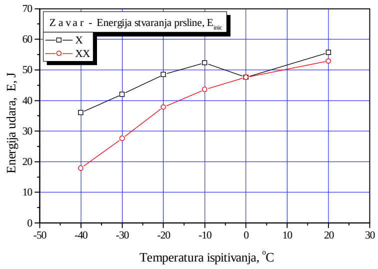
Na osnovu dobijenih rezultata udarnih ispitivanja, odnosno izmjerenih vrijednosti ukupne energije udara E_{uk}, jasno se uočavaju da najznačajniji uticaj na vrijednost ukupne energije udara E_{uk}, uzoraka ima mjesto gdje je postavljen V-zarez., odnosno da heterogenost strukture zavarenog spoja (OM, MŠ, ZUT) ima presudan uticaj na vrijednost ukupne energije udara. Također, količina unešene toplote u postupku zavarivanja ima uticaj na dobijene vrijednosti ukupne energije udara., odnosno da epruvete sa manjom količinom unešene toplote u postupku zavarivanja (X) imaju veću ukupnu energiju udara od epruveta sa većom količinom unešene toplote (XX). Razlika je posebno uočena kod zavara, što se može objasniti nižom čvrstoćom zavara.

Na bazi mjerenja ukupne energije udara (udarne žilavosti), u većini slučajeva, nije moguće saznati kako se sa sniženjem temperature mijenja rad koji se troši na elastičnu i plastičnu deformaciju uzorka do stvaranja prsline. Ovaj fundamentalni nedostatak udarne žilavosti u izvjesnom stepenu može biti prevaziđen diobom udarne žilavosti na energiju stvaranja prsline E_{inic}, i energiju širenja prsline ili energiju loma E_{lom}.

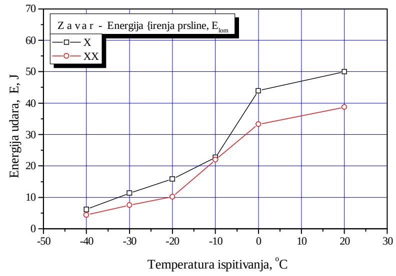
Uticaj temperature ispitivanja i mjesta postavljanja V-zareza na vrijednosti energije stvaranja prsline $E_{inic.}$, i energije širenja prsline E_{lom}, kod osnovnog metala je data dijagramski na sl. 5., a uticaj količine unešene toplote u postupku zavarivanja, temperature ispitivanja i mjesta postavljanja V-zareza na vrijednosti energije stvaranja prsline $E_{inic.}$, i energije širenja prsline E_{lom}, kod zavara je data na sl. 6. i 7., i kod ZUT na sl. 8 i 9,



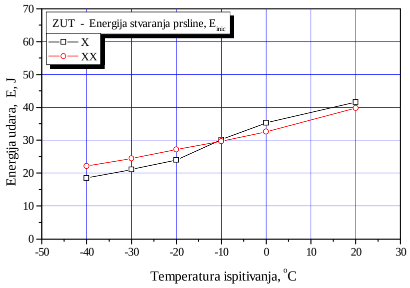
Slika 5.. Odnos energije stvaranja prsline, $E_{inic.}$, energije širenja prsline, E_{lom}, u ukupnoj energiji udara, $E_{uk.}$ kod osnovnog metala



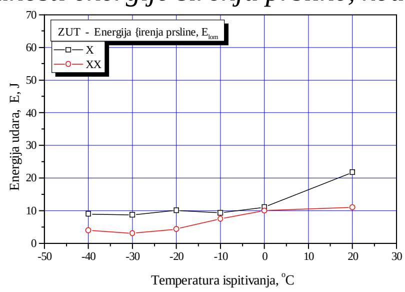
Slika 6. Uticaj količine unešene toplote na vrijednosti energije stvaranja prsline, kod MŠ



Slika 7. Uticaj količine unešene toplote na vrijednosti energije širenja prsline, kod MŠ



Slika 8. Uticaj količine unešene toplote na vrijednosti energije stvaranja prsline kod ZUT



Slika 9. Uticaj količine unešene toplote na vrijednosti energije širenja prsline kod ZUT

Odnos energije stvaranja prsline $E_{inic.}$, i energije širenja prsline E_{lom}, u ukupnoj energiji udara se mijenja u zavisnosti od temperature ispitivanja. Na sobnoj temperaturi je odnos približno 55%-45% u korist energije stvaranja prsline, a na -40°C taj odnos se povećava i približno iznosi 80%-20% u korist energije stvaranja prsline..

Uticaj količine unešene toplote na odnos energije stvaranja prsline $E_{inic.}$, i energije širenja prsline E_{lom}, približno je isti za obje količine unešene toplote

2.3. Eksperimentalno određivanje žilavosti loma K_{Ic}

Žilavost loma pri ravnoj deformaciji, epruveta izvađenih iz zavarenih ploča Č.4730 rađena su u cilju određivanja kritičnog faktora intenziteta napona, K_{Ic}. Za ispitivanje su korišćene epruvete za savijanje u tri tačke (SEB) čija geometrija je definisana standardom ASTM E399.

Samo ispitivanje je rađeno na sobnoj temperaturi na elektromehaničkoj kidalici SCHENCK TREBEL RM 400. Otvaranje vrha prsline (COD) je registrovano pomoću specijalnog ekstenzomjera "KLIP-GAGE" DD1, čija je tačnost mjerenja ±0,001 mm.

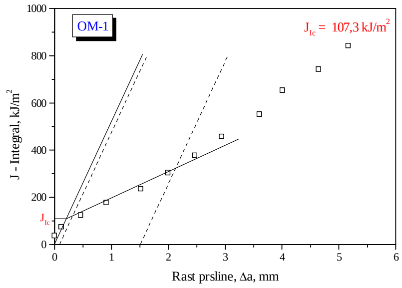
Rađene su tri grupe epruveta u zavisnosti od mjesta urezivanja zareza. i to: I grupa - epruvete sa zarezom u osnovnom metalu (OM), II grupa - epruvete sa zarezom u metalu zavara (MZ) i III grupa - epruvete sa zarezom u zoni uticaja toplote (ZUT).

Kako zahtjevi za ispunjenje uslova ravnog stanja deformacije:

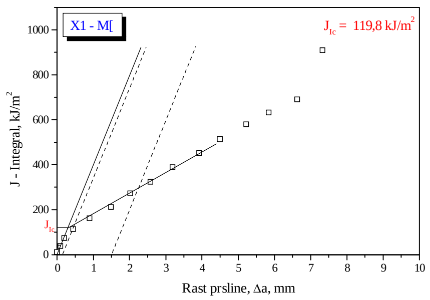
$$B \geq 2{,}5 \cdot \left(\frac{K_{Ic}}{R_{p0,2}} \right)^2 \qquad ..(1)$$

nisu zadovoljeni, umjesto primjene linearno-elastičene mehanike loma definisane standardom ASTM E399, pristupilo se korišćenju elasto-plastične mehanike loma definisane standardom ASTM E813. Cilj korišćenja elasto-plastične mehanike loma je da se vrijednost kritičnog faktora intenziteta napona K_{Ic}, odredi posredno preko kritičnog J integrala J_{Ic}, odnosno da se prati razvoj prsline u uslovima izražene plastičnosti.

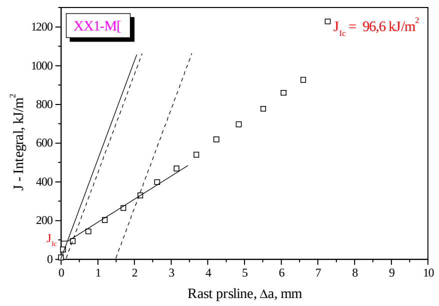
Na osnovu dobijenih dijagrama sila –otvaranje prsline konstruiše se J - Δa kriva na kojoj se konstruiše regresiona linija prema ASTM E813. Iz dobijene regresione linije dobija se kritični J integral, J_{Ic}. Primjer krivih J - Δa dobijen ispitivanjem epruveta sa zarezom u: osnovnom metalu je dat na sl. 10, sa zarezom u MŠ za količinu unešene toplote X sl. 11, i za XX sl.12 i za epruvete sa zarezom u ZUT za količinu unešene toplote X sl.13, i za XX sl.14.



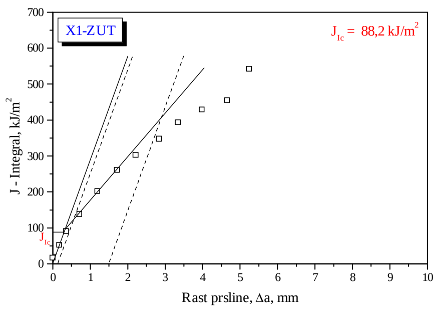
Slika 10. Dijagram J - Δa epruvete OM



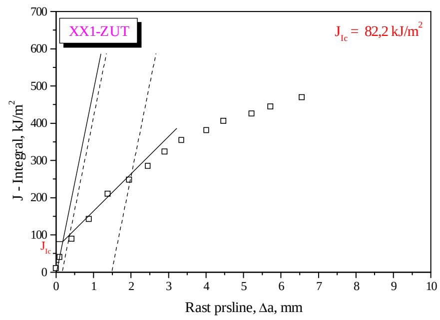
Slika 11. Dijagram J - Δa epruvete X1-MŠ



Slika 12.. Dijagram J - Δa epruvete XX1-MŠ



Slika 13. Dijagram J - Δa epruvete X1-ZUT



Slika 14. Dijagram J - Δa epruvete XX1-ZUT

Poznavajući vrijednosti kritičnog J_{Ic} integrala može se izračunati vrijednost kritičnog faktora intenziteta napona ili žilavost loma pri ravnoj deformaciji K_{Ic}, odnosno primjenom osnovne formule mehanike loma izračunate su približne vrijednosti za kritičnu dužinu prsline a_c ,tab.4.

$$K_{Ic} = \sqrt{\frac{J_{Ic} \cdot E}{1-\nu^2}} \quad , \qquad K_{Ic} = \sigma \cdot \sqrt{\pi \cdot a_c} \qquad \text{...(2)}$$

Tabela 4. Kritični faktor intenziteta napona

Oznaka epruvete	Dužina prsline, a, mm	Kritični J-integral, J_{Ic}, kJ/m^2	Kritični faktor intenziteta napona, K_{Ic}, MPa√m	Kritična dužina prsline, a_c, mm
OM-1	17,03	107,3	148,3	38,7
OM-2	17,20	115,3	153,7	41,6
X1-MŠ	15,40	119,8	156,7	40,4
X2-MŠ	14,70	116,1	154,3	39,2
X1Z-UT	14,80	88,2	134,5	29,8
X2-ZUT	17,20	89,7	135,6	30,2
XX1-MŠ	15,40	96,6	140,7	35,7
XX2-MŠ	16,10	91,1	136,7	33,7
XX1-ZUT	13,10	82,2	129,8	30,4
XX2-ZUT	13,70	81,8	129,5	30,2

Na osnovu dobijenih vrijednosti žilavosti loma pri ravnoj deformaciji K_{Ic} vidimo da najveću izmjerenu vrijednost K_{Ic} imaju epruvete sa zarezom u MŠ, što je mora se priznati neočekivan rezultat. Za očetivati je bilo da najveću vrijednost K_{Ic} ima osnovni metal. Kako je dobijena vrijednost K_{Ic} za osnovni metal na nivou literaturnih vrijednosti za ovu grupu čelika (misli se na niskolegirane Cr-Mo čelike), objašnjenje za više vrijednosti K_{Ic} kod metala šava se može tražiti u mikrostrukturnom i mikromehaničkom aspektu..

Količina unešene toplote u postupku zavarivanja utiče tako da epruvete sa zarezom u komponentama zavarenog spoja sa količinom unešene toplote X imaju bolje osobine žilavosti od epruveta sa količinom unešene toplote XX. To znači da I (X) grupa epruveta ima bolju otpornost na rast prsline od II (XX) grupe epruveta.

3. ZAKLJUČAK

Rezultati ispitivanja i analiza rezultata su pokazali da:

- Najznačajniji uticaj na vrijednosti ukupne energije udara, $E_{uk.}$, ima mjesto gdje je postavljen V-zarez. To znači da heterogenost strukture zavarenog spoja, koju prate različite mehaničke osobine pojedinih područja zavarenog spoja (OM, MŠ, ZUT) ima presudan uticaj na udarna svojstva, odnosno vrijednosti ukupne energije udara

- Kod određivanja vrijednosti žilavosti loma pri ravnoj deformaciji, K_{Ic}, odlučujući uticaj ima mjesto postavljanja zareza, odnosno heterogenost strukuture. Najbolju otpornast prema širenju prsline, odnosno najbolju žilavost loma imaju uzorci sa zarezom u metalu šava, što je bilo i za očekivati, obzirom na svukupno najbolje osobine metala šava.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

NACRTNA GEOMETRIJA U FUNKCIJI RAZVIJANJA INTELEKTUALNIH SPOSOBNOSTI STUDENATA TEHNIKE ZA PROSTORNU PERCEPCIJU

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SAŽETAK

Ovaj rad predstavlja zauzimanje za nacrtnu geometriju i potvrđivanje njenih izvornih vrijednosti, a u kontekstu njene primjene u funkciji razvijanja intelektualnih sposobnosti studenata tehnike za prostornu percepciju. Cilj je pojasniti ulogu i mjesto nacrtne geometrije, a u vremenu pojave novih računarom podržanih tehnologija i softverskih rješenja iz područja računarske grafike i računarom podržanog inženjerskog dizajna, čija primjena se nameće kao neophodna u modernom obrazovanju studenata tehnike.

Radom se želi pokazati i na koji način nacrtna geometrija, svojim izvornim potencijalima i u sinergiji s spomenutim novim računarom podržanim tehnologijama treba da omogući razvijanje intelektualnih sposobnosti studenata tehnike za prostornu percepciju.

Ključne riječi: nacrtna geometrija, prostorna percepcija

1. UVOD

Nacrtna geometrija predstavlja metodu za proučavanje trodimenzionalnih (3D) objekata prevođenjem u dvodimenzionalne (2D) projekcije (ortogonalne projekcije), pri čemu se nudi uvid u geometrijsku strukturu i metrička svojstva prostornih objekata. Ako je crtanje/modeliranje jezik inženjerskog dizajna, onda nacrtna geometrija predstavlja "gramatiku" tog jezika. Značaj nacrtne geometrije u savremenom studiju tehnike ogleda se prije svega u razvijanju intelektualnih sposobnosti studenata za prostornu percepciju, odnosno sposobnosti shvaćanja prostornih oblika iz glavnih pogleda na iste. Ujedno, studenti dobivaju uvid u bazu osnovnih geometrijskih oblika i tehnika, koje im predstavljaju osnovu za osvajanje potrebne logike razmišljanja za kreiranje složenih geometrijskih formi.
Savremeni CAD programi samo potvrđuje značaj nacrtne geometrije i potrebu poznavanja raznolikosti raspoloživih geometrijskih objekata i mogućnosti njihove upotrebe. Crteži nas vode kroz geometriju, ali nisu njen glavni cilj [1].

Nacrtna geometrija ima svoj od ranije priznat značaj za tehniku, ali ima i nove zadatke u savremenom obrazovanju inženjera. Ona je, uz osnove informatike, sastavni dio pripreme za računarom podržano modeliranje i konstruiranje - CAD. U radu su prikazani neki novi aspekti nastave iz nacrtne geometrije, uz primjenu računara, kao i prednosti njihove zajedničke primjene za razvoj sposobnosti studenata tehnike za vizualizaciju i prostornu percepciju.

2. DEFINICIJA, ULOGA I PRIMJENA NACRTNE GEOMETRIJE

Gaspard Monge (1746-1818.) smatra se osnivačem i utemeljiteljem znanstvene nacrtne geometrije, a svoju prvu *Nacrtnu geometriju* (*Geometrie descriptive*) objavio je 1789. godine. U istoj se nalazi postupak ortogonalnog projiciranja i opći metodi za rješavanje stereometrijskih zadataka konstruktivnim postupcima.

U [2] su dati slijedeći uvodni iskazi:

"Nacrtna geometrija ima dva cilja:

- prvo, ona treba dati metode po kojima se na crtaćem papiru, koji ima samo dvije dimenzije, duljinu i širinu, mogu prikazati sve prostorne tvorevine, koje imaju tri dimenzije, duljinu, širinu i visinu, a uz pretpostavku da se te tvorevine mogu točno definirati;
- drugo, ona treba dati postupak, po kojem se iz točnog crteža neke prostorne tvorevine može upoznati njezin oblik, te mogu izvesti svi zakoni koji izlaze iz oblika i međusobnog položaja njezinih dijelova.″

Data definicija pokazuje da zadatak nacrtne geometrije, da omogući da inženjer dizajner/ konstruktor svoje zamisli prikaže, analizira i predstavi u konačnoj jasnoj i preciznoj formi, potiče još od njenog osnivanja. Pojavom računara i CAD sistema, uloga nacrtne geometrije nije nimalo umanjena, niti je ista izgubila na značaju. Naprotiv, neophodno je poznavanje osnovnih zakonitosti kojima nas uči nacrtna geometrija, da bi bili sposobni nacrtati bilo kakav predmet, ili dio uz primjenu savremenih CAD softvera. Dobro poznavanje nacrtne geometrije omogućava kombinaciju složenih geometrijskih oblika i dobivanje novih interesantnijih, kompleksnijih i savremenih dizajnerskih rješenja.

Neke od definicija koje označavaju suštinu primjene nacrtne geometrije date su u nastavku:

- J. KRAMES dao je u [3] (u slobodnom prijevodu) slijedeću definiciju: "*Nacrtna geometrija* je visoko umijeće promišljanja prostora i njegovoga grafičkog predočavanja.";
- H. BRAUNER je dao prednost nazivu *Konstruktivna geometrija*, umjesto *Nacrtna geometrija*. U [4] je dao slijedeću definiciju: "*Konstruktivna geometrija* analizira 3D objekte sredstvima grafičkih ili matematičkih metoda primijenjenih na 2D slike.";
- F. HOHENBERG je u svom udžbeniku [5] usmjeren na primjenu nacrtne geometrije u tehnologiji: "*Konstruktivna geometrija* uči kako razumjeti, zamišljati, odrediti i crtati geometrijske oblike.";
- W.-D. KLIX u [6] daje prošireno objašnjenje značenja nacrtne geometrije: *"Nacrtna geometrija* je jedinstvena u unapređivanju prostornog razmišljanja, temeljnog za svaku stvaralačku inženjersku aktivnost, i vježbanju sposobnosti grafičkog izražavanja prostornih ideja kako bi bile svakome razumljive."

Cilj izučavanja nacrtne geometrije je da kod polaznika-studenata razvije sposobnost logičkog razmišljanja, vizualnog sagledavanja trodimenzionalnog prostora i sposobnost zamišljanja (imaginacije). Izučavanjem nacrtne geometrije, usvajaju se pravila kojima se omogućava primjena konstruktivno-geometrijskih postupaka za izvođenje i predstavljanje (prikazivanje) trodimenzionalnog prostora, tj. prostornih trodimenzionalnih geometrijskih formi i njihovih međusobnih odnosa, na dvodimenzionalnoj ravni–crtežu.

Prije svega, nacrtna geometrija treba da razvije slijedeće sposobnosti:

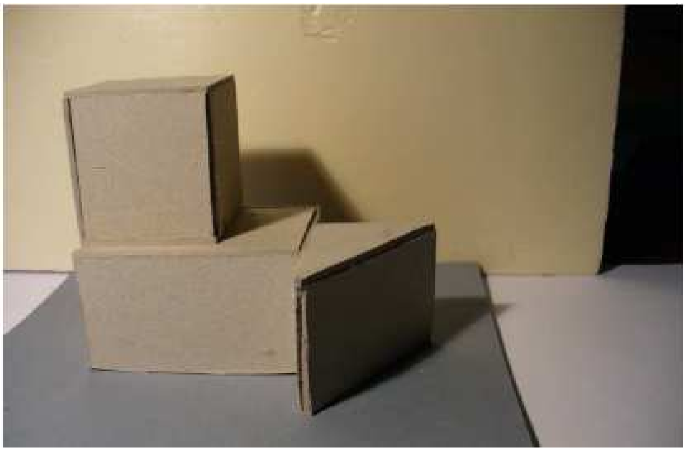
- shvaćanje i crtanje prostornih predmeta (objekata) iz datih osnovnih ortogonalnih projekcija (osnovnih pogleda) i
- obrnuto, projiciranje trodimenziono predstavljenih objekata za dobivanje glavnih ortogonalnih projekcija u dvije ravni.

Ovdje se vidi međusobna interakcija i povezanost između razvoja intelektualnih sposobnosti i razumijevanja predstavljanja predmeta od geometrijske idealizacije (apstrakcije), preko upotrebe različitih geometrijskih oblika, pa sve do krajnjeg cilja - potpuno tehnički definiranog predmeta. Rješavanje zadataka u nacrtnoj geometriji se izvodi grafičkim konstruiranjem – crtanjem, koje zbog toga mora da bude tačno i precizno.

Crtež uvijek treba da bude jednostavan, pregledan i jasan, s dovoljnim brojem pogleda i presjeka, da bi na njemu mogao da se "pročita" i sagleda prikazani objekt.

Način crtanja u nacrtnoj geometriji može biti: slobodnom rukom, priborom za crtanje na listu papira na klasičan način i uz primjenu računara.

Svaka od ovih metoda ima svoje dobre strane, ali najbolji efekti se postižu kombinacijom sve tri od njih. Izradu modela od hartije (slika 1), ili nekog drugog adekvatnog materijala, kako bi se kod studenata dodatno poboljšalo razumijevanje i razvijala prostorna percepcija, danas su uspješno zamijenile druge metode koje se baziraju na primjeni odgovarajućih softvera i računara.

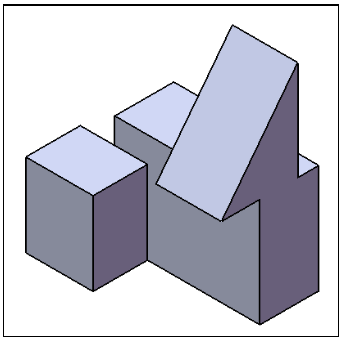


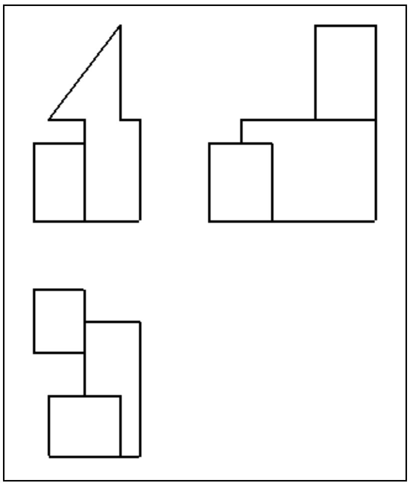
Slika 1. Model izrađen od hartije[7]

Najveći nedostatak izlaganja nacrtne geometrije na klasičan način je postojanje jedino mogućnosti da se trodimenzionalni geometrijski prostor konstruktivno obrađuje i prikazuje u različitim projekcijama samo na dvodimenzionalnoj ravni crteža.

Izlaganje nacrtne geometrije uz primjenu odgovarajućeg softvera, svakako je lakša, efektnija i efektivnija varijanta kada je u pitanju razvijanje intelektualnih sposobnosti studenata tehnike za prostornu percepciju i vizualizaciju.

Primjena pomenutih softvera i računara omogućila je vizualnu manipulaciju 3D modela trodimenzionalnih objekata, uvođenje različitih pogleda i presjeka i u praktičnoj primjeni predstavlja provjeru definisanih elemenata modela do kojih se došlo primjenom pravila nacrtne geometrije. Primjer primjene takvog softvera dat je na slici 2.





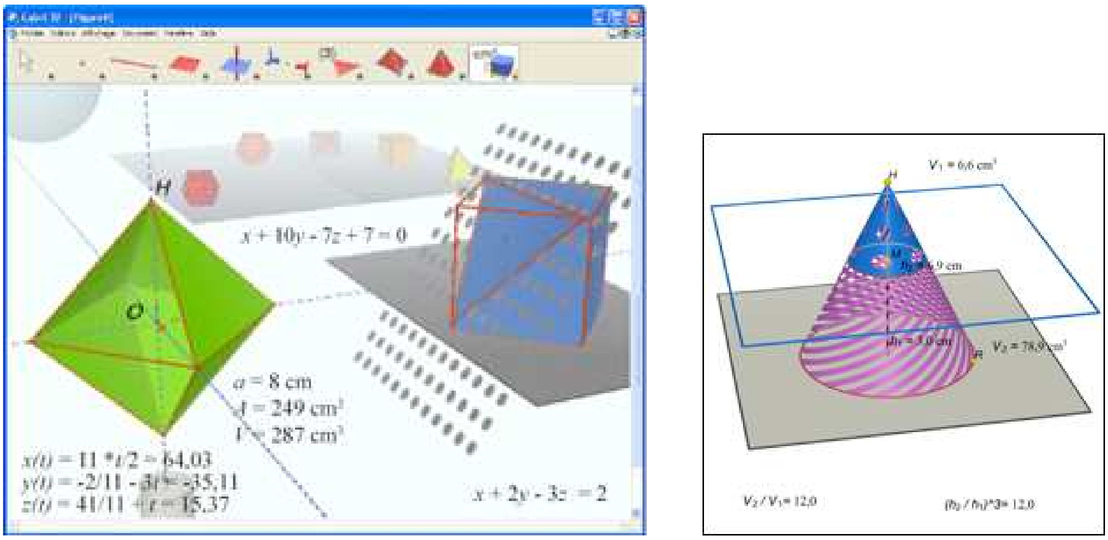
a) b)

Slika 2. Izrada modela uz primjenu odgovarajućeg softvera i računara
a) 3D model, b) 2D projekcije

Kod izlaganja nacrtne geometrije uz podršku računara, idealno je ako se ima ogovarajuća aplikacija za **interaktivan rad** studenata, kao što je na primjer softver *Cabri 3D.* Cabri tehnologija je rezultat istraživačkih laboratorija francuskog *Centre National de la Recherche (CNRS)* i univerziteta *Joseph Forier* u Grenoblu.

Korištenje interaktivne aplikacije, poput pomenutog softvera *Cabri 3D*, za kreiranje geometrijskih figura i objekata, otvaraju se nove mogućnosti u odnosu na klasične metode, pa i metodu predstavljenu kroz primjer dat na slici 2.

To se prije svega odnosi na brzu manipulaciju raspoloživim objektima u tri dimenzije (linije, poliedri, ravnine, konusi, sfere, ...), kod kreiranja novih trodimenzionalnih objekata i realizovanja različitih pratećih matematičkih izračunavanja. Moguće je i ponavljanje procesa kreiranja nekog objekta, uz promjenu ulaznih podataka (slika 3). Kod ove aplikacije, osim brojnih mogućnosti, kao što je na primjer projekcija tačke iz prostora na ravnine projiciranja, ili prikaz geometrijskih tijela i presjeka ravninom u različitim položajima, značajna je i mogućnost razvijanja mreže geometrijskih tijela (slika 4).



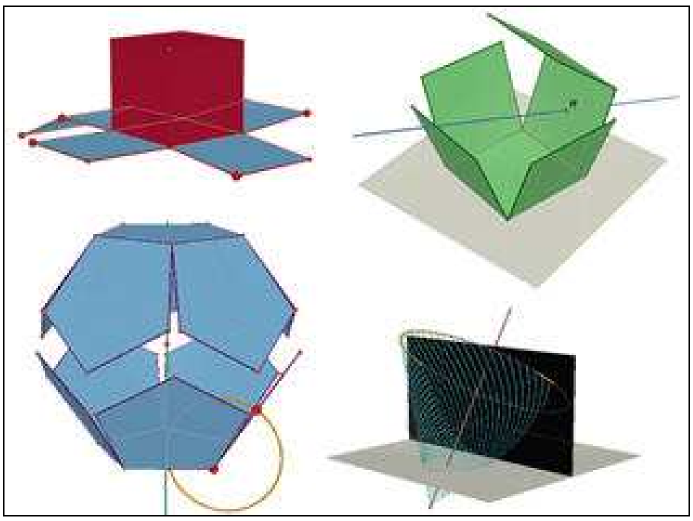
a) b)

Slika 3. Primjeri primjene aplikacije Cabri 3D za prikaz geometrijskih tijela i odgovarajuća matematička izračunavanja

a) geometrijske i matematičke operacije s prizmatičnim tijelima,

b) operacije s kupastim tijelom

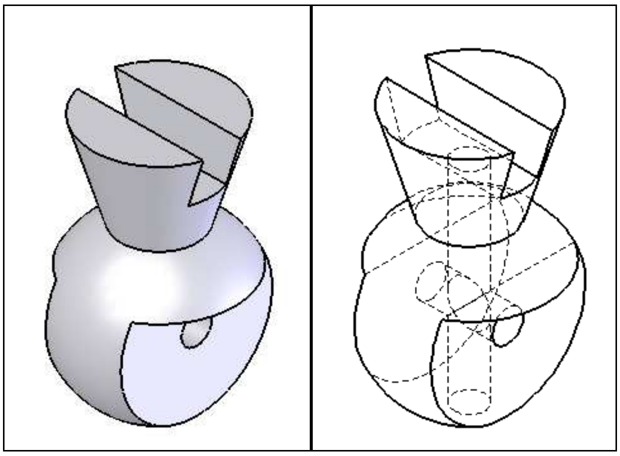
Ovakvom aplikacijom se praktično reafirmiraju osnovne vrijednosti nacrtne geometrije, a njena primjena se na najbolji način uklapa u savremene tokove edukacije iz ovog područja uz podršku računara.



Slika 4. Mogućnosti različitih načina prikaza geometrijskih tijela u softveru Cabri 3D

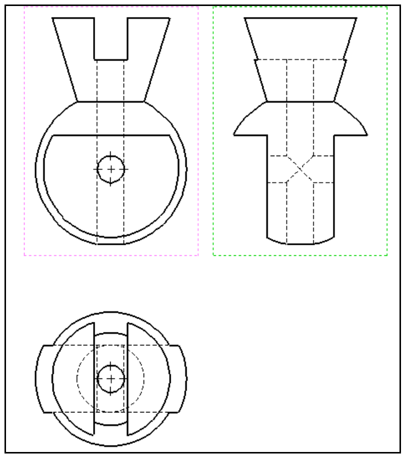
Prema saznanjima autora rada, u Bosni i Hercegovini nije razvijana aplikacija tipa softvera *Cabri 3D*. Ovaj nedostatak se često prevazilazio tako da se funkcija aplikacije tipa *Cabri 3D* nadomještala primjenom nekog od odgovarajućih CAD softvera (SolidWorks, NX, Catia, ...).

Koristeći se nekim od ovih CAD softvera, koji su prevashodno namijenjeni za 3D modeliranje (koje je u ovoj fazi edukacije studenata još uvijek nepotrebno), studenti iz baze gotovih 3D modela mogu u aplikaciju "uvlačiti" izabrane modele, okretati iste u prostoru, pomjerati ih, zumirati (slika 5), izraditi glavne projekcije (slika 6) i tako na zoran način intenzivno razvijati svoje sposobnosti za prostornu percepciju i vizualizaciju. U ovoj fazi se projekcije izrađuju bez dimenzionisanja i unošenja elemenata u vezi s izradom tehničke dokumentacije. Važno je naglasiti da je kod ovakvog rada stalno prisutna negativna praksa da studenti koji su donijeli određeno predznanje iz 3D modeliranja, zbog vlastitog isticanja skreću izlaganja s pravog toka i usmjere neke od kolega studenata na probanje mogućnosti 3D modelera koje nisu predmet izlaganja. Često i univerzitetski nastavnici, kod izlaganja materije na ovakav način, zapadaju u zamku i studentima pokazuju kako se tehnička dokumentacija može automatski izraditi u CAD softverima na bazi ranije kreiranog 3D modela. Ovakva praksa ne daje dobre rezultate, jer studenti odmah postavljaju pitanje zbog čega moraju da se muče učeći o izradi 2D tehničke dokumentacije, kada se ista može dobiti automatski. Tada je iste teško uvjeriti da je, pored sticanja sposobnosti za vizualizaciju i prostornu percepciju, u okviru ovog predmeta potrebno izložiti i obimnu materiju u vezi s pravilima i standardima za izradu tehničke dokumentacije.



a) b)

Slika 5. 3D model učitan u CAD program iz baze gotovih modela, a) solid prikaz, b) wireframe prikaz



Slika 6. Prikaz glavnih pogleda u CAD programu

3. ULOGA I MJESTO NACRTNE GEOMETRIJE I SRODNIH PREDMETA U EDUKACIJI STUDENATA TEHNIKE U BOSNI I HERCEGOVINI

Uz nacrtnu geometriju i tehničko crtanje, u okviru svih mogućnosti za edukaciju studenata tehnike iz ovog područja, nametnula su se i slijedeća sredstva:

- računari,
- razvojna programska okruženja za kreiranje odgovarajućih aplikacija za razvijanje sposobnosti studenata tehnike za prostornu percepciju i vizualizaciju, ili gotove aplikacije ovog tipa, te
- CAD softveri.

Studentima prvih godina kod većine tehničkih fakulteta u Bosni i Hercegovini u okviru predmeta *Računarstvo i informatika* (ili sličnog naziva) daju se osnovna teoretska znanja iz računarstva i informatike, te praktična znanja u primjeni programskih aplikacija opće namjene (kao što su na primjer aplikacije paketa *Microsoft Office*, aplikacija *Mathematica* i slično). Za očekivati je da će narednih godina nivo znanja polaznika tehničkih fakulteta u Bosni Hercegovini iz računarstva i informatike biti viši, te da će otpasti potreba za sticanjem osnovnih praktičnih znanja, kao što su na primjer osnovne računarske vještine za primjenu paketa *Microsoft Office*. Jedna od mogućnosti za ovo buduće vrijeme je da će se studentima jedno vrijeme pružati mogućnost za fakultativno sticanje ovih praktičnih znanja, paralelno s izvođenjem redovne nastave prvog semestra. U okviru predmeta *Računarstvo i informatika* tada će se sticati znanja višeg nivoa iz ovog područja (na primjer, napredno korištenje programa *Microsoft Office Excel)*, sve dok za to bude postojala potreba, odnosno sve dok srednje škole na ovim prostorima ne budu preuzele ulogu adekvatne edukacije iz ovog područja.U okviru predmeta pod najčešćim nazivom *Nacrtna geometrija i tehnička dokumentacija*, *Tehnička* *dokumentacija*, ili *Računarska i inženjerska grafika*, koji se obično sluša u prvom semestru, studenti treba da steknu znanja i vještine koji obuhvaćaju:

- sposobnosti zamišljanja i prostornog predočavanja trodimenzionalnih geometrijskih objekata na temelju ravninskih crteža,
- osnovne geometrijske metode i njihovu primjenu u tehnici,
- osnovne principe i zakonitosti potrebne za pripremanje i razumijevanje tehničke dokumentacije.

Ranije je već pomenuto da se na tehničkim fakultetima u Bosni i Hercegovini funkcija aplikacije tipa *Cabri 3D* često nadomještala primjenom nekog od odgovarajućih CAD softvera (SolidWorks, NX, Catia, ...). Ovdje se ističe da je u ovom slučaju važno da studenti u fazi sticanja sposobnosti za prostornu percepciju ne treba da se bave 3D modeliranjem, nego da se koriste isključivo ranije već pripremljenim odgovarajućim 3D modelima, na način kako je to prethodno već objašnjeno. Pri tome se svakako treba izbjeći pokazivanje automatske izrade tehničke dokumentacije, na bazi pomenutih gotovih 3D modela. U okviru predmeta *Računarstvo i informatika* može se organizovati i sticanje praktičnih znanja iz 2D grafike i izrade tehničke dokumentacije u 2D modeleru, tako da studenti praktično utvrđuju i sami primjenjuju teoretska znanja predmeta *Nacrtna geometrija i tehnička dokumentacija* u okviru izrade odgovarajuće tehničke dokumentacije. Ovim se praktično utvrđuju i znanja iz primjene odgovarajućih međunarodnih standarda za izradu pomenute tehničke dokumentacije.

Preporuka autora rada je da nakon znanja stečenih u okviru predmeta *Nacrtna geometrija i tehnička dokumentacija i Računarstvo i informatika* slijedi edukacija u okviru predmeta koji se najčešće zove *Inženjersko računarsko modeliranje, Modeliranje prostora, ili Oblikovanje pomoću računara*, a koji bi trebalo da se sluša u drugom ili trećem semestru. Procjena je da je u ovom trenutku, iz praktičnih razloga (nedostatak računarske opreme i nemogućnost pravovremenog zanavljanja iste na tehničkim fakultetima u Bosni i Hercegovini) pogodnije da se ovaj predmet sluša u trećem semestru. U okviru ovog predmeta studenti treba da steknu osnovna znanja iz 3D modeliranja pojedinačnih dijelova i sklopova uz primjenu odgovarajućih CAD softvera, te izrade tehničke dokumentacije na bazi kreiranih 3D modela. Ova znanja se dalje mogu dopunjavati na trećoj i četvrtoj godini tehničkih fakulteta, a u okviru predmeta koji se baziraju na primjeni CAD, CAE, CAM, pa i PDM/PLM tehnologija.

4. ZAKLJUČAK

U radu je ukazano na značaj, mjesto i ulogu nacrtne geometrije u edukaciji na tehničkim fakultetima, a u funkciji razvijanja intelektualnih sposobnosti studenata za prostornu percepciju i vizualizaciju. Pokazano je da adekvatna edukacija iz nacrtne geometrije, uz primjenu ogovarajućih interaktivnih aplikacija i računara, predstavlja osnovu za dalju edukaciju budućih inženjera koji su u svom radu oslonjeni na intenzivno korištenje 3D modelera, odnosno CAD/CAE i CAM tehnologija.

S dobrim predznanjem iz nacrtne geometrije, značajno se povećava stepen i nivo korištenja odgovarajućih CAD, pa i CAE i CAM softvera. Zbog toga, pravilno definisanje sadržaja i metodike izlaganja kod predmeta *Nacrtna geometrija i tehnička dokumentacija* predstavlja značajan izazov na tehničkim fakultetima.

U radu su izložena i određena iskustva, te su dati i prijedlozi u vezi s ulogom i mjestom nacrtne geometrije i srodnih predmeta u edukaciji studenata tehnike u Bosni i Hercegovini

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1st International Research/Expert Conference
”Manufacturing and Advanced Technologies”
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

RELAKSACIJA ZAOSTALIH ZAVARIVAČKIH NAPONA NA PRIMJERU GLAVNIH NOSAČA MOSTOVSKOG KRANA

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SAŽETAK

U ovom radu prikazana je vibrorelaksacija zaostalih zavarivačkih napona nastalih u toku izrade livačkog krana za potrebe „BH STEEL“ Zenica, na glavnim nosačima raspona 34 m i nosivosti 200 kN. Vibrorelaksacija zaostalih napona izvršena je na sučeono zavarenim spojevima. Modeliranje i simulacija vibrorelaksacije izvršena je na računaru a zatim su u realizaciji praćeni sa adekvatnom mjernom opremom, paralelno sa rezultatima kontinuirane relaksacije napona. Primjenjena metoda pokazala se vrlo uspješnom u praksi za realizaciju prelaksacije krupnogabaritnih i teških konstrukcija. Primjenjena metoda relaksacije je veoma efikasna u tehničkom i ekonomskom smislu u eliminaciji zaostalih zavarivačkih napona na krupnogabaritnim konstrukcijama.

Ključne riječi: zavarena konstrukcija, zaostali naponi, relaksacija, vibriranje

1. UVOD

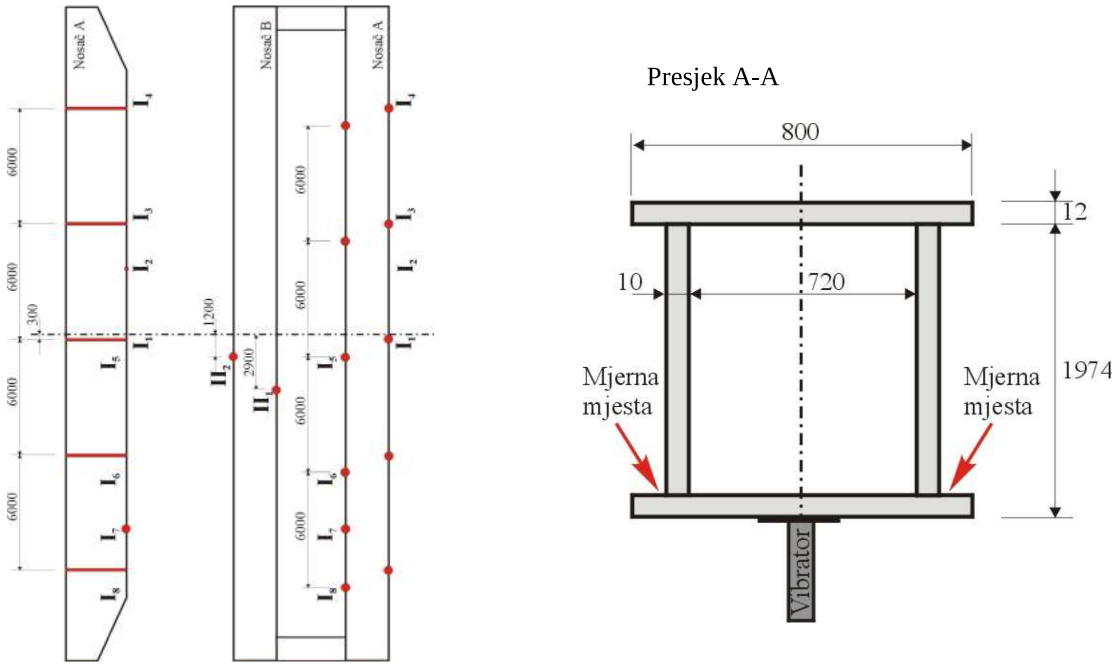
Tehnika zavarivanja je dominantna u tehnologiji izrade metalnih konstrukcija raznih namjena, pa se utjecaj zaostalih napona mora konstruktivno ili tehnološki definirati u kreiranju optimalnih konstrukcija. Obzirom na poznati nivo i predznak napona za homologovanu tehnologiju zavarivanja, konstruktor ih može ukomponovati uz radna naponska stanja pod uslovom da su ispravno detektovana i imaju nisku vrijednost ili ih pak isključiti iz proračuna ako ih u tehnološkom postupku izrade konstrukcije tehnolog uz adekvatan tehnološki postupak eleminiše. Klasični postupak neutralizacije zaostalih zavarivačkih napona termičkom obradom, na složenim krupnogabaritnim kontrukcijama, rapidno povečava cijenu konstrukcije što joj umanjuje konkuretnost na tržištu. Alternativa ovom postupku je eliminacija zaostalih napona vibrorelaksacijom, koja se pokazala primjenljiva kod krupnogabaritnih konstrukcija.

Ovaj rad ima za cilj da prikaže mogučnost primjene ove metode na veoma složenim konstrukcijama gdje je cijeli proces efikasan sa stanovišta kvaliteta eliminacije zaostalih napona, ali i niske cijene obrade konstrukcije.

U realizaciji izrade livačkog krana za potrebe „BH STEEL“ Zenica, na glavnim nosačima raspona 34 m i nosivosti 200 kN izvršena je relaksacija zaostalih napona na sučeono zavarenim spojevima. Uz prethodno modeliranje i simulaciju na računaru definisani su parametri relaksacije a zatim su u realizaciji praćeni sa adekvatnom opremom, kao i rezultati kontinuirane relaksacije napona. Primjenjena metoda pokazala se vrlo uspješnom metodom relaksacije na konkretnom primjeru mostovskog krana, kako u tehničkom tako i u ekonomskom smislu u eliminaciji zaostalih zavarivačkih napona na krupnogabaritnim konstrukcijama.

2. TEHNIČKI OPIS KONSTRUKCIJE

Glavni nosači krana realizovani su u formi kutijaste-punostjene izvedbe konstantnog presjeka u području sučeonih zavara (Slika 1.).



Slika 1. Glavni nosači konstrukcije krana.

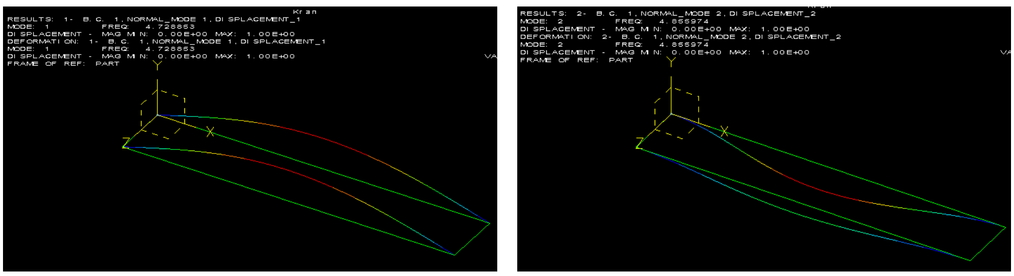
Materijal konstrukcije realizovan je od limova ≠12 i ≠10 mm čelika Č.0453 sa R_m = 420 ÷ 500 MPa, $R_{0.2}$ = 275 MPa i σ_{dop} = 183 MPa. Proračunski maksimalni napon u kritičnom prsjeku za realne uslove opterećenja je σ = 97.5 MPa. Projektovanje i izvođenje konstrukcije izvedeno je sukladno standardu JUS.MD1. … i Tehničkim propisima za zavarene čelične konstrukcije Sl. list SFRJ 41/64.

Ojačanja noseće hrbata sa "L" profilima 90×90×6 mm sa unutrašnje strane kutije omogućilo je elastičnost konstrukcije protiv izbočavanja za ovakve tipove konstrukcija. U fazi izvođenja, kontrolu zavarenih spojeva izvršio je Institut "Kemal Kapetanović" iz Zenice, i to RTG metodom, gdje je utvrđen je zadovoljavajući kvalitet zavarenih spojeva. Geodetski snimak konstrukcije uradila je interna kontrola BH Steel - Željezara Zenica. Geodetskim snimkom je utvrđeno da su deformacije nosača "A" i "B" izišle iz projektovanih vrijednosti, najvjerovatnije usljed deformacionih procesa u toku zavarivanja elemenata konstrukcije za ukrućenje hrbata ("L" profila). Nešto izraženije vrijednosti uočenih deformacija prisutne su na nosaču "B" glavnih nosača krana (30 mm).

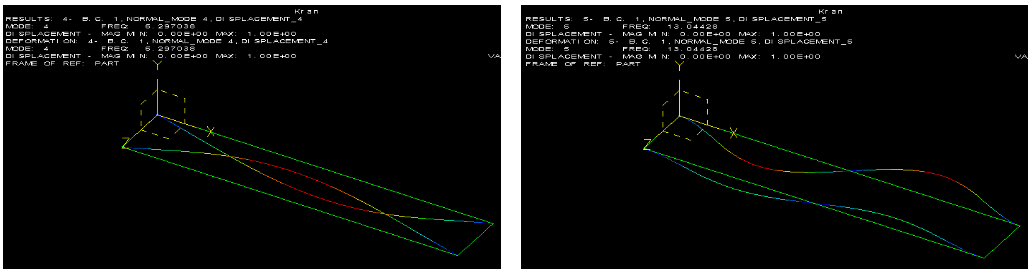
Zbog narušene geometrije nosača krana i mogućnosti uvećanja realnih napona u konstrukciji pristupilo se eliminaciji zaostalih zavarivačkih napona, koje konstruktor nije predvidio u dizajniranju.

3. TEHNOLOGIJA RELAKSACIJE

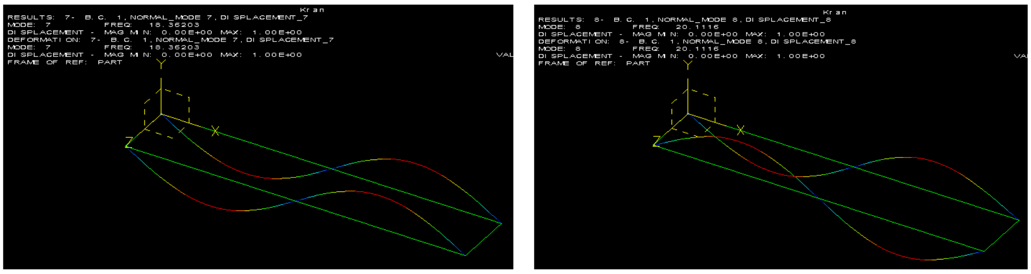
Na osnovu geometrije konstrukcije pristupilo se iznalaženju sopstvenih frekvencija oscilovanja, kako u fazi rada ne bi došla u rezonantno područje. Simulacija je urađena u programu IDEAS 11, a sopstveni oblici oscilovanja i sopstvene frekvencije prikazani su na slikama 2 – 4.



Slika 2. Prvi i drugi sopstveni oblik oscilovanja, f_1 = 4.72 Hz, f_2 = 4.86 Hz.



Slika 3. Treći i četvrti sopstveni oblik oscilovanja, f_3 = 6.30 Hz, f_4 = 13.04 Hz.

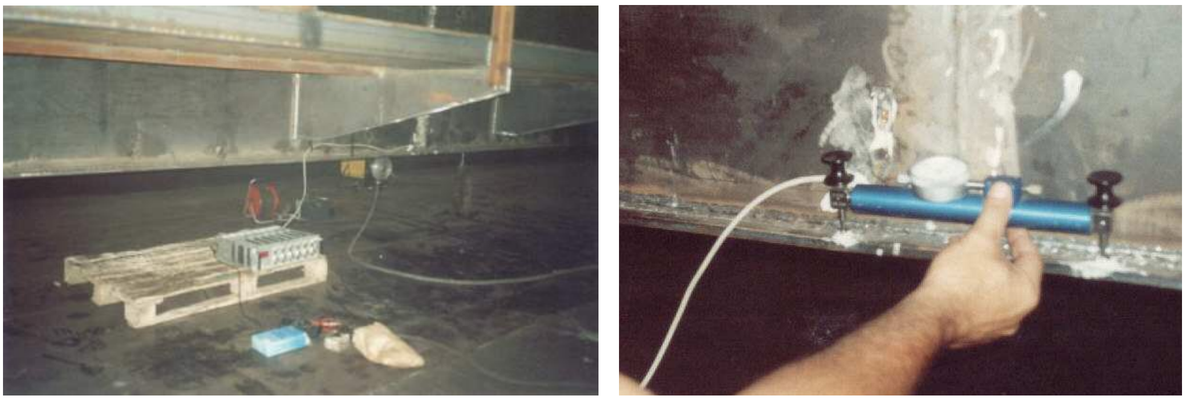


Slika 4. Peti i šesti sopstveni oblik oscilovanja, f_5 = 18.36 Hz, f_6 = 20.11 Hz.

Usvojena je radna frekvencija vibratora f = 350 Hz, te amplituda prinudne sile od 200 daN. Na ovaj način se stekao uslov za potrebnu amplitudu oscilovanja od 0.3 ÷ 0.7 mm u području zavara koji se relaksira. Cilj relaksacije bili su sučeoni zavari na hrbatu i lamelama koji su u području velikih naponskih stanja u toku rada (zavari I1, I2, I3, I4, I5, I6, I7, I8, II1 i II2).

Lokacija vibratora postavljena je u osu kutijastog nosača na donjoj lameli kako bi istovremeno djelovao na oba sučeona spoja na hrbatima i sučeonom spoju na lameli. Zavari u gornjem dijelu nosača (lameli) nisu relaksirani jer je predznak zaostalih napona (+) što umanjuje vrijednost radnih napona na tom djelu konstrukcije (-).

Proces relaksacije (lokacije vibratora, radni parametri, frekvencija , amplituda i vrijeme relaksacije), detaljno su praćeni na nosaču ‘’A’’ kroz parcijalno vrijeme rada i kontrole puštanja zaostalih napona. Kontrola opuštanja realizirana je sa dvije metode, i to ‘’deformetrom’’ osjetljivosti ± 1MPa na svim sučeonim spojevima, te elektrootpornom tenzometrijom sa mjernim mostom ‘’Hottinger KWS 7230’’ na području zavara I1 u cilju kontrole niovoa oscilatornih naponskih stanja. Nivo amplitude oscilovanja definisan je komparatorom osjetljivosti ±0.01 mm na području lokacije vibratora. Na nosaču ‘’B’’ relaksacija je vršena istim redoslijedom kao na nosaču ‘’A’’ u kontinuitetu u potrebnom vremenskom intervalu. Razlike temperatura konstrukcije u toku procesa mjerenja i njihov uticaj na naponska stanja eliminisani su uz primjenu kompenzacione mjerne trake za sistem kontrole elektrootpornom tenzometrijom i kontrolnim štapom od invara za sistem mehaničkog deformetra. Na slikama je prikazan položaj vibratora i instrumentacija u toku relaksacije.

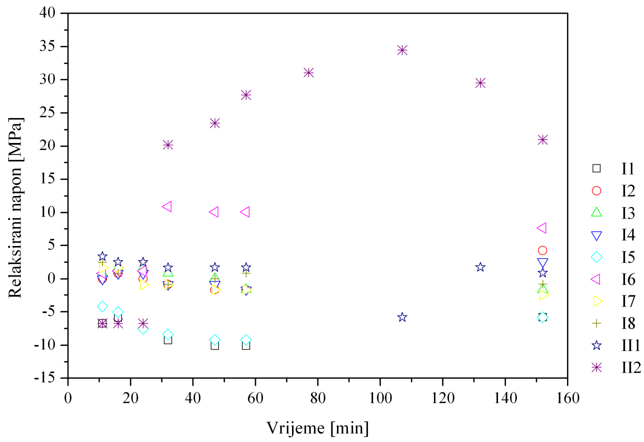


Slika 5. Oprema za mjerenje deformacija u toku vibrorelaksacije.

Slika 6. Položaj vibratora na donjoj lameli. Mjerenje amplitude komparatorom.

4. ANALIZA REZULTATA VIBRORELAKSACIJE

Na slici 7 prikazano je opuštanje zaostalih napona za sve zavare na konstrukciji glavnih nosača.



Slika 7. Relaksacija napona u zavarima.

Analizom rezultata relaksacije vidljivo je da je izvršena relaksacija napona u svim zavarima između 9 MPa i 18 MPa.

5. ZAKLJUČAK

Primjenjeni postupak relaksacije sa kontrolnim sistemom definisanja vrijednosti opuštanja zaostalih napona osigurao je eliminaciju zavarivačkih napona u strukturi glavnih nosača krana Q = 200/50 kN, L = 34 m.

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1st International Research/Expert Conference
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

THE INFLUENCE OF LUBRICATED WEAR ON CONTACTING SURFACES

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ABSTRACT
Mating surfaces usually work under lubrication. At the same time the effects of surface deviations from the ideal one have not been studied sufficiently well. The paper exemines the contact of endface friction pairs considering their surface roughness.The problem is solved by using Reynolds equation for liquids assuming the liquid film thickness to be a random variable. In the general case the liquid film thickness is described as a random field of two variables x,y and depends on two components: h(x,y)=h0(x,y)+hc(x,y) ,where h0(x,y)- nominal thickness of the film and hc(x,y)- random variation of the film.The Reynolds equation for this case is solved for the following conditions:mating surfaces are acted upon by normal force, surface roughness points have normal distribution of probabilities,the tops of individual surface asperities have the shape of an elliptic paraboloid.
Keywords: load carrying capacity of surface, surface microroughness, wear

1. INTRODUCTION
The calculation procedure of carrying ability of two flat lubricated surfaces contacting at normal loading has been carried out. Within the procedure roughness is presented as the 3D object. This approach makes it possible to solve contacting problem in conditions closer to practical. The given decision is pretty neww in field of mechanical engineering ahd appliances designing. The received result has important value at estimation of contact rigidity on bench adaptations, in measuring devices and contact units of mechanical engineering.
The roughness of surfaces of details of machine parts and devices is major parameter of quality considerably influencing operational properties and reliability and durability of products, as well. Increase of accuracy of forecasting of durability and calculation of operational characteristics of various details lead to need of the most full and adequate account of their roughness. The certain interest in practice has applied to contact mechanisms of flat lubricated surfaces, having place in face pumps, hidraulic shock-absorbers, in units of machine tools etc. Where carrying ability of contact depends on roughness of surface of contacting details. Properties of surfaces are estimated by profile parameters while asperities are spatial three-dimensional (3D) objects and all processes occur on surface as a whole. Precise estimation of such processes is impossible whithout use of microtopographical approach at account and analysis of asperities and roughness of surface.
In the framework of the thesis roughness of contacting surfaces is considered as 3D object and this aspect causes the urgency of the given theme, with reference to wear calculation of flat lubricated surfaces. Discussion opens an idea of the 3D representation of rough surface. Within the idea basic

concepts of casual fields are considered and system of the initial parameters of roughness of surface is formulated. The probability laws of casual surface are investigated. The roughness of surface in microtopographical understanding should be characterized by three coordinates in Cartesian system as following points of surface: altitude *h*, abscise *x*, and ordinate *y* . At studying of irregular roughness methods of the theory of stochastic funtions occured to be effective therefore microtopography analogosly to profile section can be presented by stochastic function like two dimensional (2D) one, i.e. casual field $h(x, y)$ of two variables *x* and *y*. As for stochastic processes in order to determine normal casual field it is necessary to know mathematic expectation and correlation function of field $\rho(\tau_1, \tau_2)$.

System of the initial parameters follows from properties of normal homogeneous casual field. It is cosidered that given field is determined if dispersion of the field and normalized correlation function is known, so problem reduces to search of parameter *Ra* or σ for surface and task of kind $\rho(\tau_1, \tau_2)$- to definition of appropriate step-by-step parameters of roughness. In the given paper correlation function of exponential type is used and for description of surfaces processed by abrasive tools it had been applied [1,2,3] succesfully,as well:

$$\rho(\tau_1, \tau_2)=exp\ (-\alpha_1, \tau_2^2- \alpha_2, \tau_2^2), \qquad ...(1)$$

where α_1, α_2 – factors of correlation function,

τ_1, τ_2 – Cartesian coordinates of vector τ_1 a variable of correlation function.

Relation of parameters of correlation function is defined by parameter of anisotropy *c* :

$$C=\alpha_2/\alpha_1=Sm_1/Sm_2\ , \qquad ..(2)$$

where Sm_1 , Sm_2 – step-by-step parameters of asperities of roughness on directions *x* and *y* , accordingly. It is proven the initial parameters of the 3D rough surface are the following: surface roughness altitude parameter *Ra* or σ , two step-by-step (spacing) parameters between asperities Sm_1 , Sm_2 (Sm_1>Sm_2).

2. DISCUSSION OF MODEL ANALYSIS

A case of contacting of ideal plane and rough surface is considered at presence of liquid lubrication layer (Fig. 1) when normal loading operates and small lateral(non-regular) sliding is possible.

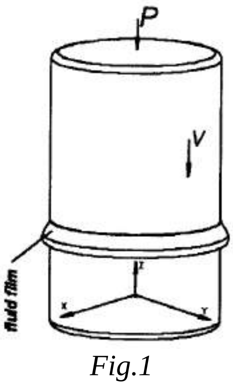

Fig.1

Under influence of normal loading pressing out of liquid environment and deformation of microirregularities of rough surface take place until there will come a balance. Thus, general force loading a surface of detail at balance is:

$$P_\Sigma=P_v+P_d\ , \qquad ...(3)$$

where

P_v – force of resistance to pressing out of liquid environment at approachement of surfaces,

P_d – force of resistance to deformation of microirregularities of rough surface.

Having divided both sides of equation (1) on size of the nominal area A_a , it follows as:

$$q_{\Sigma}=q_v+q_d\ , \qquad ...(4)$$

where

q_{Σ}, q_v ,q_d – pressure components appropriate to forces of equation (3).

At first lets consider the first component of equation (3), i.e. pressure of resistance to pressing out liquid environment at approachement of surfaces q_v. For bring out of analytical dependences of estimation of value q_v lets take advantage of equation of movement of liquid flow (equation Navue-Stocks). By consideration of movement of liquid flow between close located solids some assumptions leading to essential simplification of these equations without any loss of common value is accepted. The following ones regard to number of such assumptions:

1. Thickness of lubricant film between solids (on axis Z) is much less than sizes of the film in two other directions *(x, y)*.
2. Lateral sliding of details can not cause sliding on border of flow and firm surface.
3. Liquid is considered as newtonian to be incompressible.

Using these assumptions the equation of movement of liquid flow can be written down as Reinolds common equation :

$$\frac{\partial}{\partial x}\left(h^3\frac{\rho\partial q}{\mu\partial x}\right)+\frac{\partial}{\partial y}\left(h^3\frac{\rho\partial q}{\mu\partial y}\right)=12\rho V+6\frac{\partial(\rho Uh)}{\partial x}+\frac{\partial(\rho Wh)}{\partial y}+12h\frac{\partial q}{\partial t} \qquad ...(5)$$

where h – thickness of film,
ρ – density of liquid,
μ – dynamic viscosity of liquid,
q – pressure of liquid,
t – time of contacting process,
U,W,V – speeds of liquid flows in direction of axes x, y, z, accordingly (Fig.1).

According to conditions of task (at approachement of solid details on direction of axis Z) U=W=0 the Reinolds equation becomes as

$$\frac{\partial}{\partial x}\left(h^3\frac{\rho\partial q}{\mu\partial x}\right)+\frac{\partial}{\partial y}\left(h^3\frac{\rho\partial q}{\mu\partial y}\right)=-12V, \qquad ...(6)$$

By decision of received equation it should take into account that thickness of liquid film h is casual field of two variables x and y consisting of two sizes :

$$h=h_0(x, y)+h_g(x, y)\ , \qquad ...(7)$$

where h – constant of thickness of liquid film (clearance)
h – stochastic function of thickness of film due to roughness.

This equation cannot be solved by simple analytical approach due to parameter of viscosity μ which also is function of two variables x, y . Alteration of viscosity μ on surface of contact is small enough to assume it to be constant. Getting focused on expression for estimation of value q_v a model of contact assuming above mentioned proximity is considered. Value of parameter q_v can be described as sum of two components:

$$q_v=q_0+q_g\ , \qquad ...(8)$$

where

q_0 – constant pressure of resistance to pressing out lubricant layer due to nominal area of contact surfaces,
q_g – stochastic component of lubricant pressure due to roughness of surface.

3. FORM OF CONTACTING SURFACES

Lets consider *the first component* q_0 of equation (8). As value of q_0 characterizes constant component of pressure q_v it can be found from equation (6) taking into account independence of parameters μ and h of coordinates x, y .

$$\frac{\partial^2 q}{\partial x^2}+\frac{\partial^2 q}{\partial y^2}=-12V\frac{\mu}{h^3}. \qquad ...(9)$$

For convenience of calculation lets solve equation (9) by assumption that contacting surfaces through normal plane have form of elipse whose canonical equation looks like the following:

$$\frac{x^2}{a_0{}^2}+\frac{y^2}{b_0{}^2}=1 \qquad ...(10)$$

where a_0 , b_0 – halfaxis of elipse

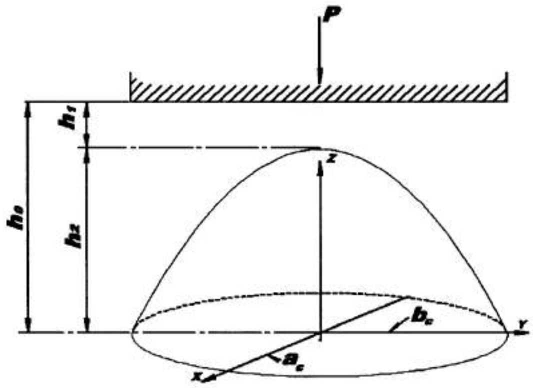

Fig.2

Thus, by reference on above mentioned the following equation of constant pressure of resistance to pressing out lubricant layer due to nominal area of contact can be obtained:

$$q_0=\frac{3\mu a_0{}^2 b_0{}^2}{2t(a_0{}^2+b_0{}^2)}\left(\frac{1}{\overline{\overline{h_2}}^2}-\frac{1}{h_0{}^2}\right), \qquad ...(11)$$

where $\overline{h_2}$ - average value of altitude of heights of irregularities of surface,

h_0 - constant value of thickness of film between average plane of rough surface and ideal plane of contact (Fig.2).

The following equation

$$q_0=\frac{3\mu a_0{}^2}{4t}\left(\frac{1}{\overline{\overline{h_2}}^2}-\frac{1}{h_0{}^2}\right) \qquad ...(12)$$

is true for a case of approachement of round surfaces $a_0=b_0$.

4. ELLIPTIC PARABOLOID ASPERITY.

The second component q_g of equation of pressure (8) was determined through investigation of contact of single asperity of surface and ideal plane. Lets assume surface is described by normal homogeneous casual field of two variables x and y. According to Beinerts [4] for that kind of field form of asperity has close proximity to alliptic paraboloid at high levels (γ≥1,5). The form is illustred on Fig.2. In this case thickness of lubricant film around the asperity is function of two variables :

$$h_g(x,y)=h_1+h_2\left(\frac{x^2}{a_c{}^2}+\frac{y^2}{b_c{}^2}\right) \qquad ...(13)$$

where h_1 – thickness of film above height of asperity,
h_2 – altitude of asperity,
a_c , b_c – short and long halfaxis of base of elliptical asperity on the middle plane.

By substitution of expression (13) in equation (6) and going through transformations Reinolds equation takes the following form:

$$\frac{\partial^2 q}{\partial x^2}+\frac{\partial^2 q}{\partial y^2}+\frac{6xh_2\partial q}{a_c{}^2\left[h_1+h_2\left(\frac{x^2}{a_c{}^2}+\frac{y^2}{b_c{}^2}\right)\right]\partial x}+\frac{6yh_2\partial q}{b_c{}^2\left[h_1+h_2\left(\frac{x^2}{a_c{}^2}+\frac{y^2}{b_c{}^2}\right)\right]\partial y}=\frac{12\mu V}{\left[h_1+h_2\left(\frac{x^2}{a_c{}^2}+\frac{y^2}{b_c{}^2}\right)\right]} \qquad ...(14)$$

This equation (14) was solved by cutting asperity on sections of profile (Fig.3). Expanding equation by Teilors line expression of stochastic pressure upon single asperity is found. Searching of average pressure upon whole number of asperities of contacting surface value of average pressure upon single asperity was multplied by number of asperities on surface:

$$\bar{q}_g=E\{P\}\times E\{N_1\}. \qquad ...(15)$$

As a result expression of average pressure $\bar{q}_g$ received in the following kind:

$$\bar{q}_g=k_1(c)\times\frac{\pi a_0 b_0}{Ra^2}\times\frac{\mu}{t}\times F_1(\gamma), \qquad if(\gamma\geq 1,0) \qquad ...(16)$$

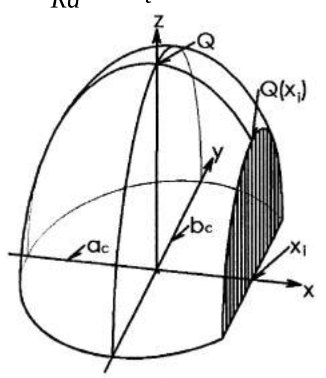

Fig.3

Actually, equations (11) and (16) make it possible to determined average pressure of resistance to pressing out liquid environment at approachement of surfaces. According to Rudzitis and Kamols [5] average pressure of resistance to deformation of microirregularities is known as expression of following type:

$$\bar{q}_g = k_2(c) \times \frac{Ra}{Sm_1\theta} \times F_2(\gamma), \qquad (\gamma \geq 1{,}0) \qquad ...(17)$$

where θ – ellastic constant of contacting surfaces:

$$\theta = \frac{1-\eta_1^2}{\pi E_1} + \frac{1-\eta_2^2}{\pi E_2}, \qquad ...(18)$$

where η, E – Pissions factor and Youngs module of contacting surfaces.

By substitution of investiged equations of pressures q_0 , q_g , q_d in expression (8) equation of carrying ability of two flat lubricated surfaces is considered as found:

$$\overline{q_\Sigma} = \frac{3\mu a_0^2 b_0^2}{2t(a_0^2 + b_0^2)} \left(\frac{1}{\overline{h_2}^2} - \frac{1}{h_0^2} \right) + k_1(c) \frac{\pi a_0 b_0}{Ra^2} \frac{\mu}{t} F_1(\gamma) + k_2(c) \frac{Ra}{Sm_1\theta} F_2(), \qquad ...(19)$$

where $k_1(c)$,$k_2(c)$ – factors due to anisotrophy c of rough surface,
$F_1(\gamma)$,$F_2(\gamma)$ – tabulated functions of relative approachement γ .

5. CONCLUSION

Definition of carrying ability of contact of two lubricated surfaces is interpreted in terms of the largest possible normal loading provided by elastic contact of asperities keeping layer of lubricant unbroken between the surfaces. Analysis of expression (19) shows that the following aspects make a substantial influence on wear of sliding friction and particulary on carrying ability of contact of two flat lubricated surfaces working at normal loading :

1) characteristics of contacting surfaces :
   - geometry of an area a_0 , b_0 ,
   - parameters of roughness Ra , Sm_1 , c , h_2 ,
   - mechanical properties E , η ,
2) parameters of process of contacting :
   - value of enclosed pressure q_Σ upon surface ,
   - size of clearance h_0 between the surfaces,
   - time t of contacting process ,
3) dynamic viscosity μ of liquid lubricant .

Thereby influence of key parameters on common carrying ability of contact of surfaces is discussed in the paper . The largest influence is performed by slopes of asperities of roughness ($\lambda = Ra/Sm$), average arithmetic deviation of roughness Ra , dynamic viscosity μ of liquid lubricant and geometry of contacting surfaces a_0 , b_0 . Increasing of each parameter by *10%* results in alteration of carrying ability of surfaces by *15%(λ) , -8%(Ra) , +7%(μ) , +6%(a_0 , b_0),* accordingly .

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APPLIANCE OF REDUCED MECHANISM ON SOLVING OF INVERSE DYNAMIC PROBLEM OF PLANE MECHANISM

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ABSTRACT
The paper presents a method of solving inverse problem of dynamic of plane mechanism, whereat is applied reduction of mechanism, hereon discarding of characteristics of acceleration of mechanism on primary and secondary characteristics of acceleration, as well as Theorem of Zukovsky. The mathematical terms which describe relation between mentioned parameters are obtained. Using this method it needs not compute forces in kinematic couples of mechanism. In order to illustration of using of obtained equations, an example is shown.
Key words: plane mechanism, reduction of mechanism, inverse dynamic.

1. INTRODUCTION
One of fundamental problems in theory of mechanisms is solving of characteristics of acceleration of single members of mechanism on dependence of forces that perform on mechanism. Very are conveniently when those characteristics we can obtain directly, independently of solving of unknown forces in kinematic couples in mechanism. Most known such methods in mechanics are: method of virtual work, Lagrange's and Hamilton's principle [2]. The method in this paper is different related other methods. It is based on reduction of mechanism and on some kinematic characteristics of mechanism.

2. PRIMARY AND SECONDARY ACCELERATIONS. REDUCED MECHANISM
The acceleration of point K_{ji} of plane mechanism with one degree of freedom of motion (i-th point of j-th members of mechanism) is (figure 1)

$$\vec{a}_{ji} = \frac{d^2\vec{r}_{ji}}{dt^2} = \frac{d^2\vec{r}_{ji}}{d\varphi_1^2}\dot{\varphi}_1^2 + \frac{d\vec{r}_{ji}}{d\varphi_1}\ddot{\varphi}_1, \qquad \ldots(1)$$

where

$\vec{r}_{ji}$ - vector of position (radius vector) of point K_{ji},

$\dot{\varphi}_1$, $\ddot{\varphi}_1$ - projections of angular velocity and angular acceleration of working rotating member on axis which is perpendicular on plane of mechanism (axis z).

From equation (1) we can see that acceleration of some point depends, in generally case, of angular velocity of working member (primary acceleration)

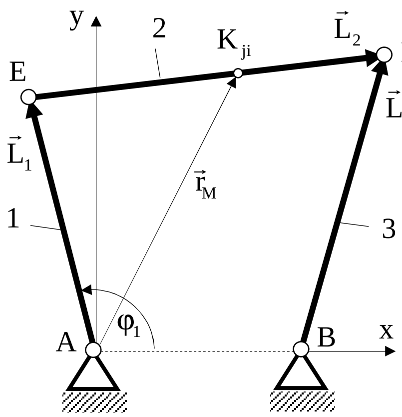


Figure 1. With analysis primary and secondary accelerations

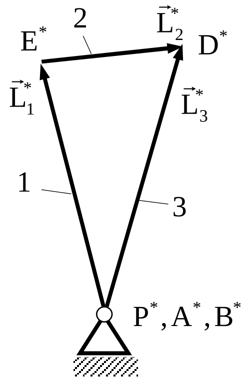


Figure 2. Reduced mechanism of shown mechanism

$$\vec{a}_{ji}^{\omega} = \frac{d^2\vec{r}_{ji}}{d\varphi^2}\dot{\varphi}^2, \qquad \ldots(2)$$

and of angular acceleration of working member (secondary acceleration)

$$\vec{a}_{ji}^{\varepsilon} = \frac{d\vec{r}_{ji}}{d\varphi}\ddot{\varphi}. \qquad \ldots(3)$$

We can see that mutual quotient between primary (secondary) acceleration of any point of mechanism and angular acceleration of working member doesn't depend of kinematic state of mechanism. It depends only of position of mechanism.

If we draw members of real plane mechanism parallel their real positions in definite proportions, whereat instantaneous poles of rotation P_j are located in common point, we obtain reduced mechanism of real mechanism (figure 2). Point P^* is pole of reduced mechanism. Factor of reduction of member (j) we define as

$$\lambda_j = \frac{\vec{L}_j^*}{\vec{L}_j}. \qquad \ldots(4)$$

3. MOMENT OF FORCE FOR POLE OF REDUCED MECHANISM

Let we suppose that force $\vec{F}_{ji}$ acting in point K_{ji} (i-th point of j-th member of mechanism, figure 3a). When moment of force $\vec{F}_{ji}$ for instantaneous pole of rotation P_j of j-th member

$$\vec{M}_{ji} = [\vec{p}_{ji}, \vec{F}_{ji}]. \qquad \ldots(5)$$

If we same force $\vec{F}_{ji}$ append on relational point K_{ji}^* of reduced mechanism (figure 3b), when moment of force $\vec{F}_{ji}$ for pole P^* of reduced mechanism is

$$\vec{M}_{ji}^* = [\vec{p}_{ji}^*, \vec{F}_{ji}]. \qquad \ldots(6)$$

Vectors $\vec{M}_{ji}^*$ i $\vec{M}_{ji}$ are collinear, and their relation is

$$\vec{M}^*_{ji} = \left[\vec{p}^*_{ji}, \vec{F}_{ji}\right] = \left[\lambda_j \cdot \vec{p}_{ji}, \vec{F}_{ji}\right] = \lambda_j \left[\vec{p}_{ji}, \vec{F}_{ji}\right],$$

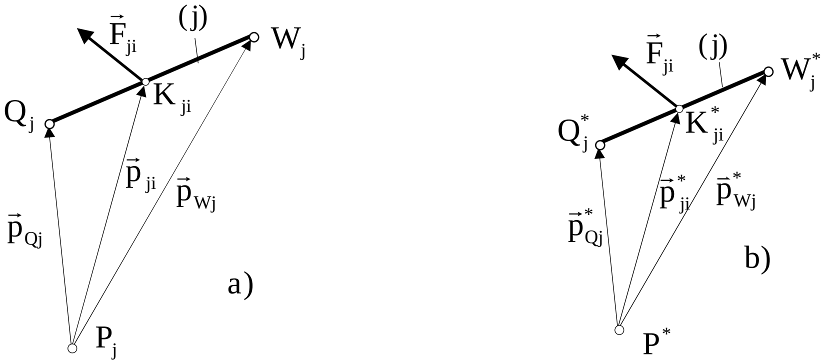


Figure 3. Definition of moment of force for pole of reduced mechanism

accordingly

$$\vec{M}^*_{ji} = \lambda_j \cdot \vec{M}_{ji} \qquad \ldots(7)$$

According theorem of Zukovski [1], main moment of forces which perform on mechanism, for pole of reduced mechanism, for case equilibrium, is equal zero.

$$\vec{M}^{*a}_R + \vec{M}^{*r}_R = 0\,,$$

where : $\vec{M}^{*,a}_R$ - main moment of active forces which perform on reduced mechanism, for his pole;

$\vec{M}^{*,r}_R$ - main moment of reactive forces which perform on reduced mechanism, for his pole;

4. SOLVING OF UNKNOWN ANGULAR ACCELERATION OF MEMBER OF MECHANISM

For case motion this condition is satisfied, if we add inertial forces

$$\vec{M}^{*a}_R + \vec{M}^{*r}_R + \vec{M}^{*in,\omega}_R + \vec{M}^{*in,\varepsilon}_R = 0\,, \qquad ...(8)$$

where

$\vec{M}^{*,in,\omega}_R$ - main moment of primary inertial forces which perform on reduced mechanism, for his pole;

$\vec{M}^{*,in,\varepsilon}_R$ - main moment of secondary inertial forces which perform on reduced mechanism, for his pole.

Whereas main moment of secondary inertial forces

$$\vec{M}^{*in,\varepsilon}_R = \sum_j \sum_i \left[\vec{p}^*_{ji}, \vec{F}^{in,\varepsilon}_j\right] = -\sum_j \sum_i m_{ji} \left[\vec{p}^*_{ji}, \vec{a}^{\varepsilon}_{ji}\right], \qquad \ldots(9)$$

where: m_{ji} - mass of point K_{ji}, according term (3) and (9) we obtain

$$\vec{M}^{*in,\varepsilon}_R = -\sum_j \sum_i m_{ji} \left[\vec{p}^*_{ji}, \frac{d\vec{r}_{ji}}{d\varphi_1} \ddot{\varphi}_1\right]. \qquad \ldots(10)$$

On equal way, for supposed angular acceleration $\vec{\varepsilon}^{\,p}_1$ of members 1 of mechanism, main moment of secondary inertial forces for pole of reduced mechanism is

$$\vec{M}_R^{*in,\varepsilon,s} = -\sum_j \sum_i m_{ji} \left[\vec{p}_{ji}^{\,*}, \frac{d\vec{r}_{ji}}{d\varphi_1} \ddot{\varphi}_1^s \right] \qquad \ldots(11)$$

According terms (10) and (11) we obtain

$$\vec{M}_R^{*in,\varepsilon} = \frac{\ddot{\varphi}_1}{\ddot{\varphi}_1^s} \vec{M}_R^{*in,\varepsilon,s}$$

If we insert derived term in term (8) we obtain

$$\vec{M}_R^{*a} + \vec{M}_R^{*r} + \vec{M}_R^{*in,\omega} + \frac{\ddot{\varphi}_1}{\ddot{\varphi}_1^s} \vec{M}_R^{*in,\varepsilon,s} = 0\,,$$

so that we obtain unknown angular acceleration of acting member 1

$$\ddot{\varphi}_1 = -\frac{\vec{M}_R^{*a} + \vec{M}_R^{*r} + \vec{M}_R^{*in,\omega}}{\vec{M}_R^{*in,\varepsilon,s}} \ddot{\varphi}_1^s \qquad \ldots(12)$$

Derive term presents quotient between two collinear vectors, accordingly quotient between his projections on axis z, which is normally on plane of mechanism. As far as acting members not rotating member, then index 1 can present any rotating member of mechanism and of this way we can obtain his angular acceleration.

For illustration of using equation (12), we show next example.

5. EXAMPLE

In position of mechanism (fig. 11.24) is acting force $F = 100$ N, whereat is mechanism in state of inaction. Everyone geometric measures of mechanism are: $\overline{AB} = R = 50$ mm, $\overline{BD} = L_2 = 150$ mm, $\overline{DE} = L_4 = 120$ mm, $\overline{EH} = L_5 = 60$ mm; ∠ABD=∠DEH=90^0, inertia moments: $J_{1A} = 0{,}002$ kgm^2, mass: $m_3 = 1$ kg. Masses of members 2, 4 i 5 are negligible. It is need calculate angular acceleration of member 1.

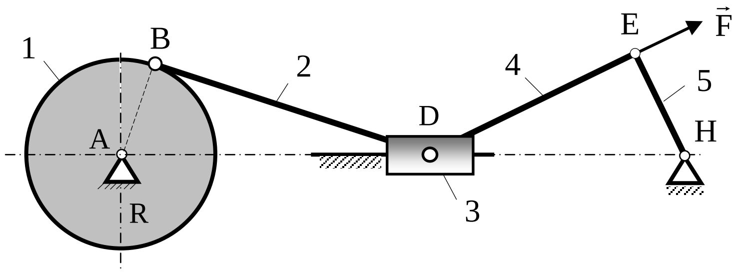


Figure 4. Mechanism by shown example

Solution

Figure 5. shows kinematic analysis of some members of mechanism, needed for defining some kinematic values. Acceleration of point D is

$$\vec{a}_D = \vec{a}_B + \vec{a}_{D,B}\,. \qquad \ldots(a)$$

Projection of term (a) on axis y is

$$0 = -a_B \sin\alpha + a_{D,B} \cos\alpha ,$$
$$0 = -R\varepsilon_1 \sin\alpha + L_2\varepsilon_2 \cos\alpha ,$$

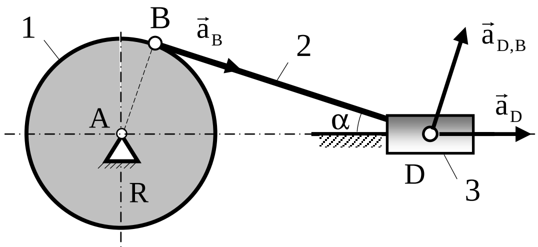


Figure 5. Kinematic analysis of some members of mechanism

so that

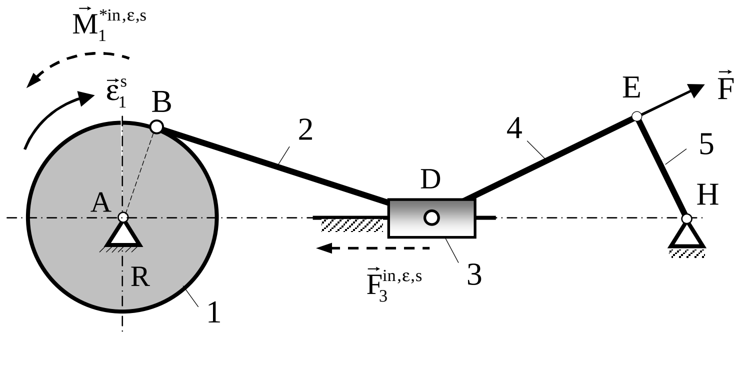
$$\varepsilon_2 = \frac{R\varepsilon_1}{L_2} \mathrm{tg}\alpha .$$

Projection of term (a) on axis x is

$$a_D = a_B \cos\alpha + a_{D,B} \sin\alpha ,$$
$$a_D = R\varepsilon_1 \cos\alpha + L_2\varepsilon_2 \sin\alpha = R\varepsilon_1 \cos\alpha + R\varepsilon_1 \mathrm{tg}\alpha \sin\alpha ,$$

and

$$a_D = \frac{R\varepsilon_1}{\cos\alpha} .$$



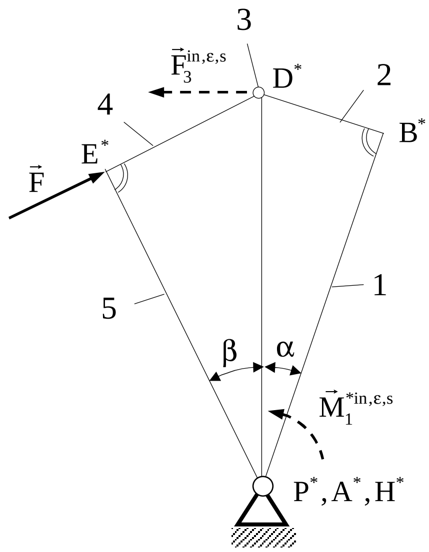


Figure 6. Mechanism with loads which perform work on virtual displacement

Figure 7. Reduced mechanism of shown mechanism with loads which perform work on virtual displacement (factor of reduction of member 1: $\lambda_1 = 1$

If we suppose angular acceleration of member 1: $\varepsilon_1^p = 1\ s^{-2}$, then secondary accelerations of points D which are consequence of supposing angular acceleration of member 1 is:

$$a_D^{\varepsilon,s} = \frac{R\varepsilon_1^s}{\cos\alpha} = \frac{R}{\cos\alpha}.$$

Inertial loads, which perform work on virtual displacement are:

$$M_1^{*in,\varepsilon,s} = J_1\varepsilon_1^s = J_1, \qquad F_3^{in,\varepsilon,s} = m_3 a_D^{\varepsilon,s} = \frac{m_3 R}{\cos\alpha}.$$

According reduced mechanism (figure 7), where factor of reduction of member 1 is: $\lambda_1 = 1$, distance between points P^* and D^* in reduced mechanism is

$$\overline{P^*D^*} = \frac{R}{\cos\alpha}.$$

Using of equation (12) and reduced mechanism, we obtain angular acceleration of member 1

$$\ddot{\varphi}_1 = -\frac{\vec{M}_{\mathcal{R}}^{*a} + \vec{M}_{\mathcal{R}}^{*r} + \vec{M}_{\mathcal{R}}^{*in,\omega}}{\vec{M}_{\mathcal{R}}^{*in,\varepsilon,s}}\ddot{\varphi}_1^s = -\frac{\dfrac{F\lambda_1 R\cos\beta}{\cos\alpha}}{F_3^{in,\varepsilon,s}\cdot\overline{P^*D^*} + \mathscr{M}_1^{*,in,\varepsilon,s}}\ddot{\varphi}_1^s = \frac{\dfrac{F\cdot 1\cdot R\cos\beta}{\cos\alpha}}{\dfrac{m_3 R}{\cos\alpha}\cdot\dfrac{R}{\cos\alpha} + J_1}\cdot 1 = \frac{F\cdot R\cos\alpha\cos\beta}{m_3 R^2 + J_1\cos^2\alpha}.$$

Angles α and β are defined by terms

$$\mathrm{tg}\alpha = \frac{R}{\overline{BD}} = \frac{50}{150} = \frac{1}{3}, \quad \cos\alpha = \frac{3}{\sqrt{10}}, \quad \mathrm{tg}\beta = \frac{EH}{\overline{ED}} = \frac{60}{120} = \frac{1}{2}, \quad \cos\beta = \frac{2}{\sqrt{5}},$$

so that

$$\ddot{\varphi}_1 = \frac{100\cdot 0,05\cdot\dfrac{3}{\sqrt{10}}\dfrac{2}{\sqrt{5}}}{1\cdot 0,05^2 + 0,002\dfrac{4}{5}} = 1034,7904\ \ s^{-2}.$$

Using the principle of pole inertia motion and principle of angular moment change we obtain same result.

6. CONCLUSION

Using primary and secondary accelerations of single points of plane mechanism, term for direct obtaining unknown angular acceleration of rotating member of mechanism, in function of forces which perform on mechanism, is derived. On this way we can obtain unknown motion lows of single members of mechanism without calculation of forces in kinematic couples of mechanism. Shown method is illustrated by an example. Method is very convenient for analytical and for graphical solving of inverse dynamic problem of plane mechanisms.

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NUMERICAL APPROACH IN EXAMINATING MICRO-CRACKS INITIATION IN TERMS OF DISLOCATION THEORY

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ABSTRACT
Several simplified 2D numerical models are developed in order to investigate the micro-cracks initiation caused by the persistent slip bands formation inside the grains of polycrystalline materials. Polycristal grains have random crystallographic orientation and the slip bands are very much related to them, therefore the structure is artificially generated using the Voronoi tessellation which represents an optimal model for the purpose of this investigation. The most suitable structure for this analysis is the martensitic structure, therefore, the properties of martensitic steel are defined. In this paper, the relationships between orientation, density, stress distribution and deformation of grains are observed and bring certain considerations.
Keywords: Micro crack; Crystal grains; Voronoi tessellation; Persistent slip bands; Shear stress

1. INTRODUCTION
Crack initiation is generally caused by stress concentrators that can be attributed to a variety of microstructural inhomogeneties.Micro-cracks can propagate and exceed certain critical length that eventually will cause failure of the loaded structure. Grain and phase boundaries are one od the most prominent microstructural fitures that can cause local stress-strain concentration, because of the elastic and plastic anisotropy of the microstructure of polycristal materials[1]. Each grain wihin a polycrystal material has a random orientation of the crystal lattice. The difference in cristallographic orientation of the grains cause stress peaks at the grain boundaries and triple lines that may exceed locally the yield strangth [1]. This will cause local plastic deformation and crack initiation. This paper deals with the possibilities of the numerical analysis in terms of interpretating the fenomena that occures in real structure near grain boundaries. The relationship between orientation, stress distribution and deformation in grains can be analysed through several 2D models that are developed. The 2D models are simulating a microstructure similar to the real polycristal material. This is established using the Voronoi algoritam that generates grain structure with random orientation in each grain. The elastic anisotropy is seen to be a key factor determining local deviations from the remote stress[1]. This is introduced to the model through the stiffness matrix D_{ijkl}, considering the genaral material law, the relationship between strain and stress vector. Details concernig the process of constructing the representative volume element, assignment of the material properties and the formation of the slip systems causing stress concentration near grain boundaries are described in the paper and the results obtained from the models are graphically displayed and analyzed.

2. NUMERICAL MODELING

The most suitable algoritam commonly used to simulate microstructure of a polycrystalline material is the Voronoi tessellation. This algoritam devides space randomly into regions that are convex polygons with various numbers of edges on a two-dimensional plane completely filling up the space without overlapping. These obtained polygons in the model are representing austenite grains within the polycristal structure, with different orientation that coincides to the crystallographic lattice of each grain. The axes of the crystallographic lattice are defining the local coordinate system of each polygon. The orientation of grains presented through crystallographic axes is shown in Figure 1. The material that is assigned to the model is martensitc steel, the bahavior of the material is elastic orthotropic and is deffined in the property module through the stiffness matrix D_{ijkl}: D1111 = D2222 = D3333 = 233000Pa, D1122 = D1133 = D2233 = 135000Pa, D1212 = 1313 = D2323 = 118000Pa. Martensitic laths share the {110} slip planes, which lie along the axis of laths [2]. In the present simulation the slip plane in martensitic laths is assumed to be the $1\overline{10}$, that means that the martensitic laths are 45 degrees inclined to the grain orientations [3]. The potential micro-crack will initiate along persistent slip bands [3] which in this case that would be the martensit lath. Example of grain partition along martensitic lath is shown in Figure 2. The interaction between the nods that lie on the separate sides of the partition should slide but not divide from each other. This is going to simulate the slip band and according to Chingshen Li in the paper [4], the nodes that lie on the slip band are constrained with the equation $V_u - V_l = tg\alpha\,(U_u - U_l)$[4]. This will permit the sliding movement during deformation parallel to the line that is dividing the grain. Figure 3 presents the node couples in three partitioned graines in one of the constructed models.

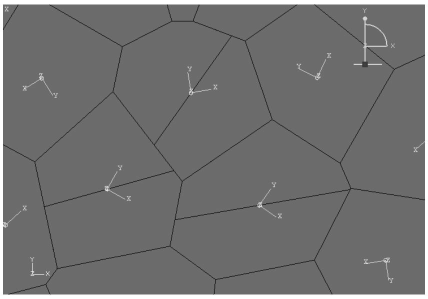

Figure 1. Grains with random oriented crystallographic axes

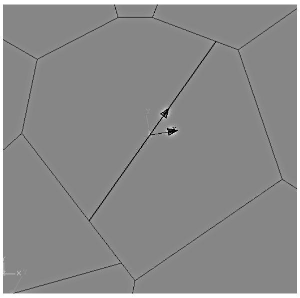

Figure 2. Partition along martensitic laths which are 45 degrees inclined to the grain orientations

In this paper, three different models are constructed each of them containing 50, 80 and 100 grains on a predefined area of 0, 27 mm^2. In each model there is a variation in the average value of the area, size and orientation of the grain. It is recommended to use 4-node linear elements when defining each grain according to paper [5.]. The present models mainly consist of 4-node linear elements (CPS4R), but there are also 3-node elements (CPS3). The mesh density depends on the required accuracy of the analysis. The finer the mash is the running cost increases but the results obtained are to be more accurate. The numbers of elements that are used in these models vary, it depends from the size and shape of each grain. The boundary conditions for all three models are exactly the same. The nodes located on the left side of the plate, except the node located at the lower left corner which is constrained ($x = 0$, $y = 0$), are free to move in y direction but not in x direction.

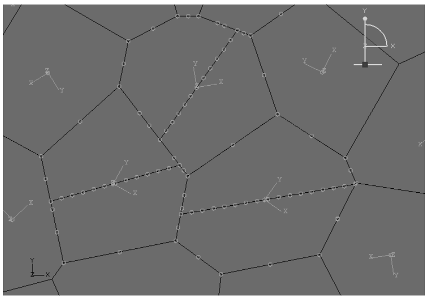

Figure 3. Node couples in partitioned grains

The loading direction for all models is in X - axe direction of the global coordinate system and it is presented in terms of assigned displacement Δl in *mm*.The stress components are calculated in each of the local coordinate systems. The relationship between the global coordinate system and the local coordinate system strongly depends from the orientation of grains. Since the shear stress on the slip band ($1\bar{1}0$) is going to be studied, the orientation angle of the potential crack α is $\varphi+45^0$[6]. In cubic lattice, the slip plane (110) is perpendicular to ($1\bar{1}0$) that is why the shear stress in this plane is the same as in (110) plane.

3. RESULTS AND ANALYSIS

The constructed 2D numerical models are anisotropic elastic, each of them have different morphology and orientations but have the same boundary and loading conditions.

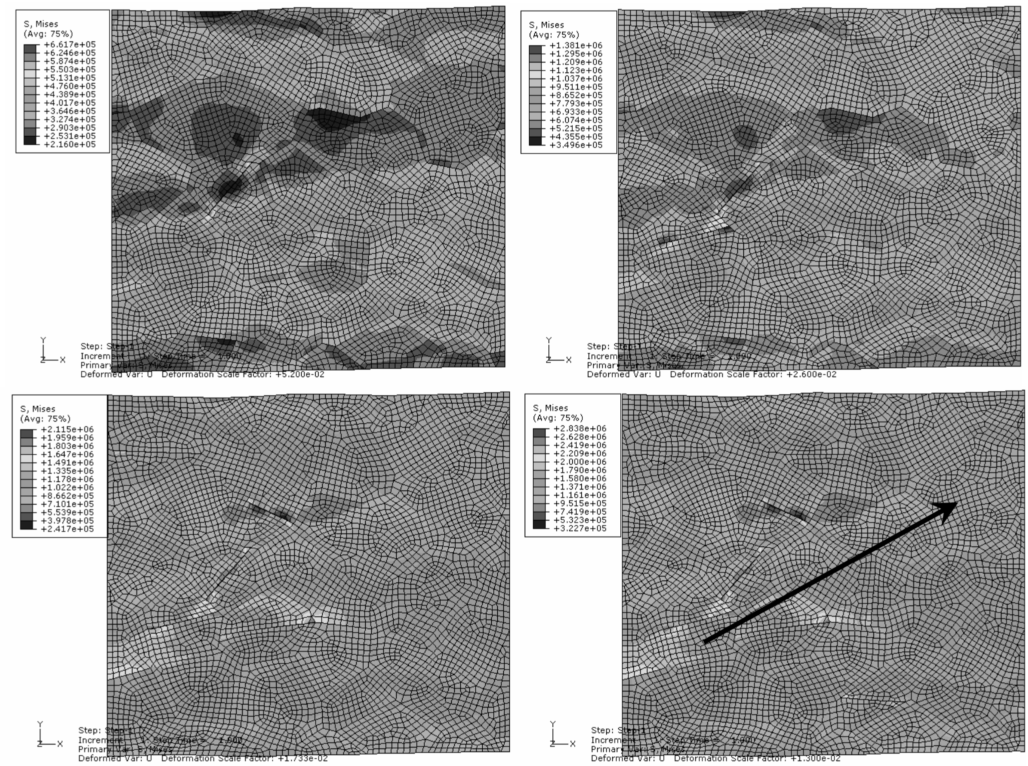

Figure 5. Model with 50 grains, Von Mises stress distribution in a) one micro-crack; b) two micro-cracks; c) five micro-cracks and d) eleven micro-cracks (arrow shows trend of crack propagation)

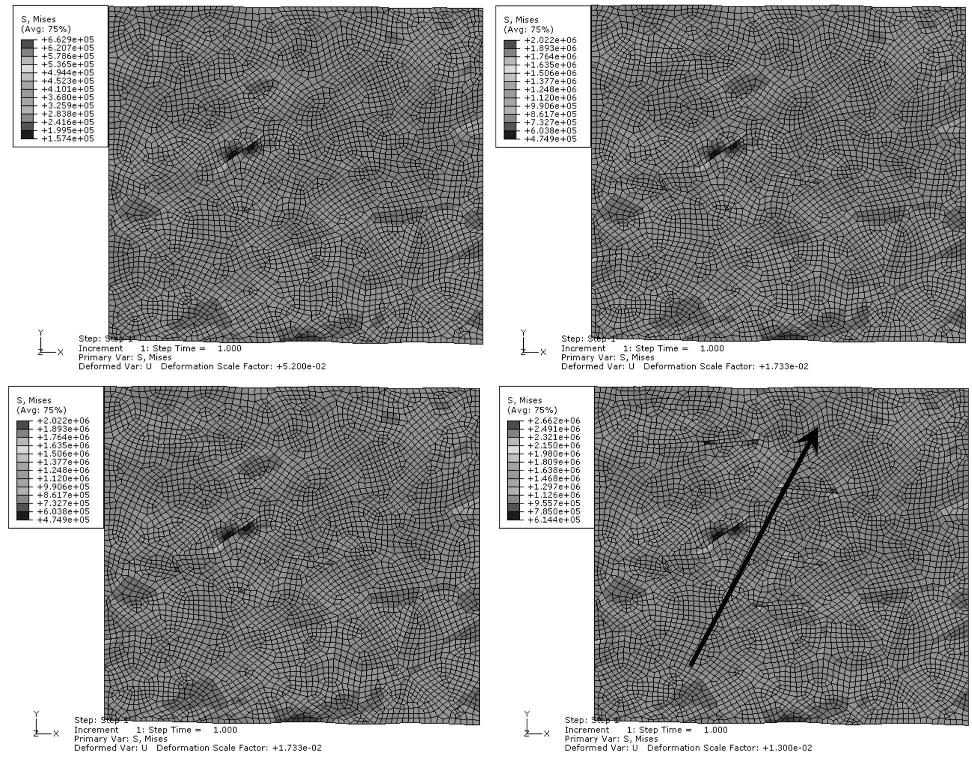

Figure 6. Model with 80 grains, Von Mises stress distribution in a) one micro-crack; b) two micro-cracks c) seven micro-cracks and d) fourteen micro-cracks (arrow shows trend of crack propagation)

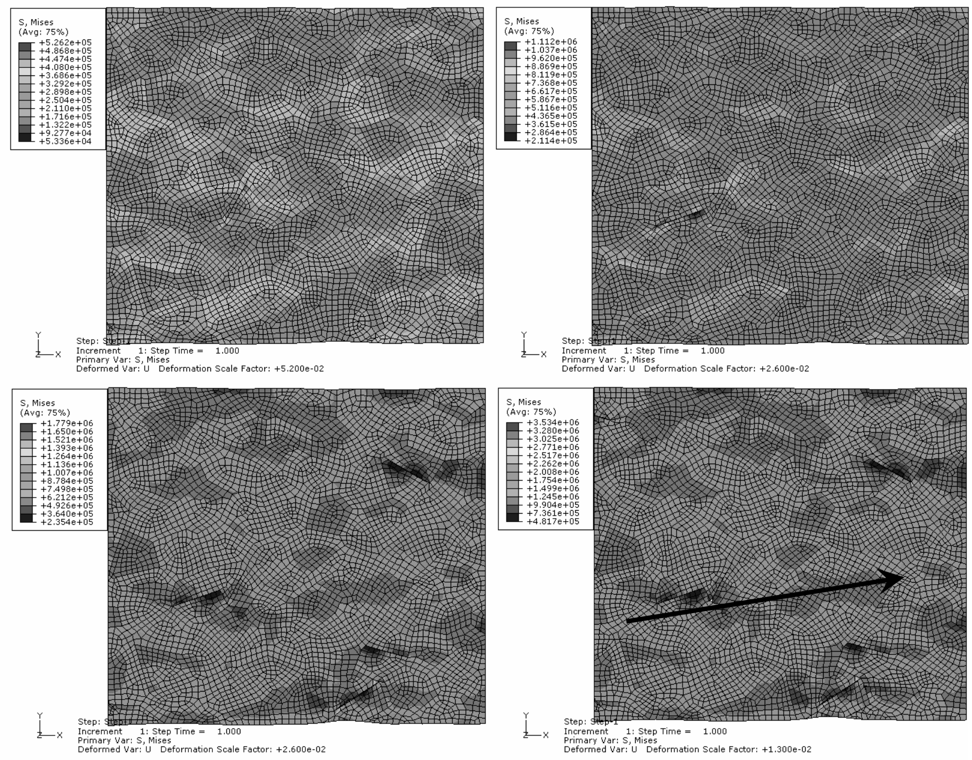

Figure 7. Model with 100 grains, Von Mises stress distribution in a) one micro-crack; b) two micro-cracks; c) eight micro-cracks and d) fifteen micro-cracks (arrow shows trend of crack propagation)

At the beginning each model has one initiated microcrack. Each of the models gave different stress values for each loading. The maximum value of shear stress for each analysis was concentrated in grains that are located near the grain with the initiated crack. The results are graphically given in Figure 5, 6 and 7 and represent the Von Mises stress distribution. The micro-cracks are initiated in the grains where the maximum shear stress is calculated according to the local coordinate system. An example is given in Figure 8, the highest shear stress is concentrated in the grain with crystallographic lattice number 46 near the boundaries of the neighboring grains. In all of the simulated models micro-cracks are initiated along the potential crack paths according to a defined failure criteria. The initiated crack is introduced into the representative volume element by separation, with length identical to the crack path, and this simulates one-segment crack as it is observed in experiments [3]. The grain that has a high level of stress and is oriented at about +/- 45^o to the loading axis is the next grain where crack can occur. From the results it can be easily detected that after each initiated crack the stress is redistributed. These micro-cracks are one-segment cracks initiated on the maximum shear stresses failure criteria and they are likely to form a macrocrack by coalescence. The expected coalescence and formation of macrkocracks is different in each model (Figure 5d, 6d, 7d). In all three models the maximum seems to be in the grains that are close to the first initiated microcracks, as a result of high local stress concentrations at the grain boundaries. Figure 9 shows the number of cracks that occurred at different displacements after reaching the predefined failure criteria.

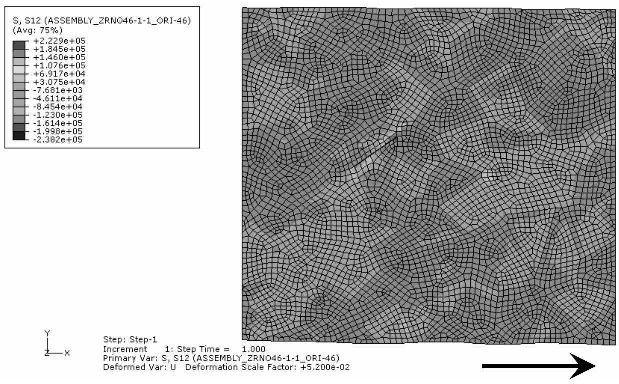

Figure 8. Representative volume element with 80 grains showing the maximum shear stress distribution in grain 46 near the microcrack (arrow shows the displacement direction)

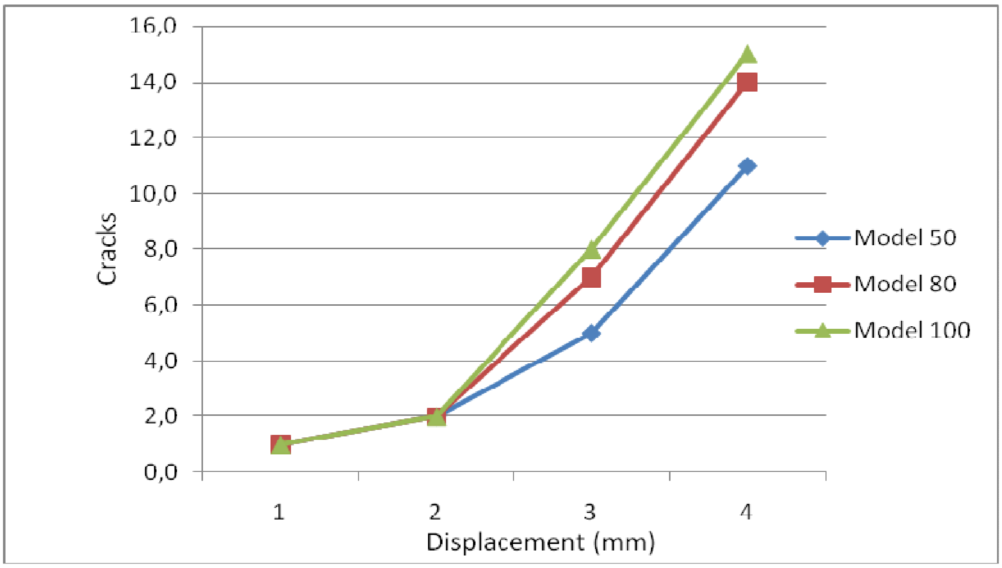

Figure 9. Number of cracks in models with 50, 80 and 100 grains for same failure criteria and boundary conditions

4. CONCLUSIONS

The results here obtained encourage further investigation of the possibilities to predict two-dimensional crack propagation numerically accounting for real microstructure data. Several studies show that loaded materials exhibiting elastic anisotropy lead to stress concentrations along grain boundaries with unfavourable crystallographic orientation relationships. Such stress concentrations, which certainly can also arise from second phase precipitates or pores, cause local plastic deformation to an extent that depends on the local slip geometry with the respect to the local direction of maximum shear stresses. The models show that stress value and distribution within grains is related to the orientation of the grain and the misorientation of its neighbouring grains. The present work arouses the existence of unifying aspects and facts that the integrity of a structure is strongly dependent from the microstructure and the interactions between the crack tip and the crystallographic orientation and shape of the adjacent grains. There are also important quantitative information that can be extracted from the models about the direction of the crack propagation and the possible coalescence. The models are very close to introduce the phenomenon of stress concentration in triple points and along neighbouring grain boundaries and can certainly be used as a tool that will assist in further understanding and investigating the materials microstructure and crack propagation.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

FLARE DESIGN AND SIZING

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ABSTRACT
In the safe, satisfactory operation of a process plant, the flare system is the single most important element for operational or emergency relief of flammable substances in the liquid or gaseous phases.
The typical flaring system consists of equipment that safely combusts vented hydrocarbons at a pressure drop which doesn't compromise plant relief systems. Because the flare system does not directly produce revenue, its design considerations and the factors influencing the flare design are often not well understood.
Most people see flares as simply a fire on top of a pipe that burns gases.
Radiation from the flare flame generally determines flare stack height. During normal operations, design intent is heat limit intensity at levels, to levels which are low enough for both humans to safely withstand and to protect surrounding equipment from heat-related damage.
This paper provides a concrete example of design and dimensioning of flare stack height and diameter as a function of the maximum thermal radiation allowed at ground. For flare sizing author uses his own Microsoft Excel Data Sheets.
Keywords: Flare, Flaring, Thermal radiation intensity, Design, Sizing

1. INTRODUCTION
The flare system fills a key role in the overall safety and environmental compliance of a hydrocarbon processing plant or production facility. Because the flare system does not directly produce revenue, its design considerations and the factors influencing the flare design are often not well understood. Our purpose here is to improve understanding of these factors and considerations so that designers and plant operators can achieve the flare system's most important objective, i.e., safe, effective disposal of gases at an inexpensive cost [1, 2].
For the correct flare sizing and for the evaluation of their thermal impact author uses his own Microsoft Excel Data Sheets. All calculations are made according to the API (American Petroleum Industry) Recommended Practice 521.
The methodology, applied to many plants, is based on a careful meteorological analysis of the site and the evaluation of the impact for a minimum period of one year with hourly resolution.

2. FLARE AND FLARING
The flare is a last line of defense in the safe emergency release system in a refinery or chemical plant. Basically, the flare system acts as a safety relief valve for the plant. It uses to dispose of purged and wasted products from refineries, unrecoverable gases emerging with oil from oil wells, vented gases from blast furnaces, unused gases from coke ovens, and gaseous water from chemical industries.

Flares are also used for burning waste gases from sewage digesters process, coal gasification, rocket engine testing, nuclear power plants with sodium, water heat exchangers, heavy water plants, and ammonia fertilizer plants.

Flaring is a high-temperature oxidation process used to burn combustible components, mostly hydrocarbons, of waste gases from industrial operations. In combustion, the gaseous hydrocarbon (natural gas, propane, ethylene, propylene, butadiene, butane and etc) reacts with atmospheric oxygen to form carbon dioxide (CO_2) and water. Several by products formed will be carbon monoxide, hydrogen and others dependent upon what is being burned. Efficiency of hydrocarbon conversion is generally over 98%. Combustion is complete if all volatile organic compounds (VOC) are converted to carbon dioxide and water. Incomplete combustion results in some of the VOC being unmoved or converted to other organic compounds such as aldehydes or acids.

The flaring process can produce some undesirable by-products including noise, smoke, heat radiation, light, SO_2, NO_x, CO, and an additional source of ignition where not desired. However, by proper design these can be minimized.

Elevated flare is the most commonly used type in refineries and chemical plants. Have larger capacities than ground flares. The waste gas stream is fed through a stack from 10 m to over 100 m tall and is combusted at the tip of the stack. The elevated flare, can be steam assisted, air assisted or non-assisted. Elevated can utilize steam injection / air injection to made smokeless burning and with low luminosity up to about 20% of maximum flaring load. The disadvantage of steam / air injection is it introduces a source of noise and cause noise pollution. If adequately elevated, this type of flare has the best dispersion characteristics for malodorous and toxic combustion products.

Capital costs are relatively high, and an appreciable plant area may be rendered unavailable for plant equipment, because of radiant heat consideration [3].

3. FLARE DESIGN FACTORS

It is very important for the flare designer to understand several factors, which can affect his flaring system design, the major factors influencing flare system design are:

- It depends on the gas stream released: Flow rate, Gas composition, Gas temperature and Gas pressure available.
- The next factor is related to the design of the facility itself and its location: Utility costs and availability
- It related to regulatory mandates: Safety requirements, Environmental requirements and Social requirements [2]

The designer of the flare system will follow exactly the flow data provided. It must be carefully determined. Overstatement of the flows will lead to oversized equipment which lead to more expensive capital and operating costs and can lead to short service life as well. Understated the flow can result in an ineffective or no safe system. Besides that, the design should be base on consideration bellow as well:

- Flare Spacing, Location, and Height (Radiant heat and pollution limitations)
- Flare Capacity and Sizing (Design capacity is design to handle largest vapor release from pressure relief valve, vapor blow down and other emergency system)
- Liquid (water) Seals (The flashback protection, which prevents a flame front from traveling back to the upstream piping and equipment).

Sizing of flare systems is a function of maximum allowable back pressure on pressure relief valves and other sources of release into the emergency systems.

The maximum emergency flow rate may occur during a major plant upset such as the total loss of electrical power or cooling water and fire. Flare systems have to be designed for a wide range of flows, ranging from the flow from a single relief valve to a ‘worst case’ maximum demand situation that may be created.

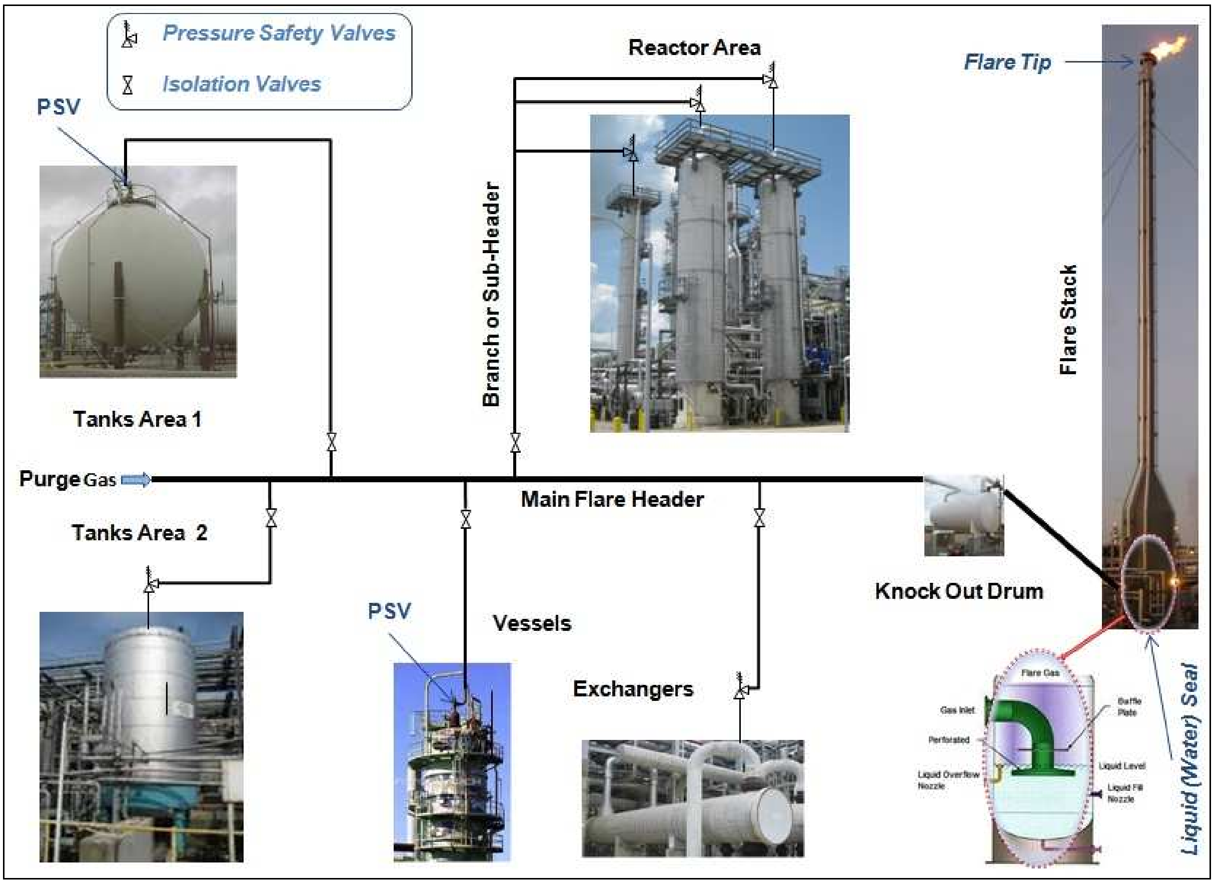
The flare tip diameter is a function of the vent gas flow rate plus the auxiliary fuel and purge gas flow rate. The purge gas flow rate is very small relative to the vent gas and fuel flow rates, so it may be ignored when determining the tip diameter. The flow rate of the auxiliary fuel, if required, is significant, and must be calculated before the tip diameter can be computed [3].

Table 1. Recommended Design Total Radiation

Permissible Design Level K [kW/m2]	Observed Effect and Limit Description
37.5	Intensity at which damage is caused to process equipment. Intensity on storage tanks.
25.0	The minimum energy required to ignite wood at indefinitely long exposure (non-piloted).
12.5	The minimum energy required for piloted ignition of wood, vegetation and melting of plastic tubing. This value is typically used as a fatality number.
9.5	Sufficient to cause pain in 8 seconds and 2nd degree burns in 20 seconds.
4.0	Sufficient to cause pain to personnel if unable to reach cover within 20 seconds. However, blistering of skin (second degree burns) is likely; 0% lethality.
1.6	Will cause no discomfort for long exposure.

The height of a flare stack is determined based on the ground level limitations of thermal radiation intensity (Table 1), luminosity, noise, height of surrounding structures, and the dispersion of the exhaust gases. Industrial flares are normally sized for a maximum heat intensity of (4.73 – 6.31) kW/m^2 when flaring at their maximum design rates. At this heat intensity level, workers can remain in the area of the flare for a limited period only. If, however, operating personnel are required to remain in the unit area performing their duty, the recommended design flare radiation level excluding solar radiation is 1.58 kW/m^2. The intensity of solar radiation is in the range of (0.79 – 1.04) kW/m^2 [3, 4].

4. TYPICAL FLARE SYSTEM



Figur 1. Typical Flare System

The typical flare system (Figure 1) generally consists of a gas vent collection header (main flare header) and piping for collecting gases from processing units (branch or sub-header), a knockout drum to remove and store condensable gases and entrained liquids, a proprietary seal – liquid (water) seal and purge gas supply to prevent flash-back, a single- or multiple-burner unit and a flare stack, gas pilots and an igniter to ignite the mixture of waste gas and air, and if required, a provision for external momentum force (steam injection or forced air) for smokeless flaring. Natural gas, fuel gas, inert gas, or nitrogen can be used as purge gas.

The total volumetric flow to the flame must be carefully controlled to prevent low flow flashback problems and to avoid flame instability. Purge gas, typically natural gas, N_2, or $C0_2$ is used to maintain a minimum required positive flow through the system. If there is a possibility of air in the flare manifold, N_2, another inert gas, or a flammable gas must be used to prevent the formation of an explosive mixture in the flare system. To ensure a positive flow through all flare components, purge gas injection should be at the farthest upstream point in the flare transport piping [4].

5. FLARE DESIGN AND SIZING IN THE EXCEL DATA SHEETS

Program for flare design and sizing in Excel sheets includes:

- Sizing – Method I.: Sizing a Flare Stack Using the Simple Approach (API 521) with design wind velocity, Case 1 and Case 2
- Sizing – Method II.: Sizing a Flare Using Brzustowski's & Sommer's Approach (API 521) with design wind velocity, Case 1 and Case 2
- Design by Sizing – Method I & Method II
- Graphic Output
- Appendix –LEL: Lower explosive limit for pure component or mixtures may be calculated as follows
- Appendix – Inside Diameter for Steel Pipes: Nominal and Inside diameter for Schedule 20 & 40

Method I: Sizing a Flare Stack Using the Simple Approach *(API 521)*			
Input, Case 1:		**Mach = 0.2**	**Mach = 0.5**
Gas Flow rate	W [kg/h]	50000	50000
Gas Compressibility factor	z [-]	0,99	0,99
Temperature of the flare gas	t [ºC]	135	135
Molecular weight of the flare gas	M_w [kg/kmol]	55,25	55,25
Ratio of specific heats (C_p/C_v)	k [-]	1,09	1,09
Mach number at pipe outlet	M_2 [-]	0,20	0,50
Pressure at the flare tip	P_2 [kPa]$_{absolute}$	101,30	101,30
Heat of combustion	q [MJ/kg]	38,00	38,00
Design wind velocity, *Case 1*	U_∞ [m/s]	40,00	40,00
Radiation at R [m] from the flare stack	K [kW/m^2]	4,73	4,73
	R [m]	34,00	34,00
Fraction of heat intensity transmitted	τ [-]	1,00	1,00
Output, Case 1:			
Inside diameter of the flare tip	d [m]	0,454	0,287
Heat liberated	Q [kW]	527778	527778
Flame Length	L [m]	45,4	45,4
Actual Flow	V [m^3/s]	8,414	8,414
Flare tip exit velocity	U_j [m/s]	52,0	130,1
(Wind velocity)/(Tip exit velocity)	U_∞/U_j [-]	0,769	0,307
Fraction of heat radiated	F [-]	0,29	0,25
Approximate Flame Distortion:			
Ratio	∑(Δx/L)	0,96	0,92
Ratio	∑(Δy/L)	0,12	0,24
	∑Δx [m]	43,60	41,78
	∑Δy [m]	5,33	10,96
Calculation of required flare stack height			
Distance from the flame center to the grade-level boundary (that is, the object being considered)	D [m]	50,5	46,9
	R' [m]	12,2	13,1
	H' [m]	49,0	45,1
Required height of flare stack	H [m]	46,4	39,6

Method I: Sizing a Flare Stack Using the Simple Approach *(API 521)*			
Input, Case 2:		**Mach = 0.2**	**Mach = 0.5**
Gas Flow rate	W [kg/h]	50000	50000
Gas Compressibility factor	z [-]	0,99	0,99
Temperature of the flare gas	t [ºC]	135	135
Molecular weight of the flare gas	M_w [kg/kmol]	55,25	55,25
Ratio of specific heats (C_p/C_v)	k [-]	1,09	1,09
Mach number at pipe outlet	M_2 [-]	0,20	0,50
Pressure at the flare tip	P_2 [kPa]$_{absolute}$	101,30	101,30
Heat of combustion	q [MJ/kg]	38,00	38,00
Design wind velocity, *Case 2*	U_∞ [m/s]	8,00	8,00
Radiation at R [m] from the flare stack	K [kW/m^2]	4,73	4,73
	R [m]	34,00	34,00
Fraction of heat intensity transmitted	τ [-]	1,00	1,00
Output, Case 2:			
Inside diameter of the flare tip	d [m]	0,454	0,287
Heat liberated	Q [kW]	527778	527778
Flame Length	L [m]	45,4	45,4
Actual Flow	V [m^3/s]	8,414	8,414
Flare tip exit velocity	U_j [m/s]	52,0	130,1
(Wind velocity)/(Tip exit velocity)	U_∞/U_j [-]	0,154	0,061
Fraction of heat radiated	F [-]	0,29	0,25
Approximate Flame Distortion:			
Ratio	∑(Δx/L)	0,86	0,70
Ratio	∑(Δy/L)	0,36	0,53
	∑Δx [m]	38,86	31,71
	∑Δy [m]	16,27	23,90
Calculation of required flare stack height			
Distance from the flame center to the grade-level boundary (that is, the object being considered)	D [m]	50,5	46,9
	R' [m]	14,6	18,1
	H' [m]	48,4	43,3
Required height of flare stack	H [m]	40,2	31,3

Figur 2. Sizing a flare stack using the Simple Approach method I (API 521)

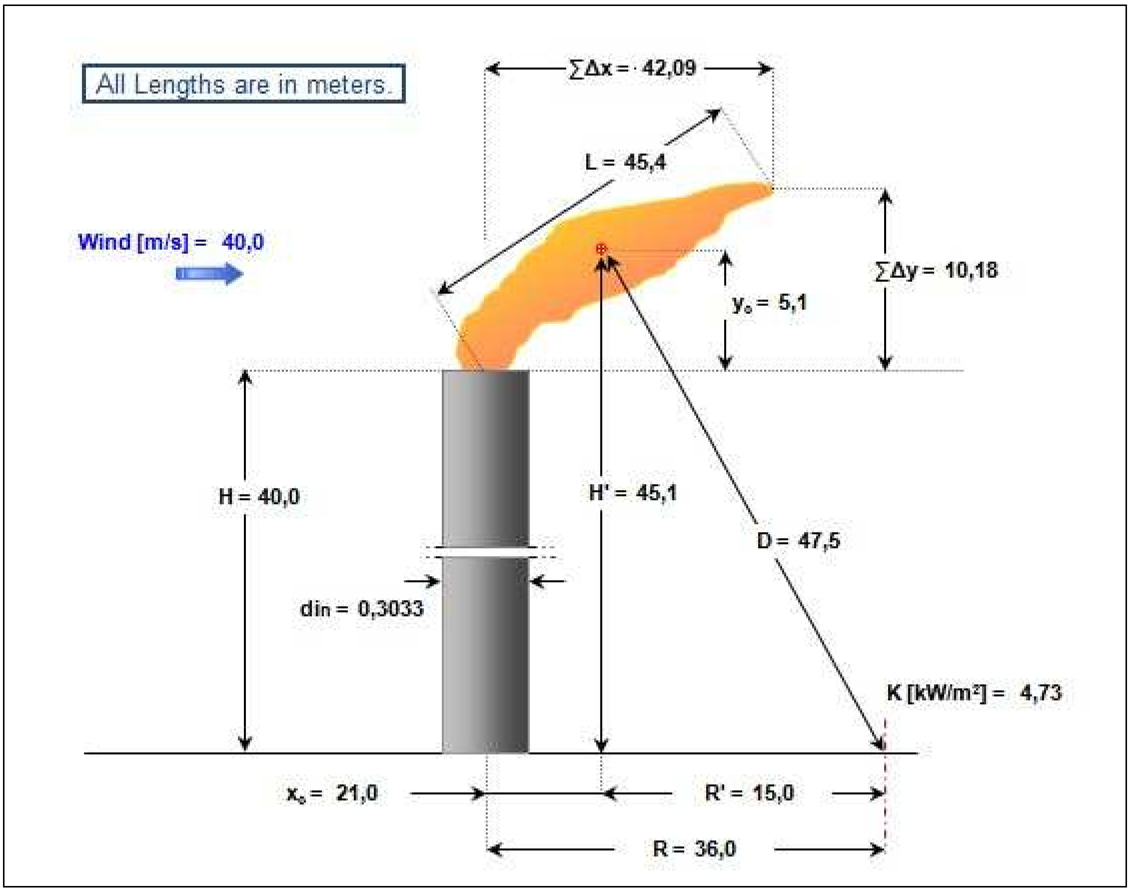
Due to limited space in this paper presents the Design and Sizing Method I. Blue numerical values are values that fills designer. In the tables, figure 2, the designer fills in the value of the gas flow, characteristics of gas, maximum and minimum wind velocity and radiation at the desired distance from the flare stack. The result is an inside diameter of the flare tip and required height of the flare stack.
The next step is to adopt the stack height and the first larger nominal diameter of the flare tip.

Method I: Design by Sizing a Flare Stack Using the Simple Approach			
Input, Design Case 1a:		**R = f(K,...)**	
Gas Flow rate	W [kg/h]	50000	50000
Gas Compressibility factor	z [-]	0,99	0,99
Temperature of the flare gas	t [ºC]	135	135
Molecular weight of the flare gas	M_w [kg/kmol]	55,25	55,25
Ratio of specific heats (C_p/C_v)	k [-]	1,09	1,09
Pressure at the flare tip	P_2 [kPa]$_{absolute}$	101,30	101,30
Heat of combustion	q [MJ/kg]	38,00	38,00
Design wind velocity	U_∞ [m/s]	40,0	40,0
Selected height of flare stack	H [m]	40,0	40,0
Selected inside diameter of the flare tip	d [m]	0,3033	0,3033
Radiation at R [m] from the flare stack	**K** [kW/m^2]	4,73	2,00
Option: Elevated terrain surrounding flare stack. Flat terrain (α = 0º) or average angle of elevation (α > 0, α ≤ α_{max})	α [grader]	0,00	0,00
	Selected α [grader]	0,00	0,00
Fraction of heat intensity transmitted	τ [-]	1,00	1,00
Output, Design Case 1a:			
Mach number at pipe outlet	Mach [-]	0,45	0,45
Heat liberated	Q [kW]	527778	527778
Flame Length	L [m]	45,4	45,4
Actual Flow	V [m^3/s]	8,414	8,414
Flare tip exit velocity	U_j [m/s]	116,5	116,5
(Wind velocity)/(Tip exit velocity)	U_∞/U_j [-]	0,343	0,343
Fraction of heat radiated	F [-]	0,25	0,25
Approximate Flame Distortion:			
Ratio	∑(Δx/L)	0,93	0,93
Ratio	∑(Δy/L)	0,22	0,22
	∑Δx [m]	42,09	42,09
	∑Δy [m]	10,18	10,18
Calculation of radius with radiation K			
Distance from the flame center to the grade-level boundary (that is, the object being considered)	D [m]	47,5	73,1
	R' [m]	15,0	57,5
	H' [m]	45,1	45,1
Radius from the base of the flare stack, with radiation K, at grade level	**R** [m]	36,0	78,5
***Option:* Calculation of minimum and maximum radius with radiation K**			
Elevation change at R_{min}	Δh [m]	0,000	0,000
	R'_{min} [m]	15,0	57,5
	H'_{min} [m]	45,1	45,1
Minimum radius from the center line of the flare stack, with radiation K, at Δh level	R_{min} [m]	36,0	78,5
Maximum average angle of elevation with radiation up to **K**, directly under the flame center:	α_{max} [grader]	6,55	53,04
Elevation change at R_{max}	Δh [m]	0,000	0,000
	R'_{max} [m]	15,0	57,5
	H'_{max} [m]	45,1	45,1
Maximum radius from the center line of the flare stack, with radiation K, at Δh level	R_{max} [m]	36,0	78,5

Method I: Design by Sizing a Flare Stack Using the Simple Approach			
Input, Design Case 1b:		**K = f(R,...)**	
Gas Flow rate	W [kg/h]	50000	50000
Gas Compressibility factor	z [-]	0,99	0,99
Temperature of the flare gas	t [ºC]	135	135
Molecular weight of the flare gas	M_w [kg/kmol]	55,25	55,25
Ratio of specific heats (C_p/C_v)	k [-]	1,09	1,09
Pressure at the flare tip	P_2 [kPa]$_{absolute}$	101,30	101,30
Heat of combustion	q [MJ/kg]	38,00	38,00
Design wind velocity	U_∞ [m/s]	40,0	40,0
Selected height of flare stack	H [m]	40,0	40,0
Selected inside diameter of the flare tip	d [m]	0,3033	0,3033
Radius from the base of the flare stack, with radiation K, at grade level	**R** [m]	25,00	50,00
Option: Elevated terrain surrounding flare stack. Flat terrain (α = 0º) or average angle of elevation (α > 0, α ≤ α_{max})	α [grader]	0,00	0,00
	Selected α [grader]	0,00	0,00
Fraction of heat intensity transmitted	τ [-]	1,00	1,00
Output, Design Case 1b:			
Mach number at pipe outlet	Mach [-]	0,45	0,45
Heat liberated	Q [kW]	527778	527778
Flame Length	L [m]	45,4	45,4
Actual Flow	V [m^3/s]	8,414	8,414
Flare tip exit velocity	U_j [m/s]	116,5	116,5
(Wind velocity)/(Tip exit velocity)	U_∞/U_j [-]	0,343	0,343
Fraction of heat radiated	F [-]	0,25	0,25
Approximate Flame Distortion:			
Ratio	∑(Δx/L)	0,93	0,93
Ratio	∑(Δy/L)	0,22	0,22
	∑Δx [m]	42,09	42,09
	∑Δy [m]	10,18	10,18
Calculation of radiation on horizontal distance R (α=0)			
Distance from the flame center to the grade-level boundary (that is, the object being considered)	D [m]	45,3	53,6
	R' [m]	4,0	29,0
	H' [m]	45,1	45,1
Radiation at R [m] from the flare stack	**K** [kW/m^2]	5,21	3,72
***Option:* Calculation of minimum and maximum radiation on the horizontal distance R**			
Elevation change at K_{min}	Δh [m]	0,000	0,000
Distance from the flame center to the object or point being considered	D [m]	45,3	53,6
Minimum radiation from the center line of the flare stack on distance R and Δh level	K_{min} [kW/m^2]	5,21	3,72
Maximum average angle of elevation:	α_{max} [grader]	32,66	65,11
Elevation change at K_{max}	Δh [m]	0,000	0,000
Distance from the flame center to the object or point being considered	D [m]	45,3	53,6
Maximum radiation from the center line of the flare stack on distance R and Δh level	K_{max} [kW/m^2]	5,21	3,72

Figur 3. Design by Sizing a flare stack using the Simple Approach method I (API 521)

With the adopted values of diameter (D) and height of the stack (H), the designer can in the Table - Design by sizing (Figure 3) to examine the radius from the center line of the flare stack (R) as a function of the radiation (K) and/or K as a function of R for the horizontal ($\alpha = 0°$) or elevated terrain ($\alpha \neq 0°$).



Figur 4. Design Graphic Output

6. CONCLUSION

For the correct flare sizing and for the evaluation of their thermal impact author uses his own Microsoft Excel Data Sheets. All calculations are made according to the API (American Petroleum Industry) Recommended Practice 521.

In addition to the two API methods of sizing and design, there are other methods. They all have their disadvantages and advantages. API methods are still used as an input method in the design. The last word in dimensioning and design provided by manufacturers of equipment, and shall bear all consequences and liability for your product.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

EMERGENCY RELEASE MODELING

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ABSTRACT
Emergency release modeling is a specific kind of air dispersion modeling that deals with accidental releases, typically denser than air. This kind of modeling is used to evaluate accident scenarios and create emergency response plans. This model is an ideal tool to predict hazardous zones and potential impacts of accidental releases.
This paper presents the simulation models and results for at least two scenarios. Lakes Environmental software is used for simulations.
Keywords: Emergency Jet Release, Gases Denser than Air, SLAB, SLAB View, Atmospheric Dispersion Model

1. INTRODUCTION
Lakes Environmental is committed to supplying robust and easy to use modeling software to consulting companies, industries, governmental agencies and academia. For this work, the author has got permission and software, during a limited time.
Emergency release modeling is a specific kind of air dispersion modeling that deals with accidental releases, typically denser than air. This kind of modeling is used to evaluate accident scenarios and create emergency response plans.
The SLAB model is an atmospheric dispersion model for denser than air releases [1]. This model is an ideal tool to predict hazardous zones and potential impacts of accidental releases.
SLAB View is a graphical user interface for the SLAB model. It can be able to show you how the release develops over time, as well as what the total footprint of the release will be.
SLAB View can model continuous, finite duration and instantaneous releases from four types of sources: a ground-level evaporating pool, an elevated horizontal jet, a stack or elevated vertical jet and a ground-based instantaneous release.
Atmospheric dispersion of the release is calculated by solving the conservation equations of mass, momentum, energy and species. The conservation equations are spatially averaged to treat the cloud as a steady state plume, a transient puff, or a combination of the two depending upon the duration of the release. A continuous release (very long source duration) is treated as a steady state plume. In the case of finite duration release, cloud dispersion is initially described using the steady state plume mode and remains in the plume mode as long as the source is active. Once the source is shut off, the cloud is treated as a puff. Subsequent dispersion is calculated using the transient puff mode.
In the conservation equations are inherently included the mathematical description of the physics of heavy gas dispersion (gravity spread, reduced turbulent mixing, etc.), as well as the description of the normal atmospheric advection and turbulent diffusion processes. The thermodynamics of liquid droplet formation and evaporation is treated by assuming local thermodynamics equilibrium. Transport of the vapor-droplet mixture is treated as a single fluid and neglects gravitational settling and ground deposition of the droplets. The thermodynamic effect of ground heating when the cloud is cooler than the ground surface is also included.

2. SCENARIOS - NUMERICAL EXAMPLES

The following two examples show the different source options and capabilities available in the model. The types of sources illustrated are: a two-phase horizontal and a vertical jet release.

2.1. Scenario 1: Two - Phase, Horizontal Jet Liquefied Petroleum Gas (LPG) Release

In this hypothetically problem, LPG is stored under pressure in the tanker. Hoses being intrinsically unsafe, an unloading arm has been provided to transfer LPG from the ship's manifold to the pipeline. An emergency shutdown system has been provided to stop the operation in the event of an abnormality. This shutdown system has an automatic quick-closing valve (QCV) on the unloading line at the jetty. The closing time was adjusted at 30 seconds to avoid development of surge pressures. Automatic closing of the QCV activates in the event of a sudden pressure drop such as caused by a hose/pipe rupture during pumping. Large release, characterized by a hole with a diameter equal to the hose/pipe diameter, produces a two-phase (liquid droplet-vapor mixture) horizontal jet.

LPG is a colorless, odorless, non-toxic, but extremely flammable liquefied gas. When mixed with air, the gas can burn or explode when it meets a source of ignition. It is heavier than air, so it tends to sink towards the ground. LPG can flow for long distances along the ground, and can accumulate in confined spaces.

The flammable or explosive limits are the limits of concentrations of a gas or vapor that will burn or explode if an ignition source is introduced. The limits are commonly called the "Lower Explosive or Flammable Limit" (LEL/LFL) and the "Upper Explosive or Flammable Limit" (UEL/UFL). Below the LEL/LFL the mixture is "poor" to burn and above the UEL/UFL the mixture is "rich" to burn.

LPG has the LEL of 2.1% by volume or 21000 ppm **(**parts per million) and the UEL of 9.5% or 95000 ppm [2].

The release is of finite duration with the SLAB dispersion calculation extending through the steady state plume regime into the transient puff regime.

2.1.1. Input Data

Input data, one important part, presents in the tables 1 - 4.

Table 1. Spill Parameters

Quantity	Numerical Value	Unit
Initial liquid mass fraction	99.37	%
Temperature of the source material	231.15	K
Mass source rate	200.00	kg/s
Source area	$4.63 \cdot 10^{-3}$	m^2
Continuous source duration	30.00	s
Source height	1.00	m

Table 2. Chemical Properties - LPG

Quantity	Numerical Value	Unit
Molecular weight	44.1	g/mol
Vapor heat capacity	1678.0	J/(kg K)
Boiling point temperature	231.1	K
Heat of vaporization	425740.0	J/kg
Liquid heat capacity	2520.0	J/(kg K)
Liquid density	500.5	kg/m^3

Table 3. Source and Field Parameters

Quantity	Numerical Value	Unit
Source: x – Coordinate	1.87	m
Source: y – Coordinate	-0.43	m
Concentration averaging time	30.00	s
Maximum downwind distance	500.00	m
Height of concentration calcul. 1	0.00	m
Height of concentration calcul. 2	0.00	m

Table 4. Meteorology Parameters (Met. Cond. 1)

Quantity	Numerical Value	Unit
Surface roughness	0.01	m
Ambient measurement height	10.00	m
Ambient wind speed	5.00	m/s
Ambient temperature	278.15	K
Relative humidity	70.00	%
Stability class	4 (D)	-

Spill Source Type: Horizontal Jet Release.

2.1.2. Output Results

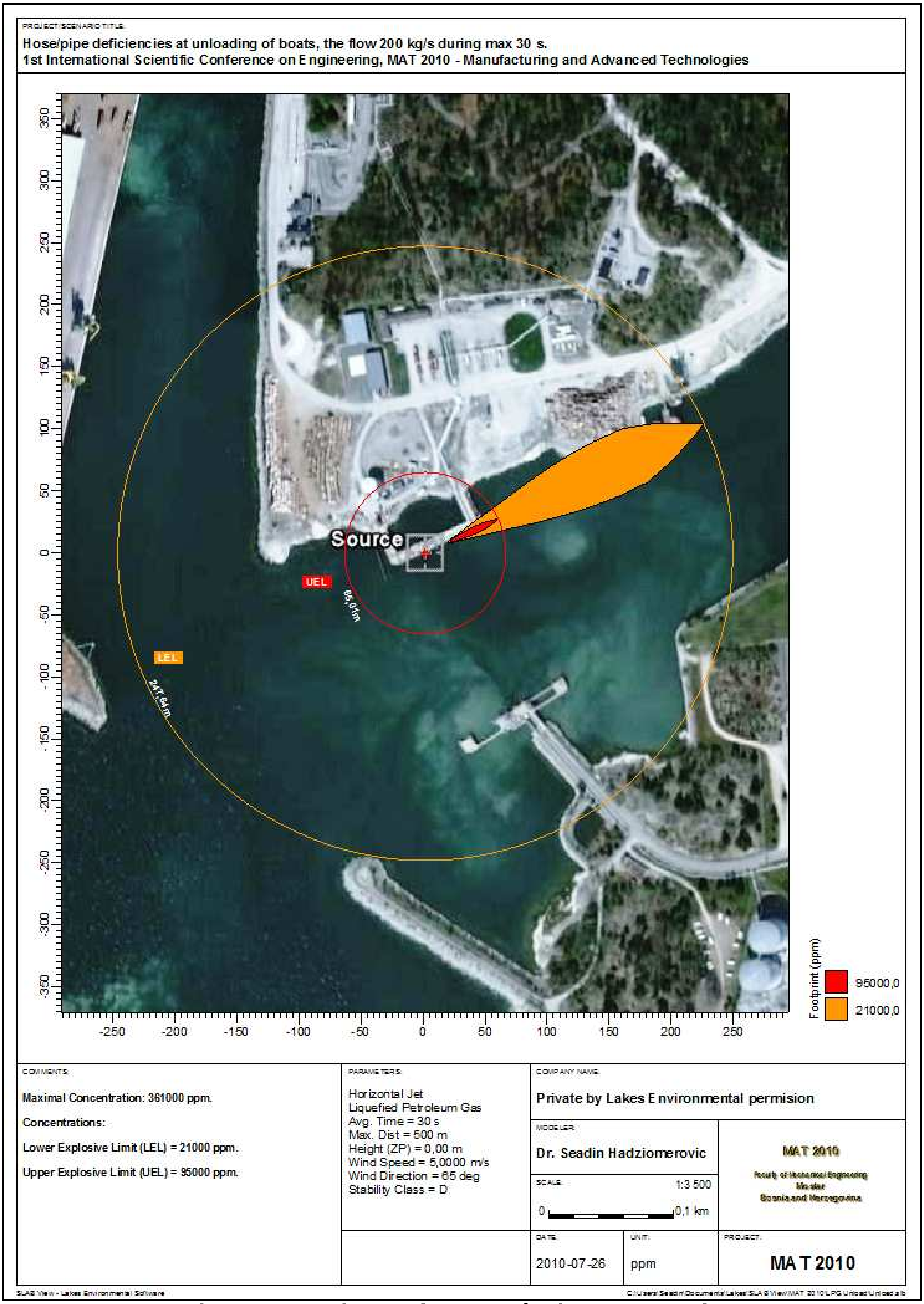

Figure 1. Footprint layout, UEL and LEL risk contours for the LPG terminal. Downwind distance UEL = 65.01 m and LEL = 247.64 m

The user can analyze the graphical and tabular output results. One part of the results showed in the Figures from 1 to 5. The circles in Figure 1 show the zone of risk in case the wind direction isn't 65 degrees.

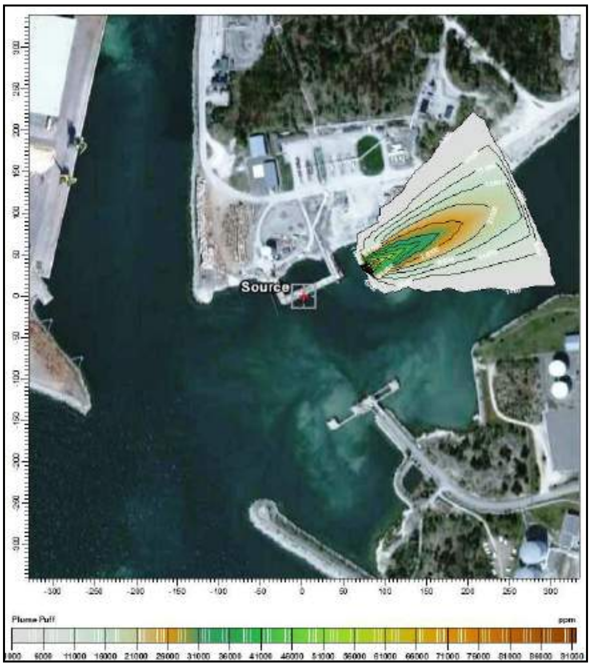

Figure 2. Transient puff level at 33 seconds

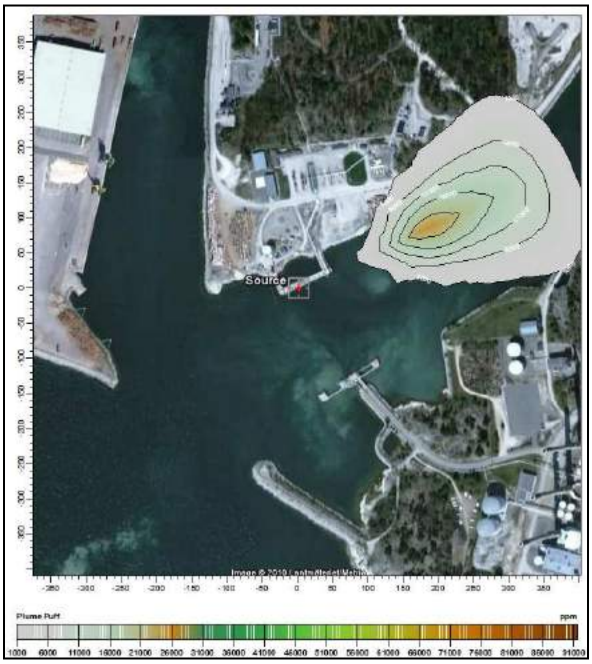

Figure 3. Transient puff level at 45 seconds

Figure 4. Footprint layout, exported to Google Earth.

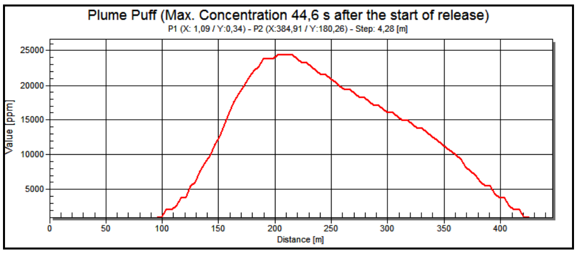

Figure 5. Maximum Concentration along the puff centerline, 45 seconds after the start of release

After running the model, SLAB view displays all the available time-dependent puffs. A puff shows the area impacted at a particular point in time after the release. The user can select from a list at which output time a puff should be displayed.

The data in the table give the results of concentration as a function of coordinates (x, y, z) and time. These data are not presented in the paper because they are too large and serve for detailed analysis.

2.2. Scenario 2: Two - Phase, Vertical Jet Hydrogen Sulfide Release

This is hypothetically problem. Liquefied Hydrogen Sulfide is stored under pressure in the storage tank. The incident scenario is small leak releases, gasket failures or valve failure characterized by the 5.0 mm diameter vertical hole.

Hydrogen sulfide (chemical formula H_2S) is a colorless, flammable, extremely toxic and irritating gas. There are no international health-based standards for H_2S. It has a characteristic rotten-egg odor that is detectable at concentrations as low as 0.02 ppm.

It is shipped as a liquefied, compressed gas.

Hydrogen sulfide is slightly heavier than air and may accumulate in enclosed, poorly ventilated, and low lying areas where it can accumulate in concentrations that can injure or kill livestock, wildlife and human beings. Highly flammable and explosive between 4.3% and 46% by volume in the air, may travel to a source of ignition and flash back [2, 3].

Guidelines:

Time Weighted Average (TWA) and Permissible Exposure Limit (PEL) = 10 ppm (Concentration averaging time = 28800 s; 8 hours per day and 40 hours per week)

Short Term Exposure Limit (STEL) = 600 ppm (Concentration averaging time = 900 s)

Immediately Dangerous to Life or Health (IDLH) = 250 ppm (Concentration averaging time = 3600 s)

2.2.1. One part of Input Data

- Surface roughness height = 0.5 m, - Ambient measurement height = 10 m, - Ambient wind speed = 1.0 m/s, - Ambient temperature = 263.15 K, - Relative humidity Spill Parameters:

- Initial liquid mass fraction = 0.633, - Temperature of the source material = 213 K, - Mass source rate = 0.012 kg/s, - Source Area = 0.357 m^2, - Continuous source duration = 172800 s (48 hours), and Source height = 1.5 m.

Field Parameters:

- Concentration averaging time: TWA = 28800 s, IDLH = 3600 s and STEL = 900 s, - Maximum downwind distance = 600.00 m.

Meteorology Parameters:

= 75 %, - Stability class = 6 (F).

2.2.2. Output Results

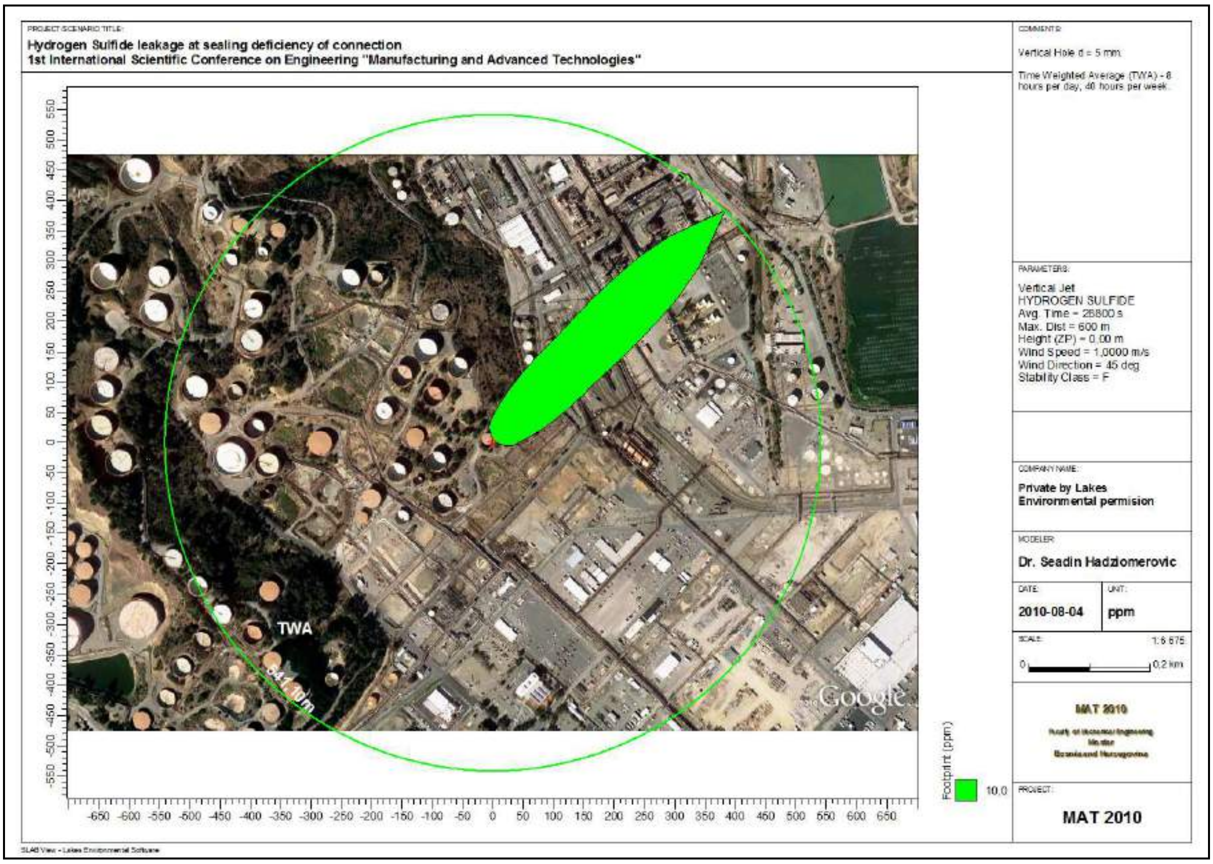

Figure 6. Footprint layout, Risk contours for 10 ppm. Downwind distances: TWA =541.10 m

Figure 7. Footprint layout, Risk contours for 250 ppm. Downwind distances: IDLH = 66.80 m

Figure 8. Footprint layout, Risk contours for 600 ppm. Downwind distances: STEL = 9.20 m

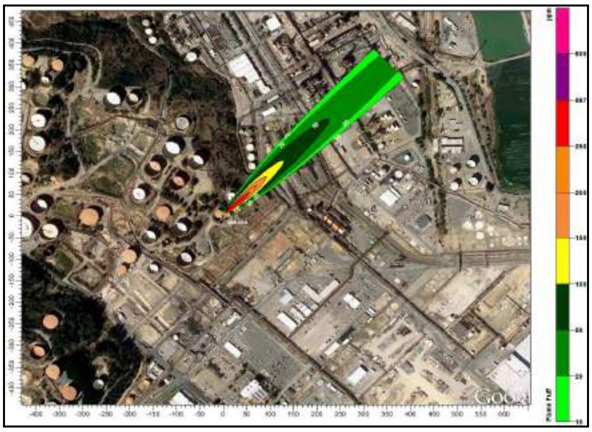

Figure 9. Footprint layout, Transient puff STEL level at 1960 seconds

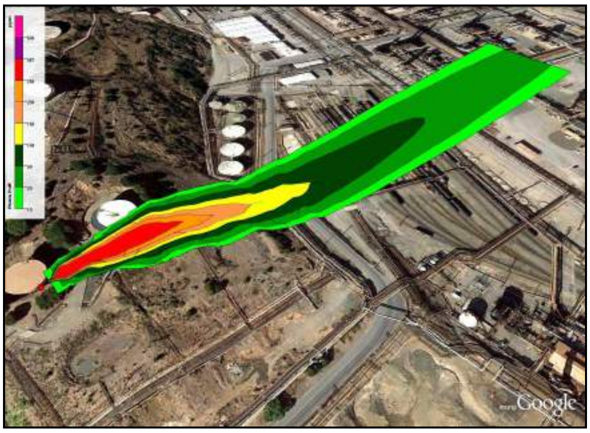

Figure 10. Footprint layout, Transient puff STEL level at 1960 seconds, exported to Google Earth.

3. CONCLUSION

This model and each release scenario were evaluated to determine the level and location of flammable or toxic vapor clouds. Simulations and consequence analysis should continue if starts to burn gas or explode when it meets a source of ignition. This refers to radiation from torch fires, or a BLEVE fireball (Boiling Liquid, Expanding Vapor Explosion) (as applicable); and the extent of overpressure following a vapor cloud explosion.

For a flammable fluid, the possibilities are: -no ignition (If flammable vapor cloud forms but never ignites, there is no hazard); -immediate ignition (If ignition occurs near the beginning of the release, the hazard may be thermal radiation from a torch fire); -delayed ignition (If there is a delay between the start of the release and ignition, a flammable vapor cloud will form. After ignition, there will be a vapor cloud fire -flash fire. If the flammable vapor cloud is contained, or partially contained, within a confined or congested space, the vapor cloud deflagrates after ignition, producing local overpressure).

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1st International Scientific Conference on Engineering
”Manufacturing and Advanced Technologies”
MAT 2010, Mostar, Bosnia and Herzegovina, 18-20 November 2010

ELASTIC-PLASTIC FINITE ELEMENT ANALYSIS OF WELDMENT FRACTURE MECHANICS PARAMETERS

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ABSTRACT

Evaluation of weldment fracture mechanics parameters is complicated fact due to the inevitable heterogeneity of welded joints, either in overmatching or as under matching case.

As the relevant parameters, the J-integral and crack tip opening displacement (CTOD) were chosen and evaluated by the elastic-plastic finite element method in the case of two-dimensional plane strain edge cracked plate loaded by remote tensile stress.

The results obtained in this paper proved that the finite element method provides reliable and efficient procedure for evaluation of elastic-plastic fracture mechanics parameters in the case of two-dimensional problems.

Keywords: finite element, weldment, fracture mechanics parameters

1. INTRODUCTION

FINITE ELEMENT MODELING

Application of the finite element method to the elasto-plastic fracture mechanics problem was in accordance with ESIS recommendations.Thus the quadrangle eight-nodded isoparametric finite elements were used, while the crack tip singularity was modeled by triangular elements with three independent nodes at crack tip and mid-side nodes and mid-side nodes.

The mesh consisted of 1431 nodes and 444 elements, what is enough for the type of problem analyzed and required engineering accuracy.

The stiffness matrix was calculated in every load increment, from remote stress level 100 MPa to 200 MPa (load factor, LF=0.1-0.2, Table 1). Having in mind relatively regular mesh, without significant differences in element size, Gauss numerical integration 2x2 was used. Loading was given in two different ways, producing slightly different results, as shown in Tab. 1 and 2. for bi-linear material curve and in Tab. 3. and 4. for multi-linear material curve. In the first variant, loading was given through displacements, whereas in the second one it was defined through edge forces.

The stress-strain relation was represented also in two different ways - as the bi-linear and as the multi-linear. In the first case two straight line were used with slopes defined by modulus of elasticity (198000 MPa) in the linear elastic range, and by hardening modulus (833 MPa) in the plastic range. The distinction point between these two ranges was yield strength (718 MPa). In the second case 12 points were used, taken from the real uniaxial stress-strain curve. The results for bi-linear curve are given in Table 1 and 3, and in Tab. 2 and 4 for multi-linear curve.

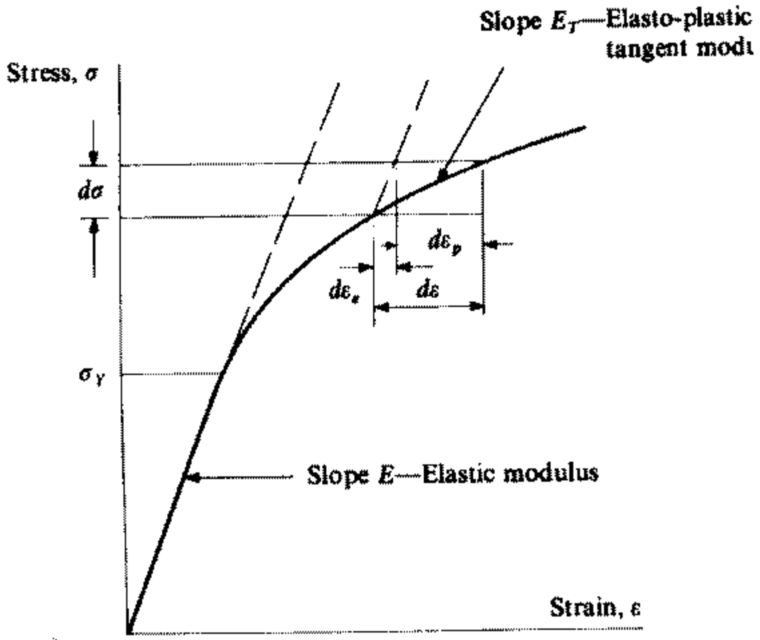

Figure 1. Non-linear stress-strain relation (E_T is the elasto-plastic tangent modulus of the unaxial stress-strain curve, E is the elastic modulus of the material)

Using finite element method it is an easy task to check the J-integral path independency. Toward this end six paths around the crack tip were used and the results given in Tab. 5. As owe can see, the different between J-integral values are not significant and certainly less than numerical error for this type of problem.

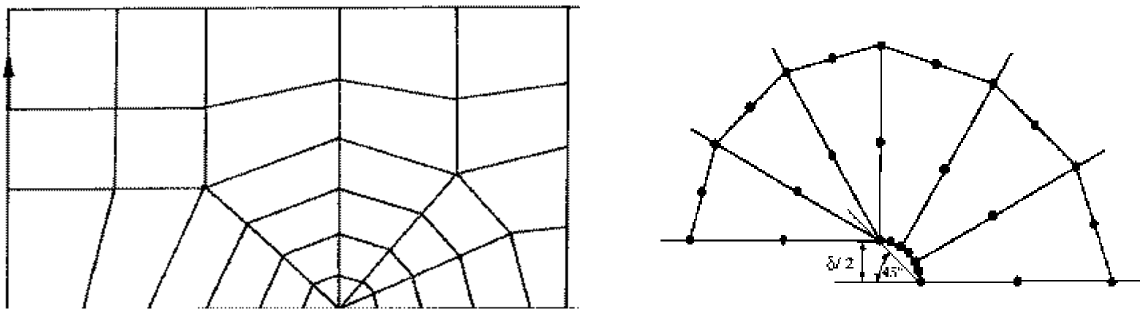

Figure 2. Finite element mesh around crack tip including deformed mesh around crack tip

If problems are investigated, a convergence study with variation of mesh refinement is advisable. “Starting” point in such a study can be mesh similar to the one which is shown in Fig. 2. Also shown in the Fig. 2. is deformed mesh around crack tip with schematic presentation of CTOD graphic evaluation, as applied in this paper. Isoperimetric elements with quadratic shape function (8-noded for 2D, 20-noded for 3D) are recommended. Constant strain triangles are also reliable (in global sense), but not capable of crack blunting modeling. The elements should be rectangular with a side ratio close to 1 in the regions of high strain gradients. Skewed elements should be avoided or, if unavoided, integrated by 3x3 points. In transition region from small to larger elements the side of later one should not be larger more than twice the smaller side of neigh-boring elements. In the case of non-linear problems stiffness reformation and equilibrium iteration at any time step is recommended, as well as a convergence study concering load/time step increments. Usually one increment should be done with not more than 10 iterations. There is a good experience with reduced integration (2x2) for the standard 8-node isoperimetric elements. For special cases (large element deformations, curved, skewed or very fine elements) 3x3 integration is necessary. Nodal point loads often leads to inaccurate deformations. For elastic analysis use collapsed isoparametric, triangle crack tip elements with one crack-tip node and quarter-point midsize nodes. For elastic-plastic analysis use triangle elements with independent crack-tip nodes and midsize nodes lying in the middle. For simulation of crack growth rectangular elements without singularity can be used. It should be noted that the same element size as with collapsed elements leads to stiffer results.

2. RESULTS AND DISCUSSION

For *L.F. (0.10)* CTOD graphic evaluation is shown in Fig. 3 to illustrate procedure applied in this paper.

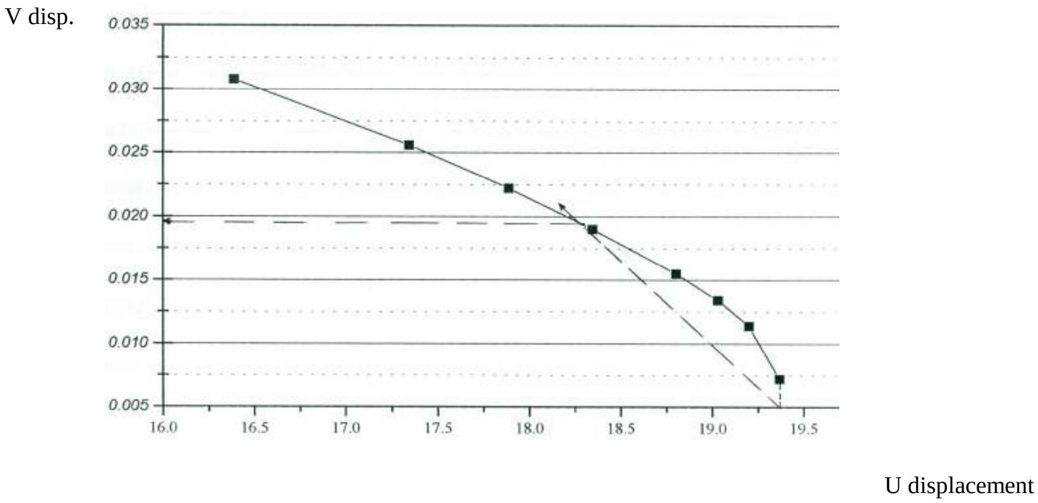

Figure 3. L.F. (0.10) CTOD graphic

The relation between CTOD and J was checked according to eqn. $J = m \cdot \sigma_{YS} \cdot \delta$ and the results are given in Tab. 1 to 4, as ratio m. One can see that value coefficient m becomes constant for higher LF values, which correspond to the plastic strain region. This is in accordance with the fracture mechanics theory, which predicts values for ratio m in range from 1 to 2.6, depending on stress state and material hardening. Namely, the higher values of ratio m are reached for plane strain state and less expressed hardening than for the plane stress and more expressed hardening. ($H = 833\,\text{MPa}$ is relatively small value, with stress-strain slope close to horizontal line, i.e. to ideal plasticity) values for ratio m.
From the results given in Tab 1-2 one can see that for bi-linear material modeling the way of prescribing the loading affects slightly CTOD evaluation procedure, but has almost no effect on J-integral values. Therefore, the values of ratio m are increased when the loading is prescribed by edge forces instead of displacement. Similar situation can be found in the case of multi-material modeling, Tab 3. and 4. If one analyses results for the same way of prescribing the loading and thus follow the influence of material modeling, Tab 1. and Tab 3., as well as Tab 2. and Tab 4. should be compared. In the first case, when the loading is prescribed by displacements, one can notice small increase of J-integral values and slightly more increased CTOD values for multi-linear material modeling compared to the bi-linear material modeling. The same situation can be seen in Tab 2 and Tab 4, so that in both case values of ratio m becomes lower for multi-linear material modeling.

Table 1. The finite element results displacement loading, bi-linear material

L.F.*	CTOD	CMOD	J-INTEGRAL	$m=J/R_{eh}/CTOD$
0.10	0.0178	0.0872	20.40	1.60
0.11	0.0202	0.0969	25.15	1.73
0.12	0.0230	0.1072	30.55	1.85
0.13	0.0260	0.1182	36.40	1.95
0.14	0.0296	0.1300	42.70	2.01
0.15	0.0333	0.1422	49.95	2.09
0.16	0.0377	0.1555	57.45	2.12
0.17	0.0426	0.1682	65.48	2.14
0.18	0.0486	0.1830	75.07	2.15
0.19	0.0553	0.1992	85.95	2.16
0.20	0.0637	0.2175	98.79	2.16

Table 2. The finite element results edge force loading, bi-linear material

L.F.*	CTOD	CMOD	J-INTEGRAL	$m=J/R_{eh}/CTOD$
0.10	0.0175	0.0852	20.41	1.62
0.11	0.0198	0.0948	25.16	1.75
0.12	0.0226	0.1050	30.57	1.87
0.13	0.0255	0.1149	36.42	1.97
0.14	0.0290	0.1270	42.72	2.03
0.15	0.0327	0.1392	49.97	2.11
0.16	0.0371	0.1521	57.47	2.13
0.17	0.0418	0.1646	65.49	2.15
0.18	0.0476	0.1790	75.08	2.16
0.19	0.0542	0.1950	85.96	2.17
0.20	0.0624	0.2130	98.80	2.17

Table 3. The finite element results displacement loading, multi-linear material

L.F.*	CTOD	CMOD	J-INTEGRAL	$m=J/R_{eh}/CTOD$
0.1	0.0188	0.0898	20.40	1.60
0.11	0.0212	0.0999	25.15	1.73
0.12	0.0242	0.1105	30.55	1.85
0.13	0.0274	0.1219	36.40	1.95
0.14	0.0310	0.1340	42.70	2.01
0.15	0.0349	0.1463	49.95	2.09
0.16	0.0396	0.1598	57.45	2.12
0.17	0.0446	0.1732	65.48	2.14
0.18	0.0510	0.1888	75.07	2.15
0.19	0.0575	0.2050	85.95	2.16
0.20	0.0660	0.2225	98.79	2.16

Table 4. The finite element results edge force loading, , multi-linear material

L.F.*	CTOD	CMOD	J-INTEGRAL	$m=J/R_{eh}/CTOD$
0.1	0.0178	0.0872	20.40	1.60
0.11	0.0202	0.0969	25.15	1.73
0.12	0.0230	0.1072	30.55	1.85
0.13	0.0260	0.1182	36.40	1.95
0.14	0.0296	0.1300	42.70	2.01
0.15	0.0333	0.1422	49.95	2.09
0.16	0.0377	0.1555	57.45	2.12
0.17	0.0426	0.1682	65.48	2.14
0.18	0.0486	0.1830	75.07	2.15
0.19	0.0553	0.1992	85.95	2.16
0.20	0.0637	0.2175	98.79	2.16

Anyhow, all differences mentioned above are not significant and certainly are smaller than numerical error usually encountered in such problems. Therefore, one can say that the finite element procedure used in this thesis is completely correct and reliable, enabling precise (at least engineering purposes) evalution of elastic-plastic fracture parameters. Using finite element method it is an easy task to check the J-integral path independency. Toward this end six paths around the crack tip were used and the results given in Tab 5. Difference between J-integral values are not significant and certainly less than the numerical error for this type of problem.

Table 5. Results for J-integral path independency analysis

L.F.*	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6
0.1	19.6	21.0	20.4	20.8	20.4	20.4
0.11	24.0	25.8	25.1	25.6	25.1	25.2
0.12	29.1	31.2	230.5	31.1	30.5	30.7
0.13	34.5	37.0	36.4	37.1	36.4	36.4
0.14	40.2	43.2	42.8	43.8	43.1	43.4
0.15	47.3	50.3	50.0	51.1	50.3	50.8
0.16	54.4	57.7	57.1	59.2	58.4	59.0

3. CONCLUSION

The elastic-plastic fracture mechanics parameters evaluated in this these, i.e. J-integral and CTOD, are not sensitive to calculation technique used. In other words, differences in their values, obtained by changing finite element techniques such as modeling the material behaviour (bi-linear or multi-linear) and prescribing the loading (by remote edge forces and by displacements), are not significant.

The J-integral is path independent, as shown by its evaluation along six different paths, which is another proof of its correct evaluation. All paths were chosen to be in plastic strain region, which is most ″suspicious″ regarding J-integral path independency problem.

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1st International Scientific Conference on Engineering
"Manufacturing and Advanced Technologies"
MAT 2010, Mostar, Bosna i Hercegovina, 18-20 Novembar 2010

ISPITIVANJA FERITNO AUSTENITNIH ZAVARENIH SPOJEVA NA POSUDI POD PRITISKOM, METODAMA BEZ RAZARANJA

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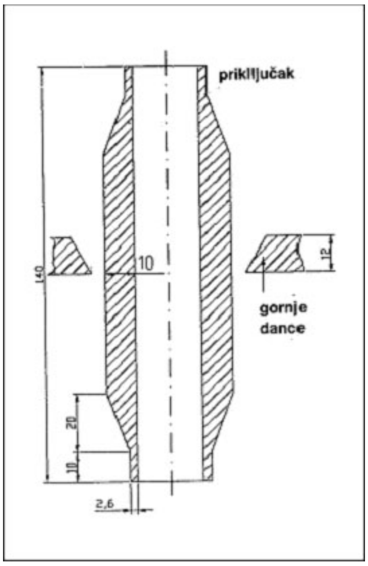
REZIME
U radu je prikazan postupak ispitivanja i ocena kvaliteta zavarenih spojeva novih priključaka ugrađenih u rezervoar za tečni ugljendioksid tokom njegove eksploatacije. Rezervoar je izrađen od mikrolegiranog čelika povišene čvrstoće P460NL1 (nioval 47), a priključci od visokolegiranog austenitnog čelika X6CrNiTi 18 10. Nakon zavarivanja spojevi su ispitani metodama bez razaranja u cilju utvrđivanja njihove eksploatacijske sigurnosti. Priroda materijala feritno – austenitnog spoja nameće ograničenja u primeni metoda ispitivanja bez razaranja, pa je ukazano na potrebu korišćenja dopunskih metoda ispitivanja (tvrdoće, replike), pre svega u cilju otkrivanja prslina u ispitivanim spojevima.
Ključne reči: zavareni spoj, prsline, ispitivanja metodama bez razaranja

1. UVOD
Tokom eksplotacije vertikalnog cilindričnog rezervoara za skladištenje tečnog ugljendioksida ukazala se potreba za ugradnjom, u njegovo gornje dance, dva nova priključka. Ugljendioksid se u ovom rezervoaru skladišti na temperaturama između -30^o i -50^{o}C. I pored spoljne toplotne izolacije rezervoara, ugljedioksid se u njemu zagreva. Usled toga raste isparljivost njegove tečne faze, što onda dovodi do porasta pritiska gasne faze ugljedioksida, koja onda dostiže pritisak pri kome se otvara ventil sigurnosti rezervoara i ugljedioksid se ispušta u atmosferu tj. javljaju se gubici. Na taj način što je viša temperatura u rezervoaru češće je ispuštanje ugljendioksida u atmosferu, odnosno veću su njegovi gubici. Ovi gubici se mogu smanjiti sniženjem temperature u rezervoaru, tj. poboljšanjem njegove toplotne izolacije ili hlađenjem gasne faze ugljedioksida preko unutrašnjeg toplotnog izmenjivača koji je povezan sa spoljnom rashladnom freonskom jedinicom. Da bi se izmenjivač i rashladna jedinica povezali bilo je potrebno da se u gornje dance rezervoara ugrade dva nova priključka. Rezervoar je vertikalna, cilindrična, toplotno izolovana posuda pod pritiskom (PPP), prečnika 2000 mm, ukupne visine 10080 mm i zapremine 25 m^3. Maksimalni radni pritisak u rezervaoaru je 25 bara, ispitni pritisak je 32,5 bara, a najniža rada temperatura je -50^{o}C [1]. Danaca i omotač rezervoara su izrađeni od mikrolegiranog čelika P460NL1 (NIOVAL 47) debljine 12 mm. Proizvođač rezervoara je za izradu priključaka upotrebio visokolegirani austenitni čelik X6CrNiTi 18 10. Za izradu PPP moraju se koristiti čelici koji imaju garantovanu žilavost na najnižoj radnoj temperaturi. Upotrebljeni mikrolegirani čelik zadovoljava ovaj uslov. Međutim, kako se zbog specifičnog postupka proizvodnje mikrolegiranih čelika od njih ne proizvode cevi, a drugi niskougljenični feritno perlitni čelici nemaju garantovanu žilavost na navedenoj temperaturi to su za

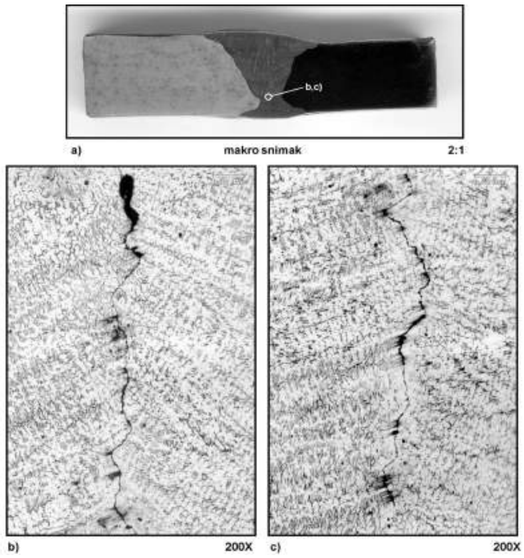
izradu priključaka upotrebljeni austenitni čelici od kojih se proizvode i cevi i koji imaju odličnu žilavost na navedenoj temperaturi.

2. ZAVARIVANJE PRIKLJUČAKA I MOGUĆE GREŠKE

Prema proračunu [2] za radne pritiske u rezervoaru i izmenjivaču, zadovoljavaju priključci prečnika 26,9 mm i debljine zida 2,6 mm izrađeni od čelika X6CrNiTi 18 10. Pošto je teško ostvariti kvalitetan zavareni spoj između materijala sa velikim razlikama u debljinama (debljina danca je 12 mm), usvojeno je da se za dance zavaruju ojačanja debljine približne debljini danca i da se onda za njih zavaruju cevi, slika 1 [3].



Slika 1. Izgled i dimenzije ojačanja priključaka i žleba zavarenog spoja



Slika 2. Topla prslina u austenitnom metalu šava zavarenom elektrodom E 29 9 R 12

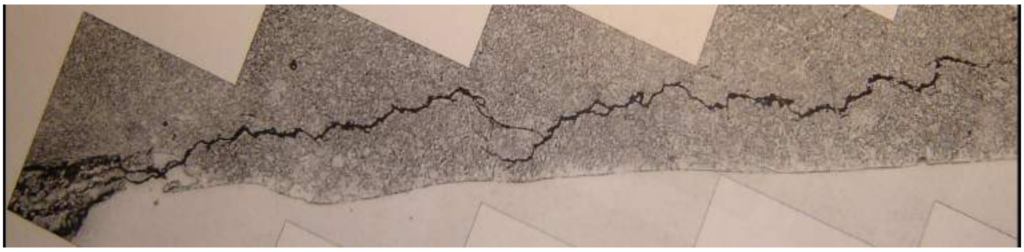
Ojačanja su izrađena mašinskom obradom iz tuljka, prema dimenzijama datim na slici 1. Postupak zavarivanja je opisan u literaturi [3]. Ojačanja su zavarena za dance E postupkom, rutilno obloženom elektrodom legiranom sa 29% Cr i 9% Ni (E 29 9 R 12 prema EN 1600). Žlebovi su napravljeni tako što su gasnim rezanjem, u gornjem dancu, prosečeni otvori prečnika jednakog prečniku ojačanja, a zatim su brušenjem obrađene ivice na zadate mere, slika 1. Pre početka zavarivanja elektrode su osušene na temperaturi 300°C. Materijal danca je predgrejan na temperaturu 230°C. Tokom zavarivanja održavana je međuprolazna temperatura 200 – 220°C. Zavarivanje je izvedeno sa spoljne strane rezervoara, nakon čega su sa korene strane spoja brušenjem odstranjene greške i zavarena su još dva korena prolaza. Nakon potpuno završenog zavarivanja spojevi su održavani na temperaturi 150°C još 1 sat. Pored uobičajenih grešaka, tipa poroznosti, nemetalnih uključaka, zajeda i dimenzionih grešaka, u ovim zavarenim spojevima moguća je pojava i toplih i hladnih prslina. S obzirom da su prsline greške koje najviše ugrožavaju integritet zavarenih spojeva od najveće važnosti je poznavanje mesta, u zavarnim spojevima, sa najvećom verovatnoćom pojave prslina i dimenzija i pravaca prostiranja prslina. To znatno povećava verovatnoću njihovog otkrivanja metodama ispitivanja bez razaranja (IBR).Poznato je da austenitni metal šava (MŠ) pokazuje povećanu sklonost ka obrazovanju toplih prslina. Sa porastom udela δ ferita iznad 5% raste sklonost MŠ ka obrazovanju toplih prslina. U razmatranom slučaju upotrebljeni dodatni materijal (DM) daje MŠ sa oko 25 % δ ferita. Tople prsline se najčešće pojavljuju na mestu dodira dva fronta kristalizacije u jednom prolazu tj. u sredini tog prolaza i dubina im je obično jednaka debljini tog prolaza. Slika 2. pokazuje toplu prslinu otkrivenu u zavarenom spoju između mikrolegiranog i visokolegiranog čelika, u sredini MŠ zavarenog DM tipa E 29 9 R 12. Prslina je otkrivena u sredini korenog prolaza i prostire se duž ose MŠ, a dubina joj je jednaka debljini jednog prolaza. U austenitno feritnim zavarenim spojevima se mogu očekivati i hladne prsline. Mikrolegirani čelik koji je upotrebljen za izradu predmetnog rezervoara pokazuje povećanu sklonost ka obrazovanju prslina u zoni uticaja toplote (ZUT). U konkretnom slučaju sklonost ka pojavi hladnih prslina u ZUT se dalje povećava usled mešanja visokolegiranog DM i niskougljeničnog osnovnog materijala (OM), što na liniji stapanja MŠ i mikrolegiranog čelika može da dovede do obrazovanja zone sa tvrdim i krtim strukturama koje su sklone stvaranju hladnih prslina. Sklonost ka pojavi hladnih prslina povećavaju i veliki zaostali naponi koji su posledica velikih razlika u koeficijentima toplotnog skupljanja dva upotrebljena čelika i upotrebljeni DM, koji zbog rutilne obloge, unosi povećanu količinu vodonika u zavareni spoj što dalje povećava verovatnoću pojave hladnih prslina. Na osnovu iznetog sledi da pri ispitivanju austenitno feritnih zavarenih spojeva, metodama IBR, pažnju treba obratiti, pre svega, na MŠ gde je verovatna pojava toplih prslina i liniju stapanja (LS) sa mikrolegiranim čelikom, gde je verovatna pojava hladnih prslina.

3. PROPISANE I DOPUNSKE METODE IBR I OGRANIČENJA U NJIHOVOJ PRIMENI

Potrebni nivoi kvaliteta za razmatrane zavarene spojeve, metode IBR koje se moraju primeniti i obim njihove primene kao i kriterijumi prihvatljivosti za otkrivene greške su definisani propisima [4] i standardima i navedeni su u literaturi [3]. Propisi predviđaju primenu vizuelno dimenzione kontrole, radiografskog i ultrazvučnog ispitivanja i ispitivanja magnetnim česticama i penetrantima. Međutim, kada se navedene metode primene na razamatrane spojeve javljaju se određena ograničenja koja smanjuju pouzdanost ovih ispitivanja. Mogućnosti primene radiografskog ispitivanja, u ovom slučaju, su ograničene prirodom upotrebljenih čelika i oblikom i dimenzijama spoja. Feritno perlitni i austenitni čelici imaju različite stepene apsorpcije X i γ zraka, zbog čega nije moguće iz jedne eksponaže (snimanja) dobiti jasnu sliku grešaka i u MŠ i u ZUT. Zato se MŠ i ZUT moraju prozračiti dva puta, jedanput sa parametrima prilagođenim austenitnom čeliku, a drugi put sa parametrima prilagođenim feritno perlitnom čeliku. Da bi se dobio radiogram na kome se greške u zavarenom spoju jasno vide, u svojoj prirodnoj veličini i na svojim stvarnim pozicijama, potrebno je da film naleže na površinu ispitivanog komada sa suprotne strane od izvora zračenja. Svako udaljavanje filma od površine materijala izaziva rasipanje zraka zbog čega se smanjuje mogućnost otkrivanja manjih grešaka i deformiše se izgled i položaj otkrivenih grešaka. S obzirom na oblik spojeva priključaka nije moguće obezbediti naleganje filma na površinu ispitivanog materijala pa se zato ova metoda, bez posebnih prilagođavanja, ne može primeniti na razmatrani tip spojeva. Ograničenja u primeni ultrazvučne metode na razmatrane spojeve su uslovljena oblikom i dimenzijama spojeva i prirodom upotrebljenih upotrebljenih čelika. Austenitna struktura i krupno metalno zrno prigušuju ultrazvučne talase (UT), zbog čega prelaz iz feritno perlitne strukture mikrolegiranog čelika u austenitni MŠ i prelaz iz sitnozrne strukture mikrolegiranog čelika u krupnozrnu strukturu MŠ može delovati kao granična površina tj. može reflektovati UT kao greška. Prema tome otkrivanje grešaka u zoni uz LS će biti jako otežano, a upravo ta zona je zona najveće verovatnoće pojave hladnih prslina u ovom tipu spojeva. Tople prsline u MŠ mogu se otkriti ispitivanjem iz unutrašnjosti tj. iz otvora priključka. Ograničenja u primeni penetranata na ispitivani spoj su uslovljena neravninama na ispitivanoj površini nastalim od tragovima brušenja tokom pripreme žleba i neravninama na licu šava. Tragovi brušenja često mogu da prikriju manje linijske greške ili da operator indikacije linijskih grešaka protumači kao tragove brušenja. Tragovi brušenja su pojavljuju u mikrolegiranom čeliku uz LS u zoni gde se može očekivati pojava hladnih prslina. Ograničenja u primeni ispitivanja magnetnim česticama na razmatrani zavareni spoj nastaju zbog nemagnetičnosti austenitnog MŠ. Magnetne linije se, pri nailasku na nemagnetični MŠ, prekidaju što rezultuje delimičnim gubitkom magnetnog polja. Međutim, praktična iskustva pokazuju da se magnetno polje uspostavlja i kada se polovi magnetnog jarma postave u feritni magnetični materijal uz samu ivicu austenitnog nemagnetičnog MŠ ili se postave tako da austenitni priključak bude između polova magneta. Prema tome, austenitni materijal u konkretnom spoju narušava tok i intenzitet magnetnog polja, što onda zbog nepoznavanja pravca i jačine magnetnog polja, smanjuje pouzdanost ispitvanja. S obzirom na ograničenja koja u ispitivanja razmatranih spojeva imaju propisane metode IBR za ispitivanje su, kao dopunske metode, korišćena merenja tvrdoće i ispitivanja mikrostruktura - replike. Tvrdoće se, na PPP, uglavnom mere Poldi metodom. Međutim, pošto je otisak kuglice kojim se meri tvrdoća, po pravilu, veći od širine ZUT nije moguće selektivno merenje tvrdoća pojedinih delova zavarenog spoja pa metoda nije pogodna za njihovo ispitivanje. Veće mogućnosti za merenja tvrdoća zavarenih spojeva pruža prenosni uređaj Mikrodur proizvođača KRAUTKRAMER [5]. Ovaj uređaj meri tvrdoće na osnovu promene rezonantne frekvencije šipke na čijem vrhu se nalazi dijamantska piramida koja se utiskuje u ispitivani predmet. Ispitivanje daje otisak oblika piramide dovoljno malih dimenzija da se mogu selektivno ispitivati pojedini delovi MŠ i ZUT. Za ispitivanje se zahteva polirana površina. Za ispitivnja mikrostruktura i otkrivanje površinskih grešaka u zavarenim spojevima PPP može se koristiti metoda replike. Ispitno mesto se priprema brušenjem, poliranjem i nagrizanjem. Otkrivena struktura se može posmatrati neposredno prenosnim mikroskopom ili se može nanošenjem plastičnog filma – replike dobiti otisak mikrostrikture koji se dalje posmatra pod mikroskopom u laboratoriji. Metoda je posbno pogodna za otkrivanje mikroprslina.

4. REZULTATI ISPITIVANJA ZAVARENIH SPOJEVA PRIKLJUČAKA METODAMA IBR

Zavareni spojevi priključaka freonske jedinice su ispitani metodama IBR u dva navrata, jednom pre, a drugi put posle ispitivanja rezervoara unutrašnjim pritiskom. Parametri i rezultati ispitivanja su dati u literaturi [6]. Vizuelni pregled i dimenziona kontrola su rađeni tokom pripreme za zavarivanje, tokom zavarivanja i nakon zavarivanja. Vrste, broj i veličina grešaka koje se mogu otkriti vizuelnim pregledom, kao i dimenzije zavarenih spojeva su dovedeni u saglasnost sa propisanim veličinama, literatura [6]. Ispitivanje penetrantima je urađeno obojenim penetrantima sa strane lica i sa strane korena spojeva, pre ispitivanja magnetima i ultrazvukom. Ispitani su MŠ, ZUT priključaka i danca i zone širine oko 30 mm od LS u oba OM. Iskustveno je utvrđeno da u ovakvim uslovima mogu da se otkriju prsline duže od 2 mm i pore prečnika većeg od 0,5 mm. Ispitivanjem osim manjih ivičnih zajeda prihvatljive veličine, nisu otkrivene druge greške. Ispitivanje magnetnim česticama je urađeno sa fluorescentnom emulzijom magnetnog praha, krupnoće 3 μm, sa strane lica i korena spojeva. Ispitane su zone u mikrolegiranom čeliku širine oko 30 mm od LS i to pre ispitivanja ultrazvukom. Ispitne površine su pripremljene brušenjem. Iskustvo pokazuje da se pri ispitivanju u navedenim uslovima na grublje brušenoj površini mogu otkriti prsline duže od 2,0 mm, a na fino brušenoj površini prsline duže od 1,0 mm. Ispitivanjem nisu otkrivene nikakve greške. Za ispitivanje ultrazvukom korišćena je eho metoda i kose ultrazvučne sonde (upadni uglovi 45^o i 70^o). Sa strane lica i korena spojeva ispitani su MŠ, ZUT priključaka i danca i zone uz LS u oba OM. U ovim uslovima se mogu otkriti greške koje imaju ekvivalentnu površinu jednaku ili veću od površine greške prečnika 1,5 mm. Ispitivanjem nisu otkrivene nikakve greške. Na oba priključka je urađeno po jedno ispitivanje mikrostrukture metodom replike i to sa spoljne strane rezervoara tj. sa strane lica spojeva. Ispitivanjem su obuhvaćeni mikrolegirani čelik, njegov ZUT i MŠ. Ispitivanjima je utvrđeno da su mikrostrukture grubozrne zone ZUT beinitne. Nije konstatovana pojava martezita. U oba spoja je, u gruborznom ZUT, uočeno više mikroprslina od kojih su dve prikazane na slici 3. Bela površina u donjem delu slike predstavlja nenagriženu površinu austenitnog MŠ. Iznad nje se jasno uočava LS koja razdvaja nenagriženi MŠ i nagriženi ZUT u mikrolegiranom čeliku. Tamne linije u ZUT su mikroprsline. Po njihovom obliku se može zaključiti da se radi o dve hladne prsline od kojih leva završava u grešci na LS. Ukupna dužina ove dve prsline je 1,8 mm.



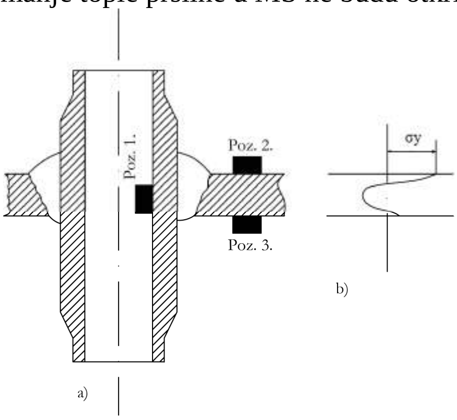
Slika 3. Mikroprsline u ZUT mikrolegiranog čelika

Tvrdoće su izmerene u mikrolegiranom čeliku i u njegovom ZUT, na mestima ispitivanja mikrostruktura na poliranoj i nagriženoj površini nakon uklanjanja replika. Za merenje je korišćen uređaj Mikrodur proizvođača KRAUTKRAMER. Na osnovu razlike u obojenju OM, ZUT i MŠ, tačno su određene lokacije svakog mernog mesta pojedinačno. U OM su izmerene tvrdoće od 166 do 190 HV, a u ZUT tvrdoće 210 do 280 HV [6]. Ove vrednosti ne ukazuju na prisustvo tvrdih struktura i prihvatljive su.Nakon merenja tvrdoća ispitivanja penetrantima su ponovljena na mestima uzimanja replika. Zbog izuzetno kvalitetno pripremljene ispitne površine (stanje polirano) osetljivost metode je veća pa se pretpostavljalo da će i ispitivanjem penetrantima biti otkrivene mikroprsline. Međutim, ovim ispitivanjem nisu otkrivene nikakve greške [6]. Nakon ispitivanja rezervoara unutrašnjim pritiskom ponovljena su IBR, osim merenja tvrdoća i ispitivanja mikrostruktura. Rezultati ispitivanja su dati u literaturi [6]. Rezultati ovih ispitivanja su isti kao i rezultati ispitivanja sprovedenih pre ispitivanja rezervoara unutrašnjim pritiskom.

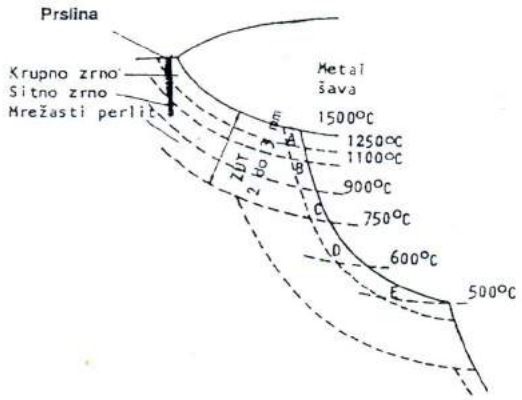
5. ANALIZA I DISKUSIJA REZULTATA ISPITIVANJA

Čelici upotrebljeni za izradu priključaka imaju različitu zavarljivost. Austenitni čelik priključka ima dobru zavarljivost, zbog čega se u njegovoj ZUT ne očekuju nikakve greške. Metal šava je, takođe, austenitne strukture i u njemu se pored uobičajenih grešaka formiranja šava (poroznost, uključci troske, neprovar i sl.)

mogu pojaviti i tople prsline. Tokom zavarivanja vođen je kontinuirani vizuelni nadzor nad radom zavarivača i sve uočene greške su odmah odstranjene tako da se sa velikom sigurnošću može tvrditi da u MŠ nema grešaka tipa poroznosti, nemetalnih uključaka, pa i nalepljivanja. Međutim, tople prsline se ne mogu ragistrovati vizuelnim pregledom pa se mora pretpostaviti da ih ima u MŠ. Pošto je ispitivanje MŠ penetrantima urađeno u uslovima koji ne smanjuju osetljivost ove metode, a prsline nisu otkrivene, može se zaključiti da u MŠ nema površinskih prslina većih od praga osetljivosti metode tj. od 2,0 mm. Međutim, ultrazvučno ispitivanje unutrašnjosti MŠ je urađeno uz određena ograničenja. Najpovoljnija pozicija za UZ ispitivanje MŠ je pozicija 1. na slici 4. zato što je osetljivost ispitivanja tada najveća. To je zato što je, s obzirom na očekivanu orijetaciju prslina, najveća površina refleksije UT, zato što na putu UT nema granične površine austenit ferit i zato što su zbog najkraćeg puta UT gubici zbog prigušenja najmanji. Međutim, ispitivanje sa pozicije 1. ovaj put nije moglo da se izvede, jer je zbog malog unutrašnjeg prečnika priključka morala da se pravi specijalna UZ sonda. UZ ispitivanje je zato izvedeno sa obe površine danca, pozicije 2. i 3. slika 4. Pri ispitivanju sa ovih pozicija UT moraju da prođu kroz graničnu površinu i MŠ. To smanjuje osetljivost ispitivanja zato što refleksija UT od grešaka koje se nalaze u blizini granične površine može da zakloni greške koje se nalaze u MŠ i zbog prigušenja koje izazivaju sama granična površina austenit - ferit i austenitni materijal MŠ. Zbog navedenog se mora računati sa tim da neke manje tople prsline u MŠ ne budu otkrivene tj. da tople prsline postoje u MŠ.



Slika 4. Moguće pozicije ultrazvučne sonde pri ispitivanju MŠ a) i raspodela zaostalih napona po debljini danca b)



Slika 5. Poprečni presek kroz zavareni spoj priključka i položaj prslina u njemu

Ispitivanjem mikrostruktura otkrivene su hladne prsline uz LS MŠ i mikrolegiranog čelika. Za nastanak hladnih prslina potrebni su tvrda i krta struktura, dovoljno velika količina rastvorenog vodonika i dovoljno veliki delujući naponi. Merenja tvrdoća i ispitivanja mikrostruktura ukazuju na prisustvo umereno krte i tvrde strukture sa tvrdoćom manjom od kritične (kritična tvrdoća je 350 HV[7]). S obzirom da su prsline otkrivene pre ispitivanja rezervoara unutrašnjim pritiskom može se zaključiti da su već sami zaostali naponi bili dovoljno veliki da izazovu nastanak prslina. Iz rezultata ispitivanja se vidi da ove mikroprsline nisu otkrivene propisanim metodama IBR. To znači da su veličine manje od praga osetljivosti penetrantske i ultrazvučne metode. Za ispitivanje magnetnim česticama je rečeno da nije pouzdano u ovoj zoni. Odgovor na pitanje da li ovolikih ili većih prslina ima i u unutrašnjosti ZUT može se dobiti analizom potrebnih uslova za nastanak hladnih prslina. Za ovu analizu se može usvojiti da su koncentracija rastvorenog vodonika i mikrostrukture u ZUT jednake po celoj zapremini ZUT. Raspored zaostalih napona po debljini ukrućenog zavarenog spoja je prikazan na slici 4.b. Sa slike se vidi da se zaostali naponi smanjuju i da iz zateznih prelaze u pritisne sa udaljavanjem od površine danca. Prema tome najpovoljniji uslovi za nastanak prslina su na površinama zbog najvećih zateznih napona. Zato je logično da u dubini materijala prsline budu manje i ređe. Pošto površinska prslina ima ekvivalentnu površinu manju od praga osetljivosti ultrazvučne metode može se očekivati da i eventualne pod površinske prsline budu ispod praga osetljivosti odnosno da ne budu otkrivene. Drugo ispitivanje metodama IBR je urađeno nakon ispitivanja rezervoara unutrašnjim pritiskom. Može se očekivati da će dalji rast napona u zoni sa prslinama, izazvan unutrašnjim ispitnim pritiskom, pogodovati nastanku novih i rastu postojećih prslina. Iz rezultata IBR [6] se, međutim, vidi da ovim ispitivanjima nisu otkrivene nikakve greške. Ovo dokazuje da nema prslina većih od praga osetljivosti metoda IBR, ali ne dokazuje da nove prsline nisu stvorene ili da postojeće nisu rasle do veličine manje od praga osetljiivosti metoda IBR. Tople prsline u MŠ se nalaze u materijalu koji ima veću čvrstoću od oba OM i obe ZUT. Zbog toga će se u MŠ javiti mala plastična deformacija čak i pri velikim opterećenjima i pri lomu OM, literatura [7]. Zbog toga ne treba očekivati rast toplih prslina u MŠ pri ispitnom pritisku, tj. ove prsline ne treba smatrati kritičnim. Logično je očekivati da hladne prsline u ZUT počnu da rastu pri porastu pritiska u rezervoaru. Međutim, ovaj rast će biti ograničen zbog smanjenja zbirnih napona i povećanje žilavosti materijala sa udaljenjem vrha prsline od površine. Zbirni napon (napon jednak zbiru zaostalih napona i napona koji su posledica unutrašnjeg pritiska u rezervoaru) se menja, po debljini materijala na isti način kao zaostali naponi, slika 4.b. tj. najveći je na površini i smanjuje se po dubinu materijala. Na slici 5. prikazan je poprečni presek kroz zavareni spoj na kome se vidi da pri rastu prsline njen vrh dolazi u finozrni deo ZUT, a zatim i u finozrnu strukturu OM. Obe ove strukture imaju daleko veću žilavost od grubozrne strukture u kojoj su mikroprsline nastale. Prema tome jasno je da pri rastu prsline njen vrh dolazi u zonu u kojoj se delujući naponi smanjuju, a žilavost materijala povećava, zbog čega će na nekoj dubini rast prsline da se zaustavi. Povoljni uslovi za rast prsline, međutim, ostaju u bočnom pravcu tj. u pravcu povećanja njene dužine. Navedeno je da se radne temperature rezervoara kreću između - 30 i - 50^{o}C. Na ovim temperaturama žilavost materijala se smanjuje, pa se, zbog toga, mora pretpostaviti da je rast prslina tokom eksploatacije rezervoara moguć. Pošto otkrivene mikroprsline nisu ocenjene kao opasne rezervoar je pušten u eksploataciju, ali je naloženo da se u određenim vremenskim intervalima metodama IBR prati njihov rast i pojava novih prslina.

6. ZAKLJUČCI

Imajući u vidu ograničenja u primeni metoda IBR treba istaći značaj neposrednog vizuelnog nadzora nad radom zavarivača, koji se u praksi kao metoda za obezbeđenje kvaliteta zavarivačkih radova nedovoljno koristi. Ovim nadzorom se mogu eliminisati greške koje se kasnije metodama IBR teško otkrivaju. Propisane metode IBR imaju ograničenja u primeni na feritno austenitne zavarene spojeve priključaka, koja su uslovljena oblikom i dimenzijama spojeva i prirodom austenitnog i ferinog čelika u spoju. Zbog toga se greške u ovakvim zavarenim spojevima mogu otkriti samo kombinacijom više metoda IBR, odnosno pored propisima predviđenih metoda potrebne su i dopunske metode. Pri definisanju postupka IBR, uvek treba poći od pretpostavke da zavareni spojevi sadrže greške i među njima i prsline kao najopasniji vid grešaka. Pitanje otkrivanja ovih grešaka se svodi na verovatnoću njihovog otkrivanja. Da bi se povećala ova verovatnoća, potrebna je prethodna analiza mogućih tipova grešaka u pojedinim delovima spoja. Time se definišu mesta najveće verovatnoće pojave grešaka koja, pre svega, treba da budu predmet ispitivanja, primenljive metode IBR i uslovi ispitivanja. Treba istaći da pouzdanost ovih ispitivanja jako zavisi od predznanja i iskustva operatora.

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1st International Scientific Conference on Engineering
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HIGH TEMPERATURE WELDED JOINTS INTEGRITY

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ABSTRACT
The techniques for assessing residual lifetimes of power plants welded components can be expensive if they involve prolonged plant shut-downs. Inspections of components can be destructive or non-destructive and are depending on component geometry, accessibility and nature of the damage anticipated. From a residual life assessment analysis we may either confirm the original expected plant life or may demonstrate that a prolonged useful life is possible or remedial action is required.
Keywords: T/P91 steel, welded joints, residual lifetime

1. INTRODUCTION
In last two decades the necessity for higher thermal efficiency of fossil fuel power plants leaded to development of new materials. The uses of such steels enable increase in stem temperature to 625°C. Scientists world wide put their highest hopes into modified 9%Cr ferritic alloys based on T/P91 (X 10CrMoVNb9-1) which resulted in alloys T/P92 (Japanese Nf 616) and E911 (European X 11CrMoWVNb9-1). Those materials are used in temperature range of 585°C to 625°C especially at thick walled components such as headers and main steam pipe in boilers.
Providing higher steam parameters lead to increased requirements for materials of water wall tubes which can no longer be made of 13CrMo4-4 steel or of T11/T12. Besides higher creep-rupture parameters, the design of water wall tubes also necessitates such welding properties where post weld heat treatment (PWHT) will not be needed. Because of that new requirement, T/P23 steel (HCM2S in Japan) and T/P24 (7CrMoVTiB10-10) are developed by Vallourec & Mannesmann, [1]. In addition the fact that they are suitable as boiler tubes materials, they are also alternative to the martensitic 9%Cr steels for heavy-wall high pressure piping systems operating in temperature ranges from 500°C to 550°C.
To illustrate the potential high economic importance of new material developments for advanced fossil fuel power plants, both for the refurbishment of existing power stations and for new constructions with conventional steam parameters, some of main technical and economic benefits is stated, [1]:

- reduction of wall thickness of components, the dimensions of which restrict the temperature transients during the start-up and shut-down of the power station;
- shorter shut-downs because of the faster cooling down of piping systems, earlier beginning of necessary repairs;
- reduction of forces and moments acting upon the steam boiler outlet and the turbine inlet;
- lower costs of piping supports and reduction of the loads on the steel work.

2. RESIDUAL LIFE ASSESSMENT

A lot of power stations components are made-up by welding. Because of their regions of different microstructure and because of the possible presence of residual stresses, welds can pose a particular problem. The base material (BM), heat-affected zone (HAZ) and weld metal (WM) have different creep properties and it may be necessary to determine the characteristics of each. Welds are also likely sites for defects, [2].

The welded joints integrity is of great importance because of many aspects, especially when the safety and economy of power stations operation is about. In terms of design, the main problem occurs with pressure vessels welded joints, particularly in petro-chemical industry where welded vessels are simultaneously subjected to aggressive environments and loading. In the same time they are expected to endure the 30 years and longer lifetimes. Those pressure vessels are often subjected to high operating temperatures where creep causes formation of internal cavities which limit the component lifetime.

During welded joint integrity assessment, several fields of uncertainties develop. Most of them refer to fabrication of welded joints, inspections, variations of material properties in the welded joints region at nozzle intersections both during welding and after heat treatment. Each of these factors results in uncertainties not only for some vessels but in each vessel. Besides, welded joints inspection methods cannot give reliable results especially in case of inaccessible T-joints. Codes of Practice usually avoid these uncertainties incorporating expression "safety" during design process to allow for uncertainties in future operating conditions and for the variability in material properties, [3].

The avoidance of excessive creep deformation and preventing fracture are two main high temperature design considerations. In most industries these objectives are achieved by the application of design codes such as BS 1113: 1989, BS 5500: 1991, RWTÜV (1978)-TRD 508, ASME 1990 and AFCEN 1985. These codes incorporate procedures for specifying maximum acceptable operating stresses and temperatures. The maximum values allowed depend upon the type of component and the consequences of failure, [2].

The extents of the safety factors are determined by experience and are dependent whether average or minimum properties data are employed. Different safety factors may also be applied to normal operating conditions, frequent, infrequent or emergency excursions.

Because most high temperature design codes are developed from codes produced from room temperature applications, they are meant at avoiding failure by plastic collapse, fatigue, fast fracture and creep. It is possible to define temperatures, which vary somewhat between codes because of different procedures employed, below which creep need not be considered for particular classes of materials. An approximate guide to some of these temperatures is given in Table 1, [2]. More precise values should be obtained from the relevant codes.

Table 1. Temperatures below which creep is not usually of serious concern in boiler and pressure vessel components

Carbon manganese steels	310°C
Low alloy ferritic steels	420°C
Stainless steels	485°C

3. NEW HEAT-RESISTANT MATERIALS PROPERTIES

In order to improve creep rupture strength of T/P9 alloy, the elements V, Nb and N are added. T/P91 steel is used in the normalized and tempered condition. Normalizing is performed in temperature range from 1040°C to 1080°C. For wall thicknesses up to 80 mm, air cooling after normalization is enough to achieve a fully martensitic structure, Fig. 1. For higher wall thicknesses accelerated cooling is required in order to avoid ferrite fractions. After normalization, the tempering at 750°C to 780°C is required to reduce high martensite hardness of even 480 HV10. During tempering, chromium carbides of type $M_{23}C_6$ as well as fine V/Nb carbonitrides are precipitated which stabilize the martensitic structure. That affect positively at the long-term strength. The further hardening effect is obtained by fine distribution of V/Nb carbonitrides, [1, 4].

T/P91 steel properties are suitable for cold- and hot-operating conditions and can be welded by all current processes. But for martensitic structure of the material, hot-bending must be followed by complete new normalization and tempering treatment in order to re-establish the original martensitic structure. As a result of temperature cycle during welding, in WM and nearby HAZ the increase of local hardness occurs. This increased hardness must be reduced by PWHT which has to be performed in the tempering temperature range. In order to achieve a most favourable martensitic structure, the first step must be a full martensitic transformation of the weld which can be obtained by cooling the weld down to less than the martensite finish temperature M_f which is approximately 100°C, but always prior to PWHT, Fig. 1. Optimized material properties are reached in the tempering temperature range from 750°C to 765°C. Speaking of impact toughness, even BM has the high value-from 80 to 200 J, which shows that T/P91 steel offers the same toughness as T/P22 (10CrMo9-10). This is an advantage for dissimilar welds with low-alloyed steels, [1].

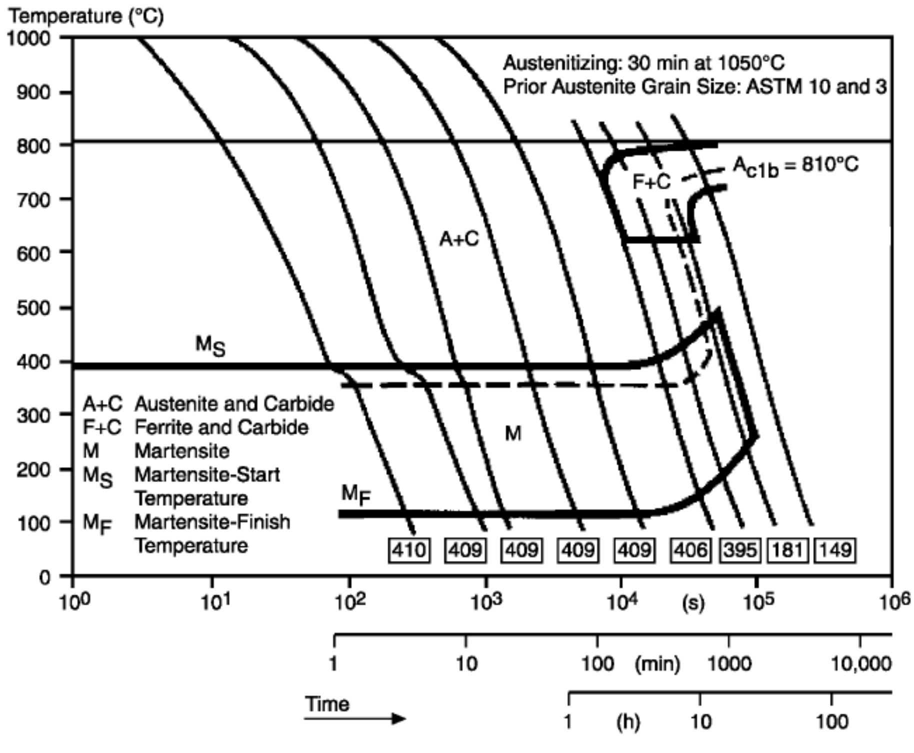

Figure 1. Time-temperature-transformation diagram of P91 steel

The techniques for assessing residual lifetimes can be expensive if they involve prolonged plant shut-downs.

Inspections of equipment can be destructive or non-destructive and are depending on component geometry, accessibility and nature of the damage anticipated. For example, to indicate overall creep deformation, the dimensional changes can be used; plastic replication can be applied for local surface texture examinations and to determine the extent of voiding and /or microcracking as illustrated in

Fig.2, [2]. This figure shows how creep damage in steam boilers can be classified (RWTÜV (1983) according to TRD 508) into four levels of severity. Level A represents isolated creep cavities, B oriented cavities, C microcracks and level D represents macrocracks. Depending on the level observed, the following courses of action are recommended:

1. Level A — continue to operate plant but monitor damage at 3 year intervals,
2. Level B — continue operation but fix inspection intervals at 1.5 years,
3. Level C — limited services possible until repair
4. Level D — repair immediately.

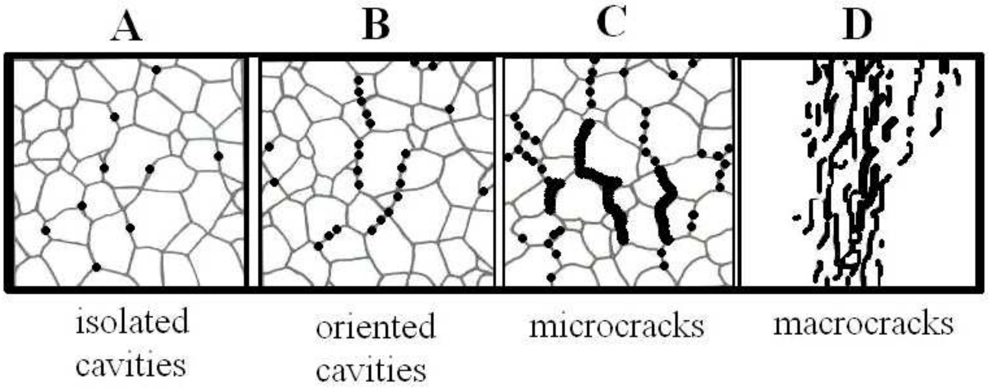

Figure 2. Classification of creep damage in steam boilers

4. CONCLUDING REMARKS

From a residual life assessment analysis we may either confirm the original expected plant life or may demonstrate that a prolonged useful life is possible or remedial action is required. Remedial action means:

-replacement of the part,
-repair of the part
-or change to the operating conditions.

In case of repairing a part it is necessary that all the damaged material is first removed and that welding is only contemplated in BM with adequate weldability. Modifications to the operating conditions can involve more gradual start-up and shut-down procedures to reduce the risk of thermal fatigue and lower the stresses and temperatures to limit further creep damage.

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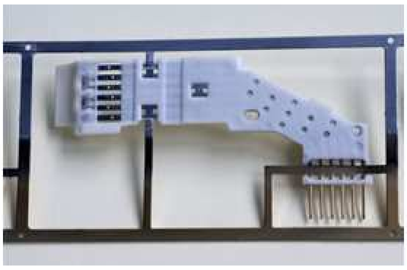


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▫*gipsarske radove* - montažu Rigips i Knauf ploča, obrada površina prema vašoj želji, ugradnja spuštenih i profilisanih plafona

▫*ugradnju stolarije* – klasične, aluminijumske, PVC

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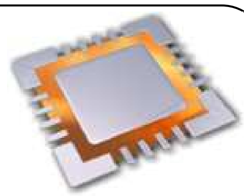

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Fakultet informacijskih tehnologija je trenutno u fazi planiranja šeste internacionalne konferencije. ICITA 2011 će se održati u Mostaru, Bosna i Hercegovina. ICITA 2011 će spojiti znastvenike, istraživače, inžinjere i student doktorskih studija da razmjene iskustva, ideje i rezultate istraživanja o svim aspektima informacijskih tehnologija. Više informacija možete naći na web stranici konferencije: http://icita.web.officelive.com.
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