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Our cover story this month deals with the development of Acura's striking ARX02a, which competes in the American Le Mans Series LMP1 class. The product of Wirth Research, the new car incorporates a host of innovative features, including the same size front and rear tyres and, predictably enough, bearing in mind Nick Wirth's Formula 1 background, a highly developed (and very dramatic looking) aero package. The Acura also clearly has pace, as the petrol-engined car claimed pole position at this year's 12 Hours of Sebring – its first event – and went on to win its second race, at St Petersburg, albeit without the Audi R15 and Peugeot 908HDi FAP diesels in attendance.

Unfortunately though, for European-based devotees of the Sports Prototype scene, the Acura LMP1 is not scheduled to venture outside of North America this year, and some observers even predict that the programme may be terminated by parent company, Honda, at the end of the current season, a victim of the sales slump in the global automotive industry and a lack of suitably high-level opposition in the American Le Mans Series.

Let us therefore fervently hope that the first signs of 'green shoots' in the US economy observed recently by President Obama turn out to be just that, and not a case of wishful thinking, for it would be disappointing in the extreme should a car so apparently full of competitive promise as the Acura disappear after just a single season. The thought of factory cars eventually appearing at Le Mans, competing against the likes of the Audis, Peugeots and Aston Martins is definitely a mouthwatering one.

EDITOR
Graham Jones

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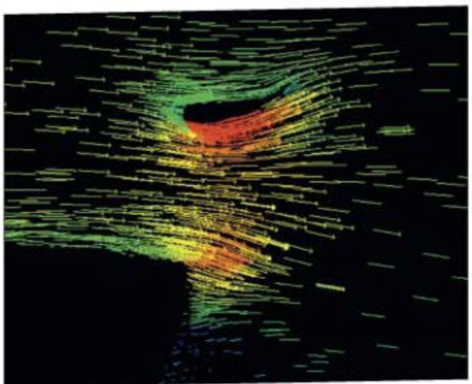

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The International Journal of Motorsport Technology
Racecar engineering

EXTRA INSIDE THIS MONTH

Stockcar Engineering section and FREE racecar manufacturing supplement

INDUSTRY

European grids still strong in face of downturn

Racecar Engineering survey points to credit crunch-busting racing scene

THE WORLDWIDE RECESSION has yet to significantly hit professional racing formulae in Europe. That's the finding of a *Racecar Engineering* survey based on grid sizes across a selection of high profile British and European championships.

By comparing the health of a cross section of racing championships year on year – 2008 to 2009 – *Racecar* found grids either level with last year or just slightly below, while some are even up on '08.

Perhaps the most surprising result – particularly in the light of the emergence of low cost alternatives such as the all-new Formula 2 – is in Formula 3, often cited as a barometer for the state of the motorsport industry. The Euro Series, for instance, has attracted 29 entries, which is the same as '08, with more demand for spaces on the Euro grid than there was last year. 'We could have had more teams,' a spokesperson for promoter ITR, said. 'More applied than last year but we had to tell some teams there was not the space for them.'


LAT

Packed entries across Europe signal a healthy year ahead for motor racing

The situation is not quite so rosy in British F3 but, with a grid still in the 20s (down by five) and some more cars thought to be on their way, things are still looking strong. Stephane Ratel, chairman of British F3 promoter SRO, said: 'For 2009 we have an exceptional line up of young talent and we are expecting more to join the series very soon. British F3 is a fantastic environment for young drivers to develop their skills, not only in racecraft but, importantly, their ability to work with race engineers to improve their performance.'

Racing seems to be in rude health at entry level too, with the British Formula Renault Championship attracting 26 entries, an amazing six *up* on last year. On this, Formula Renault UK Championship manager Simon North had this to say: 'Despite the current economic climate, we have more registered drivers than last year, which is testament to the reputation of the championship as a cost-effective single seater series.'

Perhaps an even more positive sign for the industry is the continued success of British Formula Ford, which has run with the new Duratec 1600 engine since 2006. For while it's attracted 24 cars, just one down on 2008, it also boasts seven chassis manufacturers: Mygale; Van Diemen; Ray; Spirit; MTEC (a development of last year's Comtec); Juno and Spectrum – which must bode well for a racecar manufacturing industry hit by a proliferation of spec formulae over the past decade.

As far as Touring Cars are concerned, the British Touring Car Championship has bounced back from the shock withdrawal of works team SEAT at the end of 2008 and 20 cars lined up for the first round of the championship, just four down on 2008, while a spokesman for the German DTM series says it expects the same sized grid as last year.

It's not all good news, however, and grids are down some 50 per cent in British GTs, a championship that relies heavily on wealthy 'gentlemen' racers.

SPORTSCARS

2009 Sportscar roundup

ACCORDING TO REPORTS on both sides of the Atlantic Panoz is in the advanced stages of designing another LMP1 chassis that, like its last, is to be front engined. There are also suggestions that the car will be motivated by butanol, a bio-fuel made from algae.

Meanwhile, Aston Martin's Lola LMP1 coupé made the best possible debut when it won the first round of the Le Mans series, while Audi's R15 took the spoils in the Sebring 12 Hours. However, the legality of Audi's all new Le Mans challenger has since been called into question by its rivals. The main area of dispute is the car's front aerodynamic package, and in particular a flap above the front splitter that rivals claim turns the splitter into an illegal front wing. Openings on the R15's engine cover and the grilles on the sidepods have also been cited as questionable.

Elsewhere, there now seems little possibility that the Acura ARX-02a (see cover story on p12) will ever compete in the Le Mans 24-hour race. Honda Performance Development's boss has said, however, that the next generation of the Acura (after new LMP1 rules come into place in 2011) may well be entered in the French classic.

Finally, the number of confirmed entries for the end of season Asian Le Mans Series – a new two-event championship with incentives aimed at attracting competitors from Europe and the USA – has increased to a healthy 28 cars, while next year's proposed GT1 world championship will run to a format of two one-hour races, possibly without refuelling stops, except for the Spa 24 Hours.

FORMULA 1

Diffuser dispute defused

+ NEWS EXTRA
www.racecar-engineering.com

LAT

Expect to see a raft of double-decker diffusers appearing on cars as the season progresses

THE FIA COURT of Appeal has declared the so-called 'double-decker' diffusers, as used on the pace-setting Brawn cars this year, to be legal, rejecting protests lodged by Ferrari, Red Bull, Renault and BMW Sauber.

The dispute involved the legality of the diffusers on the Brawn, Williams and Toyota cars, all of which feature extra apertures to increase the airflow through the car, and hence the generation of downforce, at the rear of the racecars.

The seven teams not to have fitted a double-decker diffuser will now almost certainly modify their cars to run with them, or at least something similar, while the Brawn GP (formerly Honda) team will be able to build upon a stunning start to its first season.

Brawn boss Ross Brawn said of the outcome of the appeal: 'We are pleased with the decision reached by the International Court of Appeal today. [And] We respect the right of our competitors to query any design or concept used on our cars through the appropriate channels available to them.'

He added: 'The FIA Technical Department, the stewards at the Australian and Malaysian grands prix and now five judges at the International Court of Appeal have confirmed our belief that our cars have always strictly complied with the 2009 Technical Regulations.'

BRIEFLY...BRIEFLY...BR

MAX TORQUE

FIA president Max Mosley has been talking about the possibility of a single, base 1600cc engine to be used across F1, WRC and WTCC. The idea is that the same engine would be used in all the FIA championships, with turbocharging used to adjust the power outputs to suit. Mosley admits that the idea is very much in its early stages and if it did happen it would not be until the 2013 season.

ONE SIZE FITS ALL...

Audi is also looking at a multi-role engine, in this case the new, turbocharged, 2.0-litre powerplant likely to become its new engine for Indy Car in 2012. Audi Sport engine boss Ulrich Baretzky has been quoted as saying that his 'dream' is that the engine could be used as a base for much of the VW Group's motorsport efforts, pushing out anywhere from 200bhp to 700bhp with turbocharging, and used in F3, LMP and other formulae.

DC JOIN BLOODHOUND GANG

DC Electronics has been announced as an official product sponsor of the Bloodhound project. David Cunliffe, director and co-founder of DC Electronics, comments on his thinking behind the brief: 'Being an ex-Royal Air Force apprentice, this is the perfect project for me. I know my way around the airframe and engine wiring systems that will be used to control the jet engine, and we will wire the rest of the vehicle in the same way we would a Formula 1 car.

PETTY AT INDY

NASCAR legend Richard Petty is to enter a car in this year's Indianapolis 500. The seven-time Cup champion will run the car, to be driven by John Andretti, in his traditional blue and red livery, complete with the iconic number 43. Dreyer & Reinbold Racing will help to run the Petty Dallara-Honda at the brickyard.

SEEN COMING SOON IN AEROBYTES...

***Racecar* has been at MIRA's full scale wind tunnel again, this time with a Formula 1 car and some fascinating new flow visualisation techniques. The full story will follow in coming issues**

Simon McBeath

INDUSTRY

Government support will help all, says MIA

New financial package from the UK Government aims to kick start the UK automotive sector

THE MOTORSPORT INDUSTRY Association (MIA) insists that the UK Government's moves to help larger automotive businesses to secure investment will have a positive knock-on effect throughout the industry.

The new Automotive Assistance Programme was recently announced by BERR (Department of Business Enterprise and Regulatory Reform), in the light of continued financial pressure on the motor industry during the global economic downturn. It is a £2.3bn scheme to facilitate loans and loan guarantees (with a minimum of £5m) to the automotive sector, which includes the supply chain and companies in motorsport and high-performance engineering that have a turnover of more than £25m. The scheme has recently been cleared by the European Commission and is now awaiting applications (go to www.berr.gov.uk for further details).

MIA CEO Chris Aylett said: 'This new scheme from BERR will help and encourage our larger UK motorsport companies to move ahead with major investments, which may have been held back due to the current economic climate and a lack of confidence or availability of finance.'

But Aylett added that he did not think that this will just be of benefit to the larger UK motorsport companies: 'All engineering companies in Motorsport Valley UK, both large and small, will gain from the trickle down from such investments and the global business and work they will be able to generate.'

Also included in the package is a particular emphasis on environmental projects, Aylett said, such as low carbon solutions: '...which plays to the strengths of our motorsport community, and the growing green motorsport initiatives led by the MIA.'

INDUSTRY

Full steam ahead...

THE BRITISH STEAM Car team has been out testing the projectile it aims to use to break the century-old world land speed record for steam-powered vehicles.

Despite weighing around three tons, the British Steam Car is made from a mixture of lightweight carbon fibre composite and aluminium wrapped around a steel spaceframe chassis. Into this is fitted 12 boilers containing nearly two miles of tubing. De-mineralised water is pumped into the boilers at up to 50 litres a minute and the burners produce three megawatts of heat. The steam, superheated to 400deg C, is then injected into the turbine at more than twice the speed of sound.

Commenting on the recent test, project manager Matt Candy said: 'Today marked the first time the car has started in superheated steam and gave both the start team and the turnaround team the chance to get some valuable practice, so it has been a great day. We've got some cooling issues to address before we go out [to the US] but other than that we are good to go and hope to come back with the record.'

The run, at the Ministry of Defence's Thorney Island facility in Emsworth, Hampshire was the final time the car was being tested publicly before it is shipped out to the US for the record attempt. It will depart from Portsmouth in May.

The car reached speeds of over 80mph during the test and the team hope to break the 103-year-old record by improving on the 127mph reached by American Fred Marriott driving a Stanley steam car in 1906 at Daytona. It is the longest officially recognised land speed record and the British team hopes to smash it by reaching somewhere around 170mph with its new car.

With 12 boilers and three megawatts, the British Steam Car aims for a century-old record


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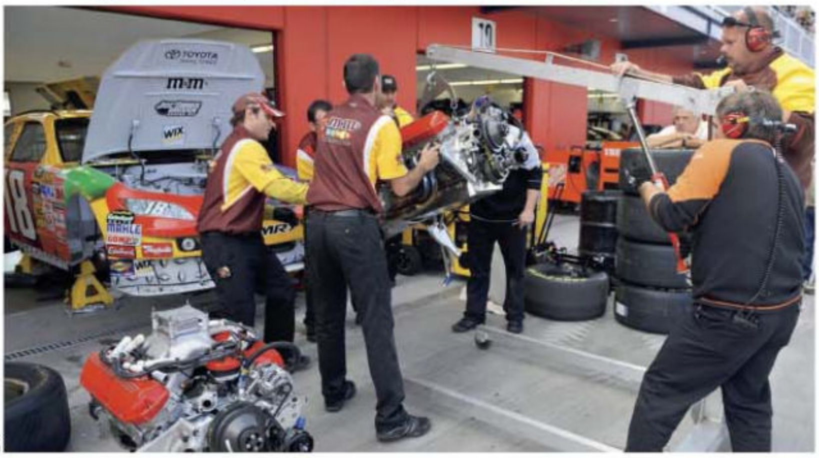
NASCAR

Engine spec checks change

New regulations posted for post-race inspections



LAT

The process is the same, but the venue is different for 2009 engine verification checks

NASCAR HAS CHANGED its post-race inspection process with regard to engines. In the past the two top finishers, plus one random car, have had their engines inspected after the end of the race. The process has involved engines being torn down by the team's engine builders, while NASCAR look on and inspect the parts for legality. Under the new regulations, the three selected teams will remove the engines at the track as before, but tear down will take place at the NASCAR R&D Center in Concord, North Carolina the week after each race. Again, team engine builders will disassemble the engines under NASCAR's scrutiny.

The idea behind the move is to save money and time at the race track, where tear down procedures can last for hours. Body and chassis inspection, however, will continue at the track.

CAUGHT

Both of the Toyota F1 cars were excluded from qualifying for the Australian Grand Prix after they failed a horizontal load test on the rear wings. Toyota insisted this made little difference to the car's performance, and the team went on to score third and fourth place in the race with suitably modified wings, despite their relegation to the back of the grid.

PENALTY: SENT TO BACK OF GRID

The Red Bull F1 team was fined after it allowed its charge, Sebastien Vettel, to continue to drive on track during the Australian Grand Prix without a front wheel – which was dragged along the track by the wheel tether – following the German's collision with BMW's Robert Kubica as they fought for second place late in the race.

FINE: $50,000 (£33,750)

VSI Racing NASCAR Nationwide crew chief Andy Punch has been fined, suspended for four events and placed on probation until the end of the year for infractions to do with fuel irregularities, which were discovered before the Bristol Motor Speedway event. Team owner Frank Varischetti was also penalised, with the loss of 50 owner points, while driver Benny Gordon was docked 50 points.

FINE: $10,000 (£6755)

PENALTY: 50 POINTS DEDUCTED (OWNER AND DRIVER)

NASCAR

Petty continue to race with R5

RICHARD PETTY MOTORSPORTS (RPM), formerly Gillett Evernham Motorsports, are continuing to race the R5 Dodge engine for the foreseeable future, while its Dodge competitor, Penske Racing, is having great success with the R6, even winning a Sprint Cup race this season.

'We are using the R5P7 right now, while the R6P8 engine is still in development with us,' commented Mark McArdle, vice president and director of competition for RPM. 'We look at it as a risk/reward issue and, right now, we think it is a little bit risky considering the situation we are in with our teams. We like what we have right now. We are making decent performance numbers with the new engine and trying to develop a level of reliability into it that we have in the R5. It's our position that in the first third of this racing season we can't afford the risk of giving away any points, so we are going to be very conservative in what we do. We are still keeping our options open with regard to our utilisation of the R6P8. When we deem it wise to race it, we will. It's likely you will see us compete with it at some point this season, but to what level of commitment we haven't yet decided.'

LAT

The Dodge R5 will remain in service for the foreseeable future, while the R6 is developed

BOOKS

Porsche 908

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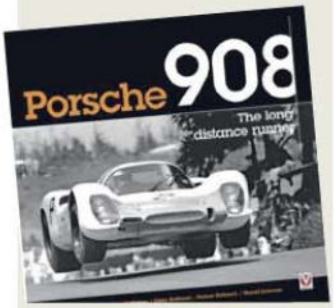

Following on from its stunning *Porsche Racing Cars* series of books (see *RE* V19N3), Veloce Publishing has come up trumps with yet another treat for Porsche aficionados.

Charting the progress of the Porsche 908, the car that cemented Porsche's reputation as a powerful force in Sportscar racing, this book provides superb archive images and in-depth analysis of the car's successes and failures. Whilst sometimes overshadowed by its bigger brother, the 917, the 908 was the first car to win Porsche the World Sports Car Championship in 1969 and was pioneering in its ultra-lightweight construction, remaining competitive in one form or another for over 10 years. The book covers both the early successes of the factory-backed cars and the later privateer efforts, including the turbocharged cars of the late '70s, whilst also looking at the men who drove the 908 to victory.

Translated from an original German text, this book is the first comprehensive work covering the 908 and definitely does this seminal Zuffenhausen car justice.

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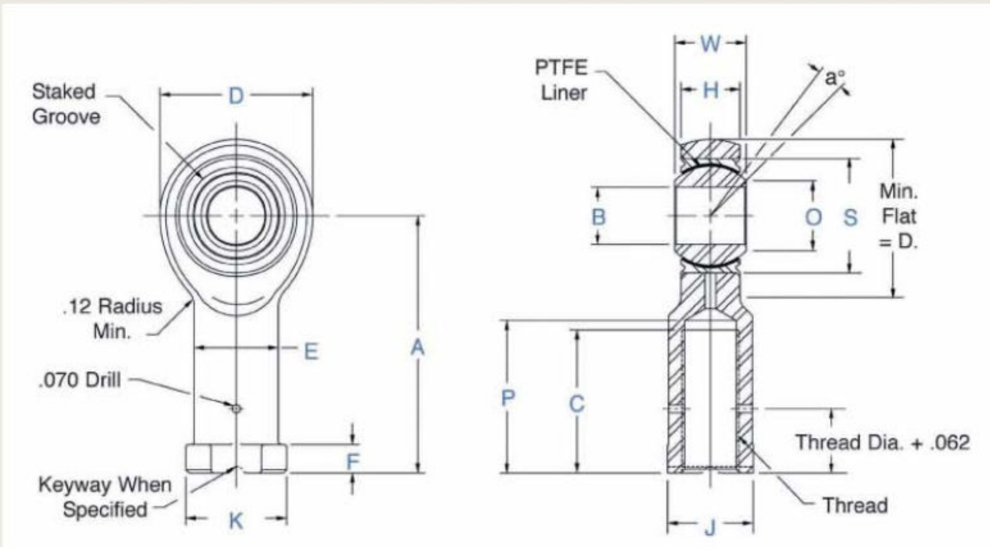
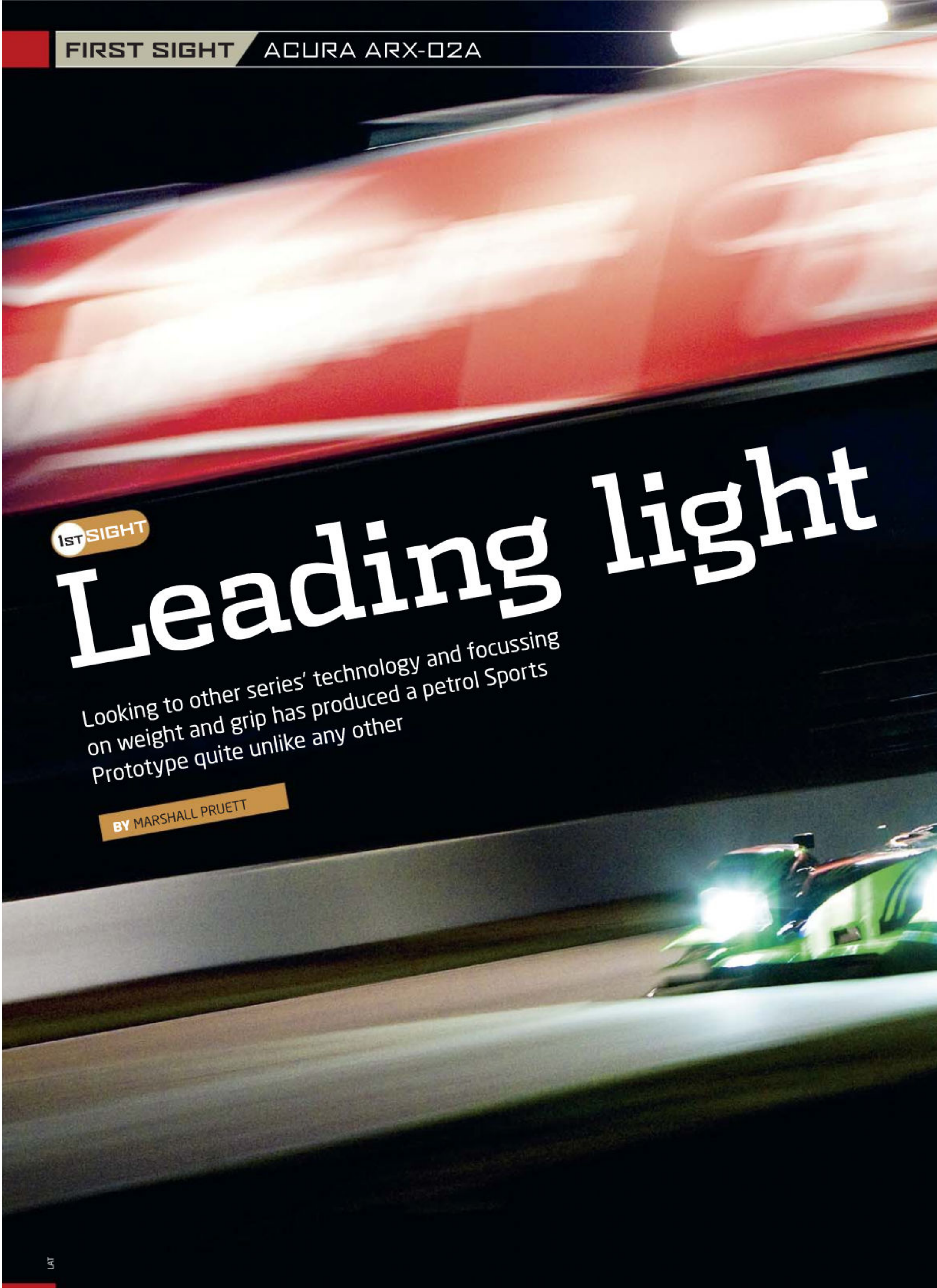




1ST SIGHT

Leading light

Looking to other series' technology and focussing on weight and grip has produced a petrol Sports Prototype quite unlike any other

BY MARSHALL PRUETT

LAT

> “It is as close to an ACO-legal Formula 1 car as we could design”
>
> **NICK WIRTH**

'All things being equal, we should be able to take the fight to the diesels,' said Wirth Research proprietor Nick Wirth at the Acura ARX-02a's unveiling in January. At Sebring the car, in the hands of De Ferran Motorsport, did just that by claiming pole position against the brand new Audi R15 TDI and the supremely fast Peugeot 908 HDI FAP.

The first images of the car testing appeared online in December and it was clear straight away that the team behind it had employed a decidedly unique approach to Sportscar design. The ARX 02a is the product of a joint project between Honda Performance Development (HPD) and Wirth Research, and it works.

TECH SPEC

ACURA ARX-02A ENGINE

Engine type: Acura LM-AR7

Normally aspirated, fuel injected, aluminium V8

Displacement: 4.0-litre

Horsepower: 620+bhp

Inlet restrictor: two x 33.9mm

Valvetrain: dual overhead camshaft with four valves per cylinder

Engine management: Continental/Acura ECU

Transmission: six forward gears, one reverse gear

Clutch: AP pull-type (carbon)

Ignition system: CDI

Lubrication: dry sump

Cooling: dual high capacity water pumps

Fuel: unleaded 100 octane E10 petrol

Fuel capacity: 23.8 US gallons (90 litres)

While a number of modern Le Mans Prototypes (LMPs) have taken cues from contemporary open-wheel designs, the ARX-02a is the first car to fully bridge the design gap. From Wirth's days at March, Benetton and his own Simtek F1 effort, the ARX-02a shows clear signs of its lineage 'It is as close to an ACO-legal Formula 1 car as we could design,' claimed the designer.

Bearing a strong resemblance to the pre-winglet and appendage F1 era earlier this decade, his work on the ARX-02a embraces a laminar flow philosophy with Acura's new P1 car. Viewed head on, Acura's P1 car is dimensionally similar to contemporary F1 cars at the cockpit and roll hoop and with its narrow nose and elevated monocoque. Add to that the use of a 'zero keel' and flexture mounts for the front suspension and the influences are clear.

Unlike rivals Audi and Peugeot, Honda has no major diesel engine experience to draw on and, as a company that largely prefers to race with powerplants that bear a strong similarity to those found in its road cars, HPD's Santa Clarita, California-based operation was never going to build a 5.5-litre TDI motor just for the sake of sport.

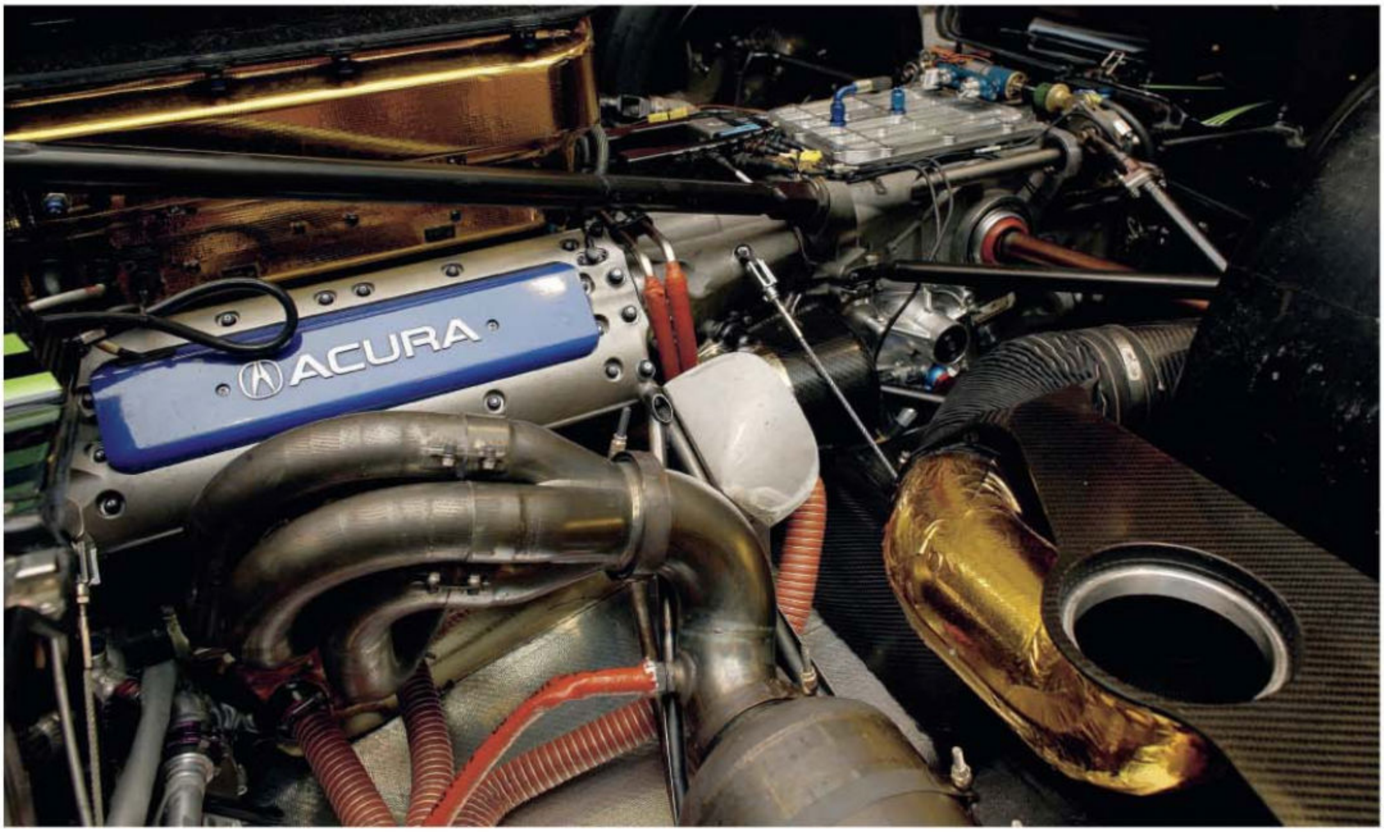
ENGINE DEVELOPMENT

So with Wirth looking after everything but the engine from his base in the UK, HPD's Allan Miller was tasked with heading the Californian team to transform its 3.4-litre LMP2 engine into a capable 4.0-litre unit. 'We started on the motor in December of 2007 – a year before we'd hit the track – which is a very short time frame. That limited our scope quite a bit. Money was also limited, whether we wanted to go diesel or turbo, so we had to work within the budget that was allocated, and that meant using the P2 motor. Consequently, it was more about external changes than anything else,' explains Miller. 'Wirth Research gave us some requests on places they'd like to see us shift weight around, but that was more about changes to the ancillaries – pumps, tanks, line routings and things like that – than anything else. We put the engine as far forward in the car as we could for the sake of chassis balance but, since we weren't doing a new engine, there wasn't the opportunity to do new, lighter block castings to lower the crank or to do new head castings.' Whilst this makes the engines appear similar, Miller says the two units are not interchangeable between the Courage LC75-based ARX-01b and the new, bespoke ARX-02a.

> "a bottom end-focussed development"

Miller also describes the P2-to-P1 motor project as a 'bottom end-focused development.' Adding that the extra 0.6-litre of displacement came from modifications to the crankshaft, with changes to the oiling and water system to accommodate the new power and heat rejection goals. 'It required a lot less people on this project because we just focused on a small portion of the engine – the bottom end. The heads stayed the same and so did almost everything else internally.'

Water and oil flow figures and heat rejection numbers were then provided to Wirth Research, where that data was used to specify and design the air-to-liquid radiators used on the car. 'The P2 engine could get quite hot in the ARX-01b but, so far, the P1 car has been flawless in



LAT

Based on the 3.4-litre Honda LMP2 engine, the normlly aspirated 4.0-litre LMP1 engine has a longer stroke crank and modified oil and water systems high ambient temperatures.' The high lateral loads the ARX-02a is capable of generating lead Miller's team to take this dynamic into account with the LM-AR7. 'It required some extra baffling and other measures to route the liquids to keep them flowing where we wanted them. It's a great problem to have to solve.' Acura's LMP1 car also sports side exhausts – a change from the chimney-style exits on their P2 car. 'Once the chassis guys said this was where they wanted them to help the aero, it didn't take long to get the pipe length and diameters done. It's a clean and efficient solution.'

Naturally, the extra displacement of the engine requires more fuel, so Miller's team also worked on finding gains in consumption of the E10 ethanol/petrol blend the motor burns. 'The P2 motor got great mileage, but we've had to address the more fuelish P1 motor. We're happy with the gains we've made, but know there's still more to be had.'

> **"maximum priority on the ARX-02a's aerodynamics and cornering abilities"**

CORNERING ABILITY

Unlike many racecars that are designed from the engine outwards, Wirth recognised immediately that the limited power a non-turbo/non-diesel engine could produce would place maximum priority on the ARX-02a's aerodynamics and cornering abilities, as horsepower and torque would never be an advantage to exploit in its favour. Wirth was intrigued by the benefits of the extra contact patch the rear tyres offered and, through extensive comparisons and calculations, found using rear tyres at the front as well would give the ARX-02a a seven per cent gain in contact patch – just the difference they hoped would claw back time over the course of a lap, albeit likely not on the straights.

'The driver behind our design was the tyre and packaging concept. We needed mechanical and aero grip, and we also had to produce a car that was significantly light to allow the use of strategically placed ballast. It wasn't just a case of saying "We think we can do a P1 car which can make up the difference between gasoline and diesel just because we're better at aero than anybody else." I think it would have been disingenuous. We know we can advance the aero and the rest of the chassis, but that alone won't put us ahead of the diesels.'

Fitment of the four 37-

TECH SPEC

ACURA ARX-02A LMP1 CHASSIS

Length: 15.26ft (4650mm) maximum

Width: 6.56ft (2000mm) maximum

Height: 3.38ft (1030mm) maximum

Weight: 900kg minimum

Monocoque: integrated crash structures including rollover protection, safety fuel cell and front crash structure manufactured in carbonfibre composite

Head protection: headrest with head protection in accordance with FIA regulations

Restraint system: six-point seatbelt, prepared for use of the HANS

Tyre size: Michelin racing tyres: 37-71/18

Wheels: one-piece, 18in forged magnesium wheels, central locking

Steering: rack and pinion, power assisted

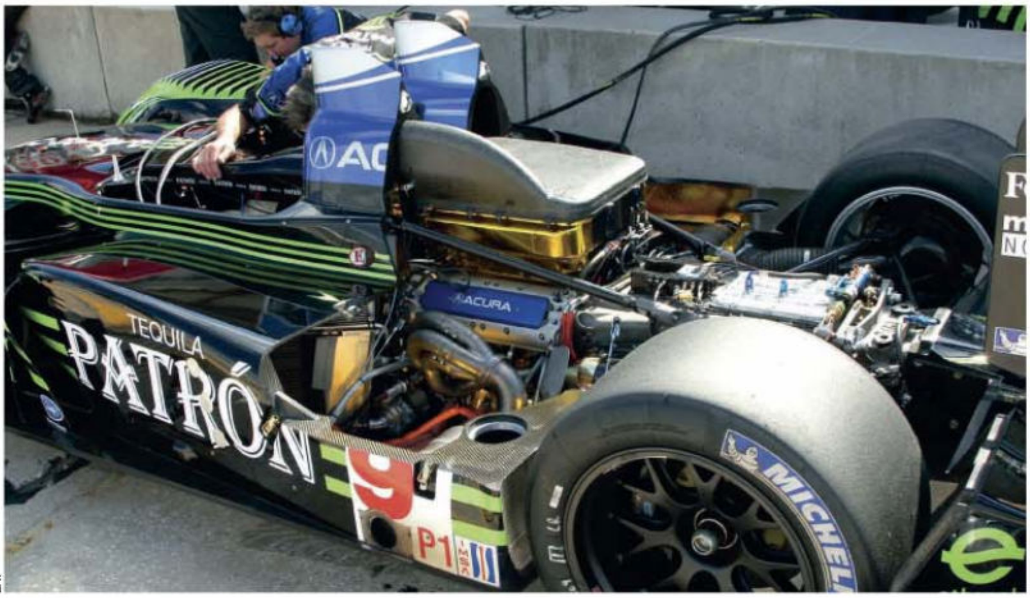
Suspension: double wishbones, adjustable toe, camber and ride heights. Four-way damper units with separate torsion springs, pushrods with anti-roll bars

Brake calipers: six-piston aluminium fixed callipers

Brake discs: internally vented carbon fibre brake discs, 380mm maximum

Transmission controls: Xtrac with paddle shifter, electronic gear selector

Differential: limited slip with traction control



LAT

Chassis development centred on the idea of using the wider rear tyres on the front to maximise contact patch area

LAT

This, combined with a light car with strategically placed ballast and an advanced aero programme, more than made up for the lack of outright engine power

71/18-sized Michelins provided as many challenges as it had potential pay offs. Packaging at the rear was no different from any other P1 car, but the sheer width of the tyres when attached to the front hubs required a complete re-think on the basic chassis design to keep the intrusively wide wheels within the ACO's 2000mm maximum chassis width regulation. To run the rears up front, the Acura would lose the fundamental airflow between the wheels and the sides of the monocoque. And with the space between the wheels and chassis a virtual solid block, Wirth had no choice but to re-route the flow path of the ARX-02a's aero beneath the chassis, which led to the adoption of a 'zero keel' design.

The F1-inspired construction method allowed Wirth to bypass the inner wheel blockages, giving the Acura's under wing an open and unobstructed expanse to flow beneath the driver's feet, split at the centre of the keel,

"F1-inspired construction method"

and travel into and around the sculpted sidepods. Once the tyre / chassis / keel concept had been settled on, solving the construction problem was academic. After two years of revamping and refining the LMP2 Acura ARX-01a/b, continuing with a customer chassis simply wasn't an option. 'The Courage chassis was initially sufficient for our LMP2 programme,' explained Wirth, 'but, as we went into year two with the car, the chassis was the only component left that wasn't significantly altered. So for the P1 project we needed to purchase the equipment and expand our infrastructure to manufacture our own chassis in-house. Even if we'd found a chassis that could have accommodated our tyres, it was time to take the company forward to handle this ourselves.'

LAT

Using the wider tyres up front meant a complete re-design of the front suspension and aero, resulting in the adoption of an F1-style 'zero keel' approach

LAT

A split CFD / wind tunnel programme was undertaken to develop the car's aero, though just a scant 15 days of wind tunnel work was done using the old LMP2 car model converted to LMP1 spec

AERO AND TESTING

To help make the most of the car's shape, Wirth developed a range of front louvre packages, ranging from full length to two hybrids. The first hybrid has a single, large louvre at the leading edge of the unit, a medium length flat section, and seven tapered louvres at the trailing edge, while the second hybrid uses two smaller louvres at the leading edge. The latter option was used for the car's debut race at Sebring, moving the aero balance rearward.

Elevated levels of downforce also led Wirth to continue with the same style of rear bulkhead-to-bellhousing support structure, something that is unique to the LMP1 Acura and isn't found on the R15 or 908.

Acura's earlier LMP2 car was widely hailed for its use of virtual development tools and, while the LMP1 car mostly followed this trend, physical testing of a wind tunnel model was also implemented. 'We did a total of maybe 15 days in the wind tunnel, which is tiny compared to the amount of aero testing done in CFD. But certainly the wind tunnel was involved in the early aspects of the car at the Auto Research Center (ARC) facility in Indianapolis. The guys there do, and continue to do, a fantastic job in development and it all has been very appropriate for the task. As you know, the LMP2 car was completely developed in CFD, but we had a wind tunnel model of the LMP2 car from back in 2006. What we decided to do was to convert that wind tunnel model into a development model for the LMP1.

'The initial design phases of the LMP1 car were done in a joint programme between CFD and scale model – CFD was looking at some areas and scale model was looking in other areas. It was simply a matter of resources. That decision was taken because we could not replace... we had not got enough resources to replace the wind tunnel aspect of what we were doing in the early phases with CFD. Essentially, it would have required another 50 or 60 per cent more CFD capacity than we had. And so we took that decision to do a split programme. But very quickly, within that programme, we stopped. We got the information we wanted and then we stopped. And then, for the bulk of the programme, we did everything in CFD.'

ADVANCED ELECTRONICS

LAT

The ARX-02 is fitted with a highly advanced electronic system designed by BERU f1systems, with direction and concepts from HPD. A key feature of this is the electronics 'pod' in the cockpit. 'It has been possible to house all the different control boxes and electrical components in a restricted space,' says BERU f1systems' John Bailey. 'Yet it still provides excellent serviceability.' Another new area for the company was the steering wheel. 'The electronics were designed, developed and produced by HPD, with us developing the carbon housing design and meetinging the packaging and homologation requirements,' adds Bailey.

CHASSIS DETAIL

Out-sourcing of a number of components was still required – most notably, the six-speed gearbox. Wirth said Xtrac was chosen over the 01b's Hewland for 'its heightened performance and the technology attributes gained from its F1 transmissions.'

The ARX0-02a uses tripod CV joints mated to the Xtrac gearbox, while outboard the driveshafts connect to uprights that HPD boss Erik Berkman was only too happy to describe. 'We've subscribed to the light weight / high-grip approach since we signed off on the project, and going with a more complex and expensive material like the metal matrix for the uprights was a necessary call to make. They could have been done in steel or aluminum, or from formed and welded panels, but that's not what was needed. It's a small point, but I hope it helps people to understand how committed we are to succeeding.'

A topic of contention about the 02a's design is the highly swept axles. With such a pronounced rearward angle, more than a few rivals have questioned the Acura's ability to compete without routine CV joint failures. For Wirth, these concerns are without merit: 'Clearly, we wouldn't put them like that unless we did our due diligence. You've got big heavy components inside the gearbox and, if you have the driveshafts straight, obviously those big, heavy components are going to be lined up with those. If you have the driveshafts at an angle, they can be in a different place.'

Wirth's team of designers had little concern for convention when creating the Acura's suspension package. At first glance, the ARX-02a sports the longest torsion bars in recent memory – units that surely carry a weight penalty. When asked about this, an amused Wirth responded by asking me to meet him in the pit lane for the following session. Once there, he produced a new torsion bar for me to hold. I'd estimate the minimal weight at between 500 and 1000g.

Acura's LMP1 car uses conventional a-arm and pushrod suspension front and rear, with torsion bars up front and a third damper in place. The rear finds the same layout, with rocker-actuated dampers housed within the bellhousing. Access to the rear dampers is tightly confined, while the third damper is readily accessible on both ends.

Some LMP manufacturers prefer to use a full damper and spring combination for its third unit, but Acura opts for a more current model that uses only an internal piston with high and low-speed bump and rebound adjusters that are symmetrical to the piston.

> "We've subscribed to the light weight/high-grip approach"

Wirth also chose flexure joints to mount the fixed position front a-arms, while spherical bearings secure the rear, which is adjustable for anti-dive and anti-squat. Indeed, between the winter test in late January and the 12 Hours of Sebring in March, the Highcroft team was seen moving the front legs of their rear upper a-arms from the top position to the lower of their two options to promote anti-dive.

A natural limitation of the wider LMP1 chassis and zero keel arrangement is the requirement of narrow front suspension. With the shortened arms on a Prototype, issues with high roll centres, limited camber curves and more pronounced toe changes are experienced. High spring rates would also be expected to keep the P1 car's aero platform stable, but Wirth insists this isn't the case. 'The range of springs in this car is greater than the P2 car. We can run it stiffer and we can run it softer, based on our needs.'

FUTURE UPDATES

A range of expected updates are planned for the ARX-02a, along with bespoke components for the two street races on the American Le Mans Series calendar. Custom steering arms and a-arms for the St Petersburg and Long Beach events were expected and, according to Wirth, a return of the F1-style brake shrouds that first appeared on the 2008 ARX-01b.

HPD's Miller also explained two further stages of the LM-AR7 were planned prior to Audi's withdrawal from the championship: 'There's no point in spending the money on improving the motor this year if the only people we have to beat are ourselves. But, if Audi or Peugeot decide to return for Petit Le Mans and Laguna, we'll go forward with either stage two or three of the build project.'

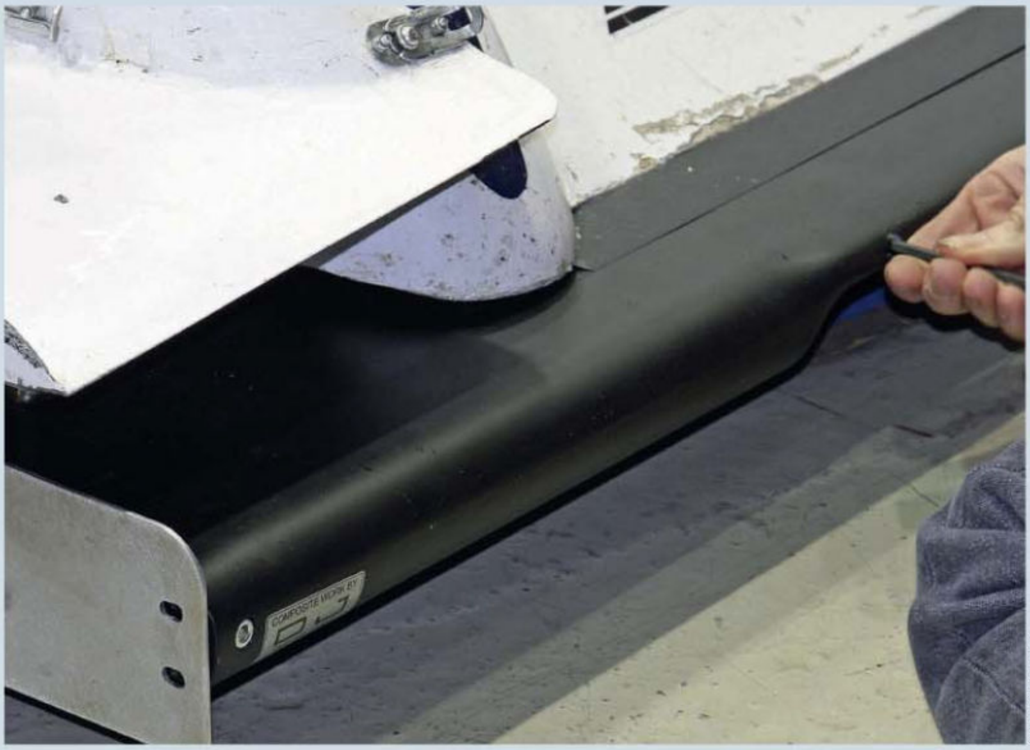
If there's a flaw in Acura's LMP1 concept, it's the lack of a powerplant capable of helping the chassis to play the role of giant killer. Whispers within the team reckon the 4.0-litre LM-AR7 to be 100bhp down on the diesels, and hundreds of lb ft shy on torque, but present form suggests that may not be as big a problem as it sounds.

FIRST PRINCIPLES

Simon McBeath is an aerodynamic consultant and manufacturer of wings under his own brand of The Wing Shop - www.wingshop.co.uk. In these pages he uses data from MIRA to discuss common aerodynamic issues faced by racecar engineers

Size matters

At least it does when it comes to front splitters, and wind tunnel data on an 'LMP3' Ligier JS49 shows by how much



Photos: S McBeath

A selection of interchangeable leading edges made evaluating different length splitters possible

The perceived and well-founded wisdom on splitters is that the longer they are, the more downforce they generate, at least up to a point. We saw in an early CFD-based Aerobytes (V14N11) that this was certainly the case when a NASCAR-type model was fitted with a splitter (perhaps thereby sowing the seeds of the 'Car of Tomorrow' concept?). However, in a recent MIRA full-scale wind tunnel session on a V de V UK series Ligier JS49 we had the opportunity to take some measurements on some cleverly crafted splitter extensions.

Chevron Racing runs this particular Ligier on behalf of the car's owner, Barry Gates, and had contracted racecar and wing manufacturer, DJ Racecars, to produce a number of development parts for the car. This included a set of interchangeable, radiused leading edges (see picture above) for a development splitter that had been designed and manufactured specifically for this car. This gave us an ideal opportunity to evaluate various splitter lengths with properly made parts, as opposed to the usual MDF mock-ups (not that there's anything wrong with mock-ups, of course!).

The results are illustrated below and overleaf in table 1 and figure 1 respectively, and once again reflect the accepted notion that adding length to a splitter adds front downforce with very little, if any, drag penalty (note, on the day, only three lengths were actually tested, so the '60mm extension' front lift coefficient

TABLE 1

Effects of adding splitter extensions, relative to no extension

	Delta (Δ) CD	Δ –CL	Δ –CLf	Δ –CLr	Δ %front	Δ –L/D
+30mm extension	+1	+10	+19	–10	+1/1%	+0.01
+90mm extension	+2	+19	+36	–17	+2.1%	+0.03

TABLE 2

Baseline coefficients

	CD	–CL	–CLf	–CLr	% front	–L/D
'As delivered' values	0.557	1.445	0.596	0.849	41.3	2.59

DOWNFORCE INCREASES

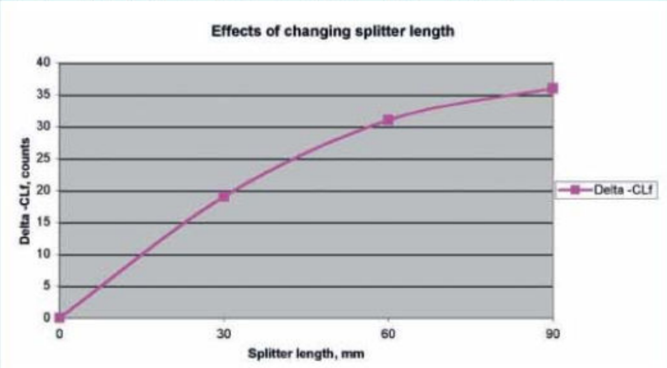


Figure 1: effect on front downforce of varying splitter length

value in figure 1 has been estimated). The results in table 1 are given as changes ('deltas') in the coefficients, relative to the previous configuration, expressed as 'counts', where a count of one is equal to a coefficient change of 0.001. As a guide to the overall aerodynamic properties of the Ligier at the start of this session the 'as delivered' coefficients prior to the fitment of the development splitter are also given in table 2.

extending the splitter yields little benefit from this effect, although it does add plan area for the low pressure beneath to act upon it, and this is where most of the downforce gain will come from.

Splitters tend to be more effective when located at the base of bluff front ends, and comparing the Ligier to the photo of the Radical SR10 LMP1 shown here provides a clue to a possible small improvement to the Ligier.

RAZOR SHARP
The bodywork above the splitter between the nose duct and the wheelarches on the Ligier was too sleek to be able to derive much benefit from the splitter extensions...

CALL MY BLUFF
...whereas the blunter shape of the Radical SR10's frontnd above the splitter adds to frontal downforce

MIND THE GAP
Adding this folded aluminium in-fill panel to the gap in the splitter added 15 per cent front downforce for no drag increase

> **"splitters tend to be more effective when located at the base of bluff front ends"**

Perhaps the only surprising aspect of the results from these reasonably significant splitter extensions is that the downforce increments were not larger. The 90mm extension added roughly seven per cent additional front downforce, which seemed relatively modest. However, we can look to one of the mechanisms by which splitters generate downforce for an explanation of this. Part of the splitter's downforce comes from the fact that it extends forwards under the 'stagnation zone' at the front of the car. This is where the airflow encounters the front of the car, and either passes above or below it. The air in between this 'divide' slows down and, as such, the local static pressure increases. But, as shown in the photos, the Ligier has a very sleek front end, so any static pressure increase ahead of here will be relatively small. Because of this,

Notice that there is a small, bluff but radiused leading edge to the Radical's front body directly above the splitter. This would create a small zone of high pressure ahead of itself and hence on the top of the splitter, generating additional downforce. On a return visit to the wind tunnel with the Ligier (which apparently did previously have a slight bluff front end but this had to be cut off to accommodate the splitter), a trial with some suitably shaped pieces of polyurethane foam would prove the worth of this notion in terms of downforce, balance and efficiency.

As tested though, there were three areas where the shape of the Ligier's front end would generate raised static pressure, one of which was beneath the nose section in the centre where a towing eye, a jacking point and a pair of small ducts feed cooling air to the front brakes. For access to the jacking point, the centre of the splitter here had been cut away here, so missed out on exploiting this central zone of high pressure. An infill section was made up and taped in place to evaluate the potential benefit here, and the results of this (and partial taping over of the nose 'duct') are shown in table 2.

This modification alone added 15 per cent front end downforce at no drag penalty, and also served to increase the static pressure at the brake cooling duct inlets, either increasing their effectiveness or enabling them to be reduced in area to knock a few counts off the drag figure. In fact this whole centre section could probably be packaged more efficiently to sharpen up the front end in every sense.

Thanks to Barry Gates, Nick Reynolds at Chevron Racing and DJ Racecars for allowing us to expose the Ligier and its aerodynamic modifications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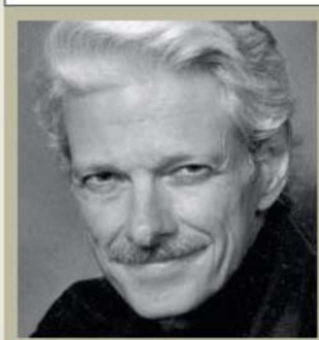

FIRST PRINCIPLES
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THIS MONTH:
Q How much attention should be paid to pre-load on springs and Belleville stacks when setting up a monoshock-equipped single seater?
Plenty, and it is also important to understand why you might choose to have the stacks unequally pre-loaded on the shuttle, as it has a significant effect on this interconnective springing system

Sam Collins

In a monoshock set up the spring only acts in ride, the elastic roll resistance comes from the Belleville washer stacks

Mono-a-mono

Q How do you go about sorting out ride and roll rates for a monoshock-equipped Dallara F3 car and how much notice should be paid to pre-load on the springs and Belleville stacks?

Also, can you explain how one might go about calculating Belleville stack rates, wheel rates and load transfer distributions? My understanding is further muddied by the application of pre-load on ride springs and stacks, but I'm hoping to ignore these for now. Is this wise?

A Taking the last question first, no, we cannot ignore pre-load, especially on the washer stacks, though on the ride spring, it depends whether the spring is pre-loaded at static ride height or only at full droop.

If the ride spring is pre-loaded at static, the suspension is solid in ride (wheel rate approaching infinity, or undefined) until the pre-load is exceeded. If it is not pre-loaded at static, it provides a rate for the wheel pair that is equal to the spring rate times the square of the spring-to-wheel motion ratio. This is the number of pounds of load change for the wheel pair, per inch of ride travel. It corresponds to the sum of the two individual wheel rates in ride in a conventional suspension so, if you have an equation that calls for individual wheel rate in ride, then you use half of that ride spring rate times the square of motion ratio quantity.

If the equation in question is for lateral load transfer, then you use zero for the ride spring rate. The ride spring in a monoshock suspension acts only in ride and does not contribute to roll resistance or elastic lateral load transfer at all. All the elastic roll resistance in a monoshock set up comes from the Belleville washer stacks. There is a stack on each side of the rocker where the shuttle passes through. Ordinarily, we use identical stacks on both sides of the rocker, which act in parallel so the rate of force change with respect to displacement at the shuttle is the sum of the rates of the individual stacks, if they are both active. However, they may or may not both be active and that's where pre-load comes in.

When both stacks are equally pre-loaded, there is a compressive load on each stack, and a reaction force from each stack trying to extend itself. Since these act on the shuttle in opposite directions, however, there is no net force trying to move the shuttle to either side.

Correspondingly, if there is an increase in extension force from one stack, and a decrease in extension force on the other, those force changes act additively, and the force trying to re-centre the shuttle is the sum of the two.

That force acts on the wheels, through the pushrods and the rest of the suspension, at some motion ratio. The rate of force change with respect to displacement at the wheels is the rate at the shuttle times the square of the motion ratio.

Like an anti-roll bar, the shuttle mechanism is an interconnective springing system. It generates force in response to a displacement difference between two wheels ie an oppositional displacement of the pair. To define a motion ratio for such a system, we need to resolve the question of what we call an inch (or mm) of motion: is it an inch at each wheel, meaning two inches difference between the two, or is it half an inch at each wheel, meaning one inch difference between the two? I prefer the former method, because it puts wheel rates for all modes, from all springing devices, in the same terms: force per unit of displacement per wheel. Using this method, the angular roll resistance is the wheel rate in roll times the square of the track times 0.5. That gives the angular rate in lb/in or N/mm per radian. To get lb/in or N/mm per degree, divide by 180/π or 57.3.

Most books use the method above to calculate the component of angular roll resistance due to the ride springs (again, this is zero for a monoshock suspension), and use a different formula for the component due to the anti-roll bar. The more common method for the bar component is as above, except the rate is taken as force per unit of displacement per wheel pair, and the angular rate from the bar is then as above, except with the multiplication by 0.5 omitted. Both methods work fine, and give the same answer for total angular rate, provided you use the method that goes with your expression of rate.

The angular roll displacement is then the sprung mass times the lateral acceleration times the moment arm of the sprung mass c of g about the roll axis, divided by the sum of the front and rear angular roll resistances. The front elastic lateral load transfer at that roll displacement is front angular roll resistance times angular roll displacement, divided by front track.

LAT

Most factory racecars, such as these Dallara F3 cars, come with a rate table from which you can start fine tuning

UNDERSTANDING THE BASICS

If you are setting up a factory-built racecar with a monoshock suspension, the factory will generally furnish a table stating the rates for various stacks. If you are building a car from scratch, or want to try stacks that aren't in the table, it helps to understand the basic rules governing the behaviour of Belleville washer stacks.

For readers unfamiliar with Belleville washers, they are simply spring steel flat washers, dished a bit so they can serve as a short-travel compression spring. The dished washer has a concave, or cup, side and a convex, or cone, side. If we stack a number of washers cup-to-cup and cone-to-cone, we have a compression spring with a useful amount of travel.

A Belleville washer is not a perfectly linear spring, but if we approximate its behaviour as a constant rate, and call that k, and if we have a number of washers, which we call N, we can state some rules about the rates of combinations of such washers.

If we stack N washers cup-to-cone, or nest them, they act in parallel and the rate is kN. If we stack them cup-to-cup and cone-to-cone, they act in series and the rate is k/N. If we have two stacks, each of an overall rate K, on each side of the rocker, and both are active, then the rate of the assembly is 2K.

> "a Belleville washer is not a perfectly linear spring"

Both stacks are active as long as there is a load on both. Once the inside stack (the one toward the inside of the turn) unloads, it ceases to contribute to the rate, and the rate from that displacement one is K rather than 2K. If the stacks are not pre-loaded at all, only the outside one is ever active, and the rate is always K. If the stacks are loose on the shuttle at static, the rate is zero until the clearance on the outside stack is taken up, and then it's K.

VARIABLE RATE STACKS

It is possible to create stacks in which some of the washers are nested and some act singly. In that case, we can have a rising-rate stack. If the portion with nested washers has a rate L and the portion with unnested washers has a rate M, then the whole stack has a rate of LM / (L+M). If we compress this stack far enough, the un-nested washers bottom out (that is get squashed completely flat) and we are left with the nested ones still active. The rate then goes to L (possibly in a handbasket).

When we have variable-rate stacks, either rising-rate ones or ones where there is a chance of a pre-loaded stack unloading, we have to determine at what roll displacement we will get a rate change, and compare that with our predicted roll displacement using the rate we have at static. If this comparison shows that we will encounter a rate change, then we have to work backwards and calculate at what lateral acceleration we encounter the rate change. We then calculate what load transfers we have at that lateral acceleration, using the angular roll resistance rates for the first part of the travel, and finally we calculate further load transfer for the additional increment of lateral acceleration, using the rate that applies for that increment.

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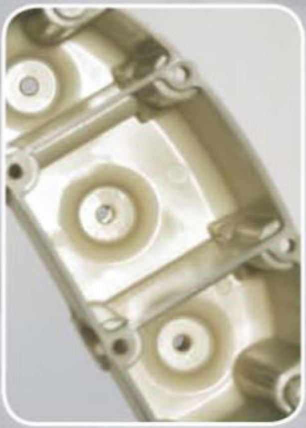
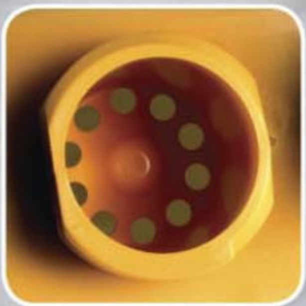
FLUID CONTROL





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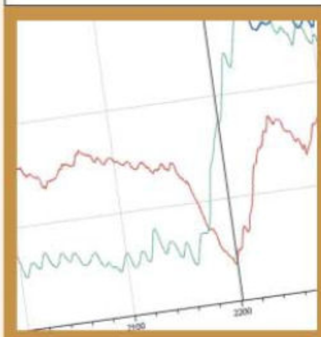


FIRST PRINCIPLES

Databytes gives insights to help you improve your data analysis skills each month as Pi Research's engineers share tips and tweaks learned from years of experience with data systems. Plus we test your skills with a teaser each month.

To allow you to view the images at a larger size they can now be found at www.racecar-engineering.com/databytes

Fast forward

Making the most of racecar video logging

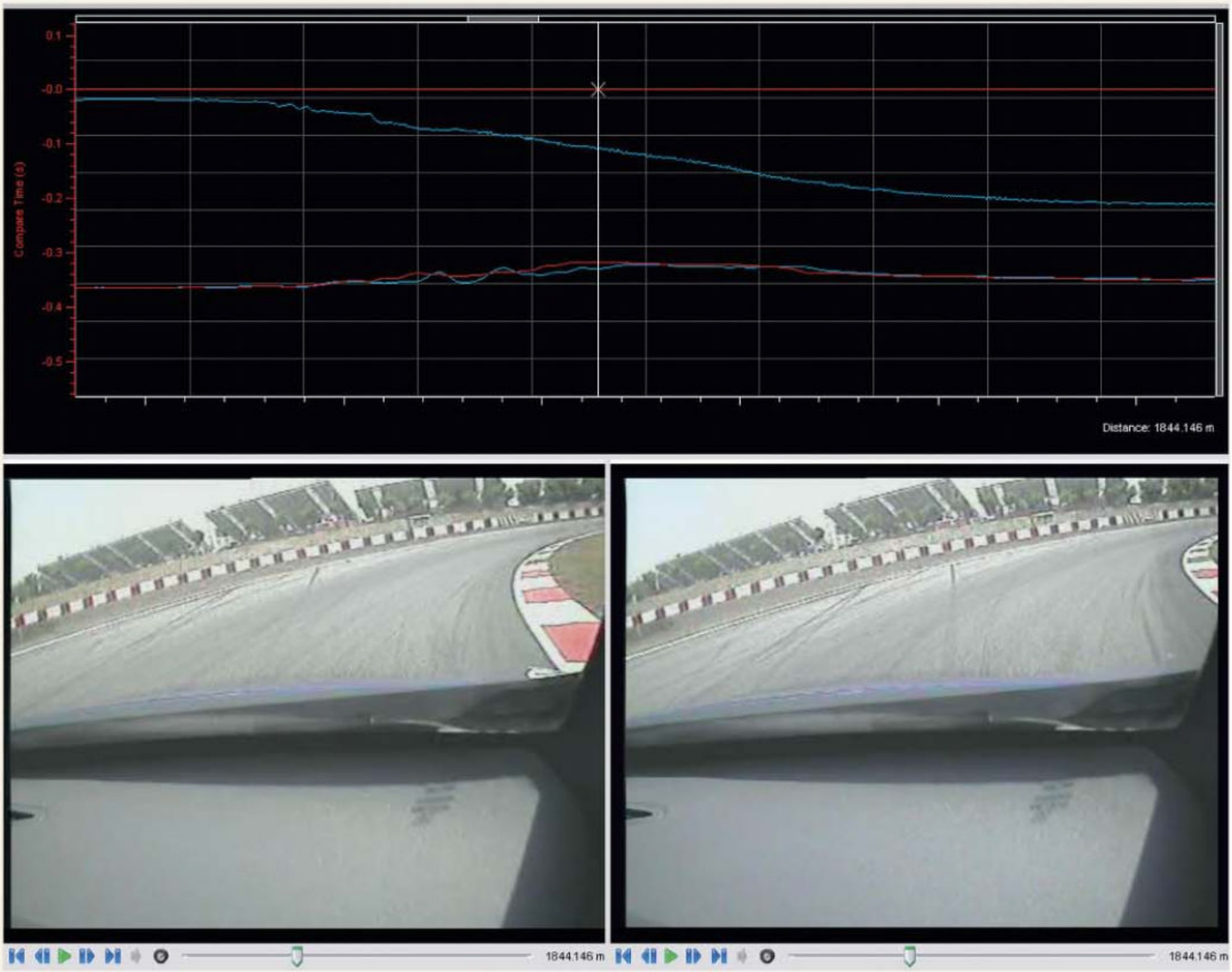
There is a vast array of sensors and tools on the market to help engineers visualise what the chassis or components are doing while a racecar is on track, yet one of the greatest sensors available is the human eye.

Unfortunately, it is normally impossible for the engineer to be physically in the car with the driver, but the use of video cameras can be a very useful substitute.

> one of the greatest sensors available is the human eye

Before the reader starts duct-taping the family camcorder to the rollcage of the car, however, it should be noted that, like all things, the quality and system capabilities are key factors when it comes to the power and usefulness of the video captured.

On-board video has been used since the 1980s, where simple cameras were placed within and around the car. And while the systems produced a lot of video data, it would take a great deal of time to go through all the footage to perhaps gain a few basic pieces of information, such as approximate cornering lines and obvious issues on the car. Since these early days, the basic systems available have of course improved in quality, and then reduced in size, but the time-consuming issue of hunting through gigabytes of video data still remains.



Video data of a racecar on track is a useful visual aid, but combining it accurately with data from sensors opens up a whole new world of opportunities

However, there is now a solution to this problem, which unlocks the full potential of video data analysis. 'Indexing', or synchronising the video with the chassis data, enables the engineer to analyse the sensor traces as before, but with the added benefit of having the video automatically scan to the exact point in an outing that matches to the trace. This means that one can 'fast forward' through the reams of video data that aren't of interest and pinpoint the areas of interest identified by the data traces. The other key benefit of indexing the video is that your video files can be overlaid. Fig 1 is a Compare Time trace showing time lost, and we can see from the steering trace that the turn in for the slower lap was slightly later. Judging by the oscillation, a small oversteer moment also occurred. Using the video images as well can not only confirm the oversteer response but also physically show the consequences of this behaviour by how far from the apex the driver is.

SYNCHRONISATION

The importance and usefulness of the synchronisation can be seen by how it enables the user to find the important areas of the video data quickly and easily. The reader should also take into account, however, how the data is synchronised to the video.

The method of doing this is to place a known event within both the video and data at the same time. This event can then be located by the analysis software and matched together, becoming a reference point in both data types. The specific point of interest in the data can then be found by referencing how far from the synchronisation event it is and locating that same point in the video.

Less sophisticated systems use the beacon signal once a lap as the synchronisation event. However, due to the different logging rates of channels, the frame rate of the camera and the system's ability to process the video data, it is possible for the video and data to drift within the lap. Good video systems continuously sync the video and data up to every second to ensure parity between the data sources. This enhances the video data further, meaning that not only can the camera be used to observe a general overview of the chassis and driver, but also can be positioned to view a specific component – for example, a wishbone or wing – to see how it deforms on the track. Then, because the data can be trusted to be valid at the point of interest in the video, the user can see the exact conditions that are causing the deformation (eg strain gauge readings).

Systems like this have been tested and shown to be capable of matching data of wheel movement to the nearest bump in the kerb at race speeds!

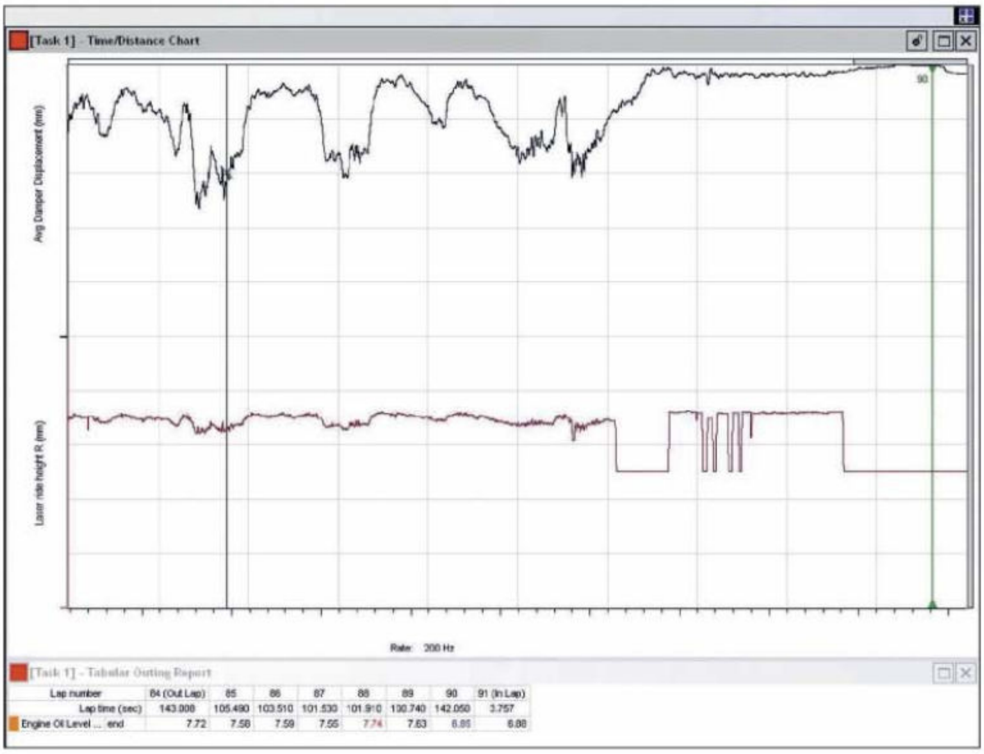
Video data need not be limited solely to an engineering tool either. With the rise in popularity of video and community websites, a race team can now post interesting sections of video data to promote itself and attract fans and sponsors.

In short, video data is an important and often overlooked race engineer's tool that can be used for driver improvement, component engineering and even marketing purposes.

> **"pinpoint the areas of interest identified by the data traces"**

CHALLENGE

Test your own data analysis skills. The answer will be in next month's *Racecar Engineering*



Following a run, it was noticed that the rear laser ride height sensor was reading zero. The traces above cover the end of the car's run, showing the average rear damper displacement and the rear laser ride height before and after the problem. What has happened to the sensor during the run?

a) The sensor has been damaged on the final lap and is broken
b) All the painted lines in the pit lane and the shiny garage floor are causing a false reading
c) There is oil on the sensor window causing a zero reading

The answer will be printed in next month's *Racecar Engineering* magazine – or, if you can't wait that long, you can find it at www.racecar-engineering.com/databytes

The answer to last month's challenge is: a) Car being lowered from jacks.
Pi's Robin Cull explains why at www.racecar-engineering.com/databytes

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The

The standard Lotus Exige is a natural for motorsport, but now there are two racing interpretations of the same car to choose from

BY GRAHAM JONES AND CHARLES ARMSTRONG-WILSON

The team may no longer be competing in Formula 1, but the Lotus name retains powerful appeal among motorsport aficionados on both sides of the Atlantic. The brand also continues to be well represented in motorsport, and recently the 2-Eleven factory-built racer has been competing successfully in the GT4 Supersport category in Europe. With a smartly turned out Lotus Exige S making its on-track debut at Sebring this year, an in-depth look at the two cars seemed in order.

THE EXIGE S

Prepared by Hyper Sport Engineering of Buford, Georgia, the Exige has been built to compete in the GT class of the SCCA's SPEED World Challenge Series. Lotus participation in the World Challenge dates back to the series' inception in 1990, with the marque having scored eight race wins courtesy of the Esprit Turbo. The team has been absent from the World Challenge since 2000 but now, with the Exige, the famous green and yellow badge is back on the grid attached to a potentially very competitive car. With experienced US racers Joe Foster and Charles Espenlaub handling the driving duties, and Hyper Sport Engineering boss, Kirt Wightman, acting as team technical director and race engineer, it's clear this is a serious effort.

Before delving into the details though, it's worth noting that this particular Lotus is very much a product of the rules governing the SPEED World Challenge, the aim of which is to encourage diversity in terms of the vehicles on the grid, but also to ensure close competition. This is achieved by assessing each prospective new car using a formula that is based on power-to-weight ratio, as well as other performance-related factors, including tyre size, and results in a list of permissible modifications that apply to that particular model. As Wightman explains, the process involves face-to-face negotiations with SCCA technical staff: 'The World Challenge Series is awesome, because it's a sprint race, with one driver, and there's enough latitude in the rules to compete. The Exige has to run against Corvettes, Dodge Vipers and the like, but by adding a turbo, which is allowed, we can get close to their performance – on paper at least. We've had a meeting with the series' technical people and we've gone with a conservative package initially, while we develop the car.'

That 'conservative package' involves the Exige carrying 500lb of ballast and, in common with other competitors in the series, a sealed Trackmate data-logging system. This records a range of performance parameters and allows SCCA technical officials to review the performance of the Lotus and compare it with its rivals. As they learn more about the car's potential, they will adjust the amount of ballast carried, possibly even on a race-by-race basis.

Apart from this initial 'performance balancing' procedure (the Exige is new to the Speed World Challenge this season) series organisers operate a 'reward' system, whereby a specified amount of weight is added to car / driver combinations that finish on the podium and removed from those that finish outside of the top positions. In short, ballast is regularly adjusted to ensure competing cars don't stray too far outside the desired performance window.

RACE PREPARATION

With that in mind, how has Hyper Sport Engineering tackled the preparation of the Exige? 'A lot of it was driven by the rules for this particular series,' says Wightman. 'It therefore retains the stock chassis, with its galvanised sections, the windshield frame and the steering rack.' The bodywork on this first car is a combination of the glass fibre of the standard Exige and a number of carbon fibre parts, including the roof, the wheelarch extensions and the undertray. Future cars, however, will feature all-carbon bodywork.

'I wouldn't have changed the bodywork,' explains Wightman, 'but the SCCA decreed that we had to run 18in diameter wheels with 245 section front tyres and 275 rears, which is massively different from the standard car, along with a minimum ride height of 3.5in. By the time we'd figured out the centres and the rest of the suspension geometry with this set up, we were just not there. I was therefore allowed to make my own uprights and change the pick-up points on them to get everything back to essentially stock geometry, just lowered on the upright. We also had to widen the body and cut out the wheelarches to clear the tyres. They crash a lot in this series, so everything has to be bolt on and bolt off, and made as easy to work on as possible. We have a good relationship with Lotus, so I was conscious of not messing up their product and keeping it as stock looking as possible.

'One of the things they allowed me to do is fit a complete, flat bottom, carbon undertray, which is really nice. They haven't allowed anybody else to do that, or to mess with their uprights but, because of the nature of this car, they've given me a set of rules that allows me to do those things.'

“essentially stock geometry, just lowered on the upright”

Built to contest the GT class of the North American SCCA SPEED World Challenge series the Lotus Exige S looks, on paper at least, to be a promising option

In Europe, the open topped 2-Eleven variant has its sights set on the lower powered GT4 Supersport category. Part of the car's appeal is its reasonable price

TECH SPEC

LOTUS EXIGE SPEED WORLD CHALLENGE

Car: Lotus Exige S to Speed World Challenge regulations

Design: Lotus extruded aluminium chassis, bonded frame, bolted steel rollcage, composite bodywork
Design and construction: Kirt Wightman, Hyper Sport Engineering

Engine

Type: Toyota 2ZZ-GE in-line four, transversely mounted, turbocharged

Engine management: MoTeC M800

Lubrication: dry sump

Capacity: 1796cc

Power: 378bhp / 384ps

Torque: 291lb.ft / 395Nm

Drivetrain: Quaife 32G six-speed sequential

Clutch: Quartermaster

Steering: Lotus rack and pinion

Suspension: Hyper Sport Engineering, unequal length upper and lower wishbones front and rear

Dampers: Moton

Brakes: 14in (356mm) discs front / 12in (305mm) discs rear, Alcon calipers – 6-pot front / 4-pot rear

Wheels: BBS

Tyres: Toyo Proxes 888, 245/40 x 18 front, 275/35 x 18 rear

Dimensions/weight

Length: 151.5in (3848mm)

Width: 70.75in (1797mm)

Height: 45in (1143mm)

Minimum weight: 2400lb (896kg) with driver

Tank capacity: 15.4 gallons (70 litres)

Safety

Fire suppression: Safecraft

Seatbelts: Safecraft

Exige S engine is a turbocharged version of the road car's Toyota 2ZZ-GE in-line four, with MoTeC management

Front uprights were re-manufactured to accommodate 18in wheels and the ride height specified by the series organisers but otherwise the race version retains essentially the stock Exige road car's suspension geometry

Power for the Exige derives from a turbocharged version of the standard model's Toyota 2ZZ-GE DOHC, in-line four, which has been rotated about its longitudinal axis to shift the weight as low in the chassis as possible. Control is via a MoTeC M800 ECU and dash, and the engine is mated to a Quaife 32G sequential gearbox. As for power output, Wightman comments, 'We've asked for 380bhp, and the turbo on it is good for 500bhp. I don't think the stock crank would last at that, but certainly we could run at 450bhp if we wanted to.' Even allowing for the current ballasted minimum weight of 2400lb (with driver), the Exige should offer respectable performance.

> "the turbo on it is good for 500 bhp"

Stopping power is provided by 14in diameter front discs and 12in rears, clamped by six-piston and four-piston Alcon calipers, front and rear respectively.

'They've given us the same brakes as the Porsches,' explains Wightman. 'I wanted to go to centre-lock wheels and, because of my contacts with Porsche, we ended up using Porsche Cup wheels, with the centres, the bearings and all of that, which I knew would be easy to work with and could handle the stresses.'

With an eye to reaping some commercial benefit from the work invested in the project, Hyper Sport Engineering has recently concluded an agreement with KSS Motorsport of Atlanta to sell the parts developed for the Exige separately. The hope is that these will find a ready

The 2-Eleven also uses the Toyota 2ZZ-GE engine, only this time tuned by adding a supercharger and intercooler

Cockpit shot of GT4 version shows gear shifter for ZF sequential transmission, Lifeline plumbed-in fire extinguisher system and, just visible on the left, a panel that includes a selector for the adjustable traction control system

market with Lotus Club members throughout North America.

GREAT PROSPECTS

The first outing for the Hyper Sport Engineering Exige was at Sebring in March, where it was ultimately listed as a 'DNS' – the result of a wiring harness short circuit that led to a Lambda sensor problem. With a crowded race weekend schedule and only a 15-minute qualifying window, there was insufficient time to diagnose and rectify the fault at the track. Still, it's clear this experienced team fancies its chances with the Exige.

'The other factor in this whole thing is the Toyo Proxes tyre [that is mandated for the series],' says Wightman. 'It's very easy for the high-torque cars to burn those off in 10 or 15 minutes of a 50-minute race so, even if we're not the best qualifier, I think we're going to be there at the end of the race. Certainly, on the tight, twisty circuits, it's going to be a great car, and the SPEED World Challenge takes in a lot of street circuits and short courses, so I like our prospects. You're starting with something great anyway, so you take what the rules give you and run with it.'

THE 2-ELEVEN GT4 SUPERSPORT

While the Lotus Exige one-make series continues to prosper under LoTRDC with MotorSport Vision (see side panel on p36), attempts to take the car into GT competition against other marques have in the past had limited success. However, the fast developing GT4 category could transform all that with its acceptance of the 2-Eleven Supersport car into its list of homologated vehicles.

Launched two years ago for customers who wanted something more track

TECH SPEC

LOTUS 2-ELEVEN GT4 SUPERSPORT

Car: Lotus 2-Eleven to GT4 Supersport regulations

Design: lightweight bonded aluminium, high-sided variant of Lotus Elise chassis, bolt-on composite bodywork, SCCA-spec rollcage, GT3-style carbon fibre adjustable rear wing, front splitter, rear distributor

Engine

Type: Toyota 2ZZ-GE in-line four, transversely mounted, supercharged, intercooled

Engine management: Lotus T4e EEMS with variable traction control

Lubrication: wet sump

Capacity: 1796cc

Power: 270ps / 266bhp

Torque: 247Nm / 182lb.ft

Drivetrain: ZF six-speed sequential

Clutch: sport clutch and cover

Steering: Lotus rack and pinion

Suspension: fully independent, unequal length wishbones, adjustable front anti-roll bar, rear double-sheer track control arm and ride height

Dampers: Öhlins two-way adjustable coilovers

Brakes: AP Racing, 308 × 26mm ventilated / cross-drilled discs front, 288 × 26mm discs rear, 4-pot calipers front, 2-pot rear, servo-assisted, track-tuned, four-channel ABS

Wheels: Lotus Sport alloys, 7×16in front, 8×17in rear

Tyres: Yokohama Advan AO48 195/50 R16 front, 225/45 R17 rear

Dimensions/weight

Length: 152.4in (3872mm)

Width: 68.3in (1735mm)

Height: 43.8in (1112mm)

Minimum weight: 1543lb (700kg)

Tank capacity: 15.4 gallon (70 litre) bag tank

Safety

Fire suppression: Lifeline plumbed-in system

Seatbelts: Schroth six-point harness

LOTUS CUP EUROPE

In addition to the successful Elise Trophy run on UK circuits, the organisers have unveiled a new Lotus Cup Europe for 2009. The six-round series, taking place on some of the most appealing European circuits, is open to Cup models of the Lotus Elise, Exige and 2-Eleven. Organiser LoTRDC has seen the UK series grow to more than 60 cars entered each round, requiring two heats per event. It hopes the European series will be equally successful and, by sharing four rounds with the UK series, the aim is to make it affordable to compete in both series. Meanwhile, Lotus has unveiled a revised version of its Exige Cup car, with a 38kg weight saving taking it under 900kg in race trim.

Subject to confirmation, the Lotus Cup Europe rounds will be held at:

- **Donington Park (UK)**
- **Le Mans (France) or Zolder (Belgium)**
- **Zandvoort (Holland)**
- **Brands Hatch Grand Prix (UK)**
- **Dijon-Prenois (France)**
- **Spa Francorchamps (Belgium)**

orientated than the Elise and Exige models, it shares the same chassis but with deeper side members made possible by its open, door-less bodywork. Like the road and track day version, the 2-Eleven GT4 Supersport is powered by a supercharged Toyota engine, in this case delivering 266bhp. These four-cylinder units are highly rated at Lotus and are tuned simply by adding forced induction, without any need to open the production road car units for additional work.

Wet sump lubrication is retained, not just to keep costs and complexity down, but simply because dry sump lubrication has not been found to be necessary. However, cooling has been supplemented with a water / oil heat exchanger that makes use of the extra capacity in the main water radiator that is uprated to a triple-pass element.

The engine now drives through a six-speed, sequential race gearbox from ZF, offering a choice of ratios and faster gear selection. One of the deciding factors for gearbox supplier was the size of the unit, allowing it to be accommodated in the Elise-style chassis. An interface with the engine management allows flat shifts on up changes and an 'autoblip' facility matches the revs on down changes.

For racing, the suspension is uprated with stiffer springs and Öhlins two-way adjustable dampers, while the rear toe links are also upgraded to cope with the demands of the car's higher spec. As standard, the car sits on Yokohama's semi-slick A048 tyres, but the rubber the car races on will depend on the rules of the race series entered.

STANDARD UPGRADES

Safety is dealt with by a number of upgrades. The Supersport is fitted with an FIA-standard rollcage that is different from that used in the road car and made by rollcage manufacturer Caged. A Schroth six-point harness, a HANS-approved carbon seat and a GT4-spec, plumbed-in fire extinguisher system completes the package. Access is improved with a removable

Nestled beneath the FIA-spec rollover structure is a HANS-approved carbon fibre seat fitted with a Schroth six-point harness

steering wheel and a 70-litre bag tank gives enough range for endurance events.

Aerodynamics are supplemented with a one-piece rigid tonneau covering the cockpit to reduce drag, plus a revised aero package comprising a carbon fibre rear wing, rear diffuser and deep front splitter that increases downforce to 80kg at 100mph – amounting to 10 per cent of the car's weight. It retains the road version's variable traction control and ABS, having already been proved in competition.

The reason Lotus' last foray into GT racing foundered was that the Elise struggled to reach the bar for performance set by SRO and the FIA for the GT3 race series. The organisers test each car and adjust its specification to equalise performance and can give or take away speed using minimum weights, restrictor sizes and aerodynamic elements like wing sizes and splitter lengths. In GT3, the performance bar was set by the organisers as the Porsche GT2 and, though initially Lotus felt this was within reach, as the programme progressed, the company felt the bar moved out of reach of the car's scope. As Chris Arnold, head of Lotus Sport, points out, a car with a 6.0-litre V12 on restrictors has a wealth of untapped potential, whereas the Lotus philosophy of low power and low weight left no spare capacity to release to keep the Exige competitive. It left the car uncompetitive and therefore unmarketable, which caused the programme to be dropped.

> **"for customers who wanted something more track orientated"**

PERFORMANCE BENCHMARK

In contrast, however, the GT4 rules have a lower performance benchmark that Lotus believes it can match comfortably with the 2-Eleven and at a much lower price than most of its competitors. Initially, Lotus is planning a production run of 10 cars that, thanks to the flexible nature of Lotus Cars' manufacturing system, can be built on the same production line as its road cars. Selling at £78,255 ($112, 570) makes the GT4 Supersport very attractive to competitors in both national and international GT series and, within three weeks of its launch, Lotus had already received four orders. It will also be possible in the future to uprate existing 2-Elevens to GT4 specification with a kit of parts that Lotus will soon be making available, allowing track-day drivers to graduate to racing if they so wish.

Lotus hopes that with its new version of the 2-Eleven, it will be opening the door of GT racing to a new market and that sales of the car will inevitably follow.

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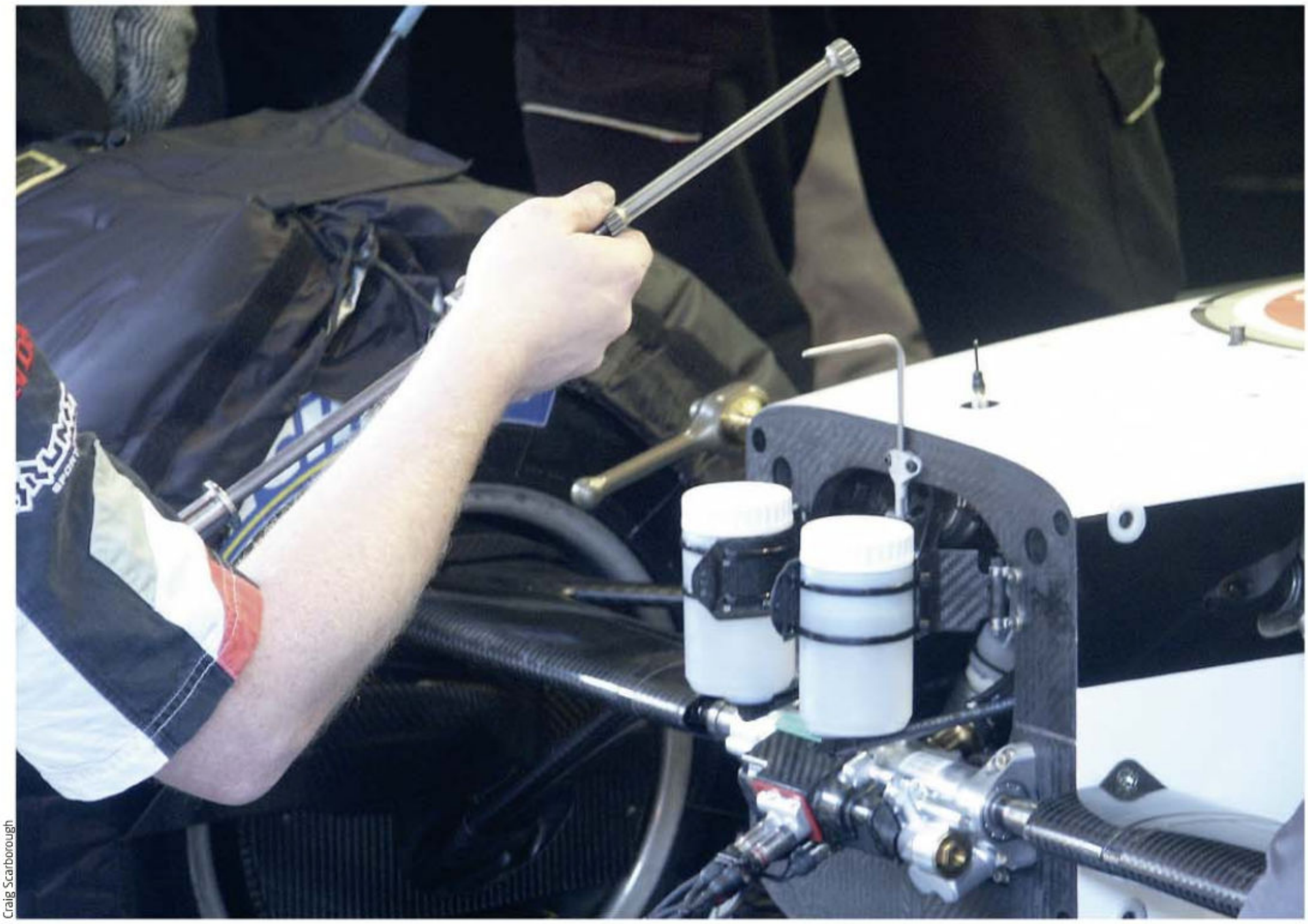

Craig Scarborough

Twisted logic

Part 1 of our two-part feature on torsion bars traces the history of this type of suspension and investigates the advantages of its use on a racecar

BY MARK ORTIZ

Automotive suspension springs can be of several types: pneumatic (air springs), elastomeric (rubber springs) or metal. Metallic springs fall into three categories: leaf springs, coil springs and torsion bars.

A torsion bar is a long, narrow piece of material with a lever arm of some sort attached to one end, and the other end constrained in some manner so it cannot turn. When force is applied to the end of the arm, the arm twists the long piece of material and then, when the force is released, the piece of material unwinds and releases the energy stored in it as it was twisted.

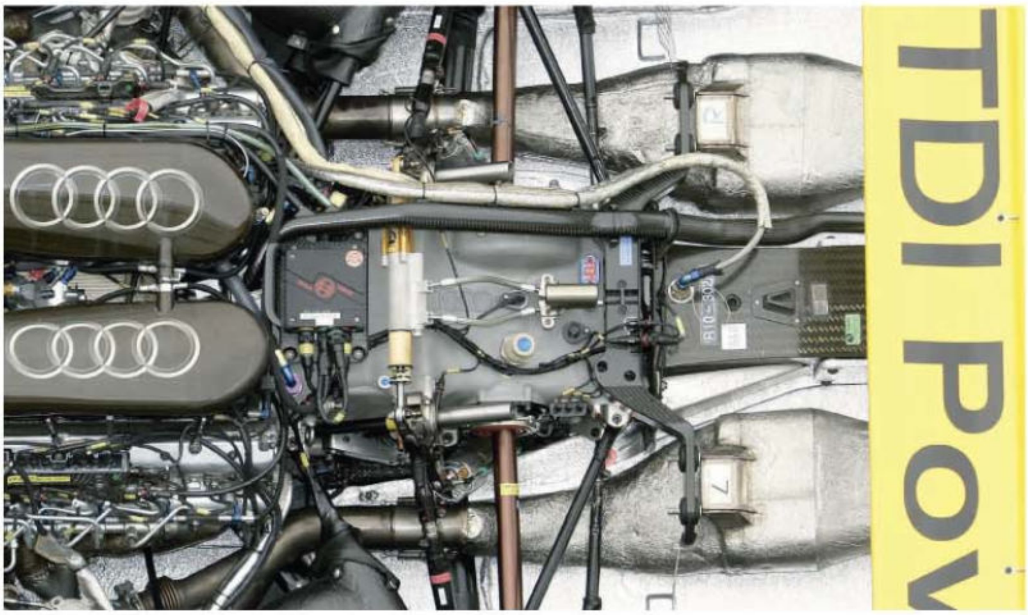
Ordinarily, the long, narrow piece of material is round in section and made of steel, but torsion bars can also be non-metallic, and they don't necessarily have to be round. It is imperative to have some way of attaching the arm to its end of the bar though, a bearing of some sort near the arm to support the bar radially while allowing it to rotate and a means of preventing the fixed end from rotating. Usually, to achieve this, the ends of the bar are splined, but a conventional hex can be used instead.

The earliest known device functionally similar to a torsion bar wasn't actually a metal bar at all, but a long, narrow, straight torsional spring made of fibre. Hanging from it was a device called a *foliot*, which was a horizontal beam with weights out toward the ends. When displaced rotationally about the axis of the 'bar' and then released, the *foliot* would swing back and forth, the frequency of this oscillation depending on the *foliot*'s moment of inertia and the 'bar's' torsional spring rate.

Hanging from the *foliot* was a rigid vertical shaft called a *verge*. The *verge* had two small paddles projecting from it and a simple bearing at the bottom that located the bottom of the *verge* radially. The paddles mated with the teeth of a crown wheel and the whole device regulated the crown wheel's speed of rotation. The complete device was called a *verge escapement*, and it was the type of *escapement* that was used in the earliest European mechanical clocks.

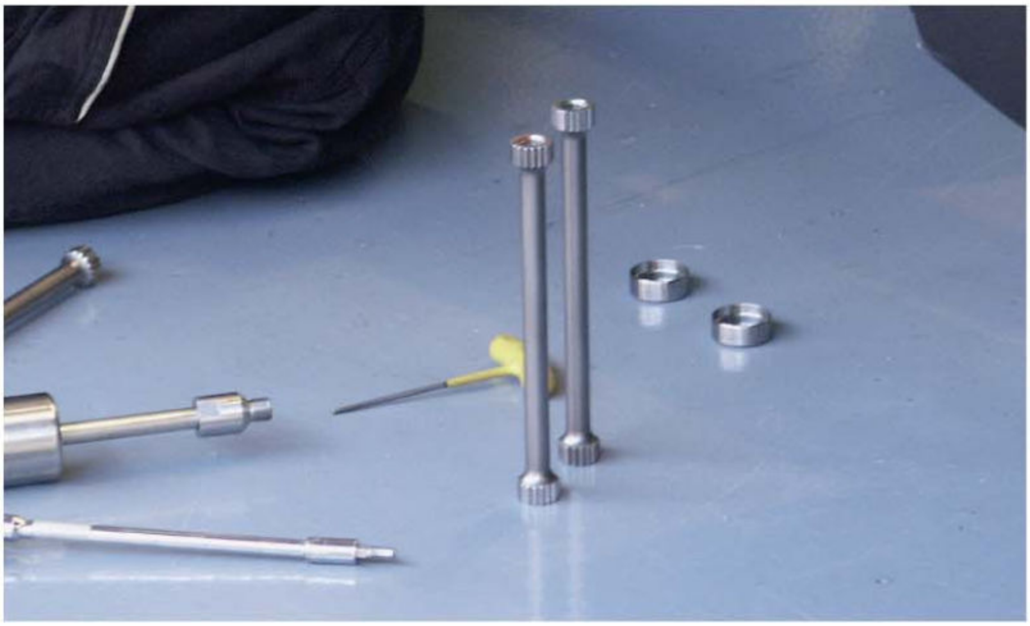
I have so far been unable to find any account of torsion bars being used as suspension springs prior to the automobile. Leaf springs were used in both horse-drawn carriages and railroad cars, and coil springs were also used on rail cars, but no torsion bars, as far as I can determine.

The earliest use of torsion bars in automotive suspension was on a Leyland car, in 1921. Tatra followed soon after that



The Audi R10 Le Mans Prototype uses torsion bars in its rear suspension layout

Formula Vee racercars use modified VW Beetle front suspensions, with transverse leaf stacks that work in torsion



Formula 1 torsion bars are complex pieces of engineering and, as such, manufacturing costs can count against them

and, in the 1930s, torsion bars were used on both the Auto Union and Mercedes-Benz grand prix cars (at the front and rear on all the Auto Unions, and at the rear only on the Mercedes), while the Citroën Traction Avant of 1934 was also fitted with them. Ferdinand Porsche was a leading exponent of torsion bars, using them not only on the Auto Unions but also on the Panzer tank, the Kübelwagen and on the KdF Wagen, which later became the VW Beetle.

By 1954, 21 makes of European car were fitted with torsion bars, at least at one end, yet in the US during that period, only Chrysler adopted them, starting in 1957. Torsion bars still remain in use on road vehicles today, including various Porsche models, and the front ends of many AWD sport utility vehicles.

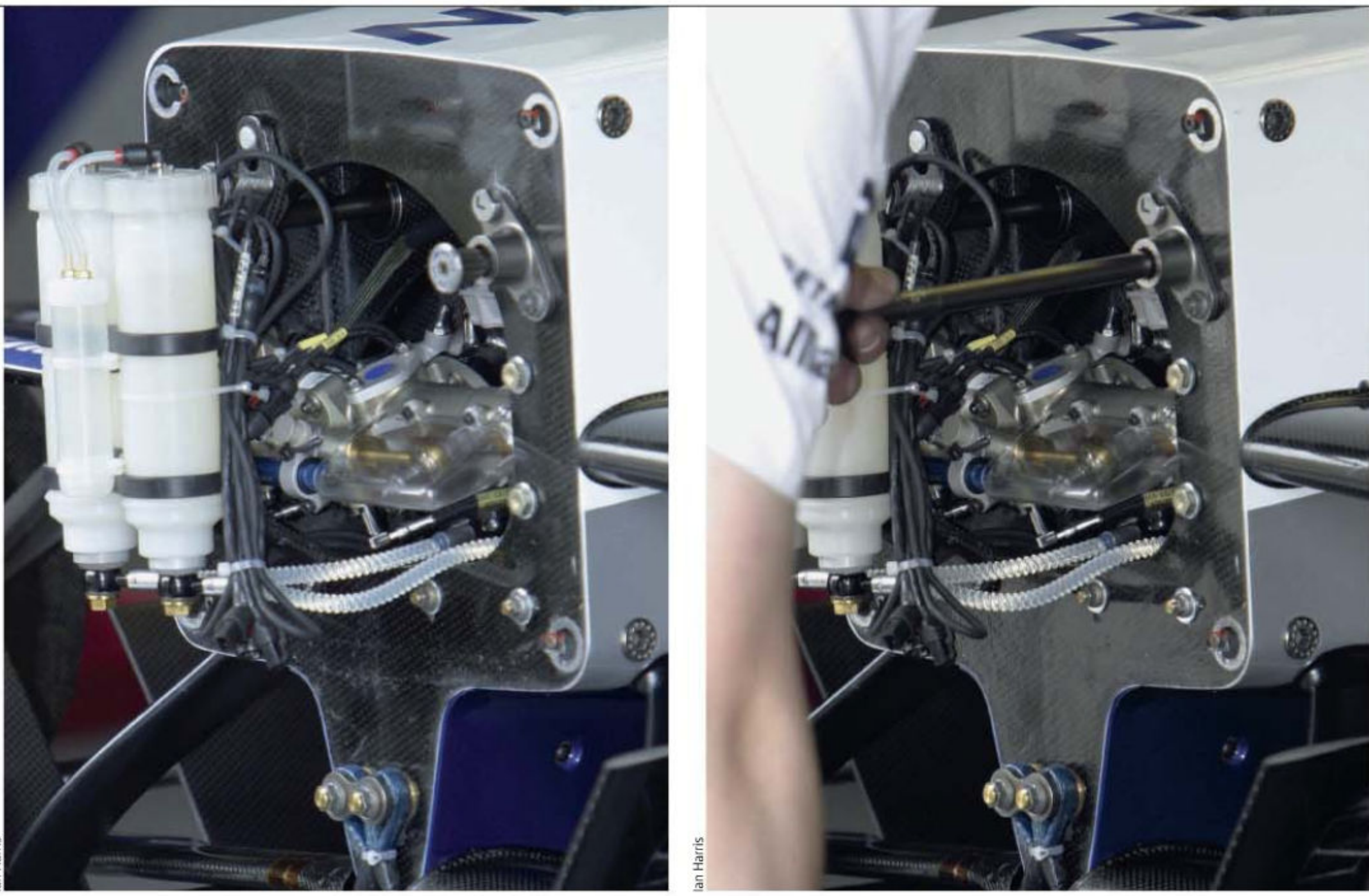
> **"torsion bars work, but they have not taken over"**

Recently, however, torsion bars have made something of a comeback on F1 and LMP cars. In these installations, the bars are shorter than in road cars and stand more or less upright rather than lying in the more traditional horizontal plane, and are actuated by the rockers of the pushrod suspension.

LOGICAL CHOICE?

What emerges from all of this is that torsion bars work, but also that they have not taken over from other forms of springing, nor have they conclusively fallen from favour. In many cases, we find them used only at one end of a vehicle, with a different style of spring at the opposite end. But what accounts for this? What factors logically lead a designer to choose a torsion bar over other styles of spring?

First of all, it is important to realise that there is no magic to be obtained from any kind of spring. They all do basically the same thing – that is they deform elastically in response to a load and recover their shape as the



Shown in use on an F1 car, the pair of short, horizontally mounted torsion bars in the front suspension of the Williams mount inboard of the nose cone

load is removed. The differences come down to packaging, cost, weight, interactivity with other elements of the suspension and motion ratio relationships.

At this point, we should probably also note that a compression coil spring is actually a torsion bar in a sense. When it deflects in compression, the wire actually mainly deforms in torsion, although it also bends a bit. There is also such a thing as a torsional coil spring, sometimes called a hairpin spring. These are found in mousetraps, clothes pegs and occasionally, automotive valvetrains. Here, the spring as a whole acts in torsion, but the wire mainly deforms in bending. Finally, there are torsional leaf springs, familiar as clock and watch springs. These operate similarly to torsional coil springs, but can generally deflect a much greater angular amount. Torsional coil and leaf springs are seldom used in automotive suspensions, but compression coil springs are very common.

So what we really should be asking is what are the pros and cons of winding a torsion bar into a helix so we won't need a lever arm to operate it vs keeping it straight and having a lever arm?

DISADVANTAGES

As a rule, it costs less to wind a wire into a helix, and then close and grind the ends to make a coil, than it does to machine and polish a torsion bar so, from a cost standpoint, the coil will generally get the nod. A torsion bar will normally have its middle portion turned down to a smaller diameter than the ends, and the ends then need to have splines or hexes, and often at least one bearing surface, added. In many cases, torsion bars are also gun drilled, to create a hollow bar. Torsion bars tend to be more highly stressed than coils, so it is vital to have the portion that deflects free of stress raisers. This means that the outside diameter has to be polished and, if there is an inside diameter, it too should be polished.

ADVANTAGES

One advantage a torsion bar has over a coil is that almost none of the spring itself is unsprung mass. In a coil, half of the spring moves as the suspension moves, and hence functions as a part of the unsprung mass. Worse, the moving coils can oscillate in their own right – a phenomenon known as coil surge. However, the torsion bar requires a lever arm, and part of that is unsprung mass, even if we decide not to call it part of the spring. Coil surge probably does occur in suspension springs to some extent, but it is much more of a problem in valve springs. Consequently, we could say there is a stronger case for torsion bars in valvetrains than in suspensions. Unfortunately, it is hard to find room for the length of a torsion bar valve spring in an engine where multiple cylinders lie in close proximity. Panhard flat twins had torsion bar valve springs, but that was practical only because each head served only one cylinder.

“ almost none of the [torsion] spring itself is unsprung mass ”

With all types of springs, there is a three-way trade-off matrix, involving weight, compactness and stress levels. Generally, anything that makes the spring smaller and lighter increases stress. Short of the point where the spring immediately sags or breaks as soon as we run the car, there is a range of stress levels where the spring will operate satisfactorily but, as we try to shrink and lighten it, its longevity, and its reliability decrease. In engineering terms, its safety factor decreases. To help understand this, some equations will be helpful.

First, the equation for rate of a coil spring:

$$S = (Gd^4) / (\pi ND^3) \qquad (1)$$

where:

S = rate, lb/in

G = shear modulus of material 11,500,000 lb/in² for most steels, 11,800,000 lb/in² for spring steel

d = wire diameter, inches

N = number of active coils

D = diameter of the coil, at the wire centre line

Next, the equation for rate of a torsion bar:

$$S = (\pi Gd^4) / (32R^2L) = (.098Gd^4) / (R^2L) \qquad (2)$$

LAT

Conversely, a pair of short, horizontally mounted torsion bars are housed in the bellhousing at the rear of the Peugeot 908 Hdi FAP LMP1

On road cars, probably the most well known torsion bar suspension is that of the Volkswagen Beetle, which combines a leaf stack at the front with a pair of transversely mounted round bars at the rear

where:

- S = rate at lever arm end, lb/in
- G = shear modulus, as in equation (1)
- d = diameter of the active portion of the bar, inches
- R = effective length (moment arm length) of lever arm, inches
- L = length of active portion of the bar, inches

Note that these equations are very similar. The active length of wire in the coil spring is πND. That corresponds to L in equation (2). The coil diameter, D, has an influence similar to the lever arm length, R. The rate varies inversely with its square, once wire or bar length is separately considered. Viewed this way, the denominators look nearly identical. The numerators are both Gd^4 times a constant. Of course, since we know that a coil spring is essentially a torsion bar, this should come as no surprise.

It will also be apparent that if we make D, N, R, or L smaller, we can make d smaller, and have a lighter spring without losing any rate. But what might limit our ability to do this? In a word, stress. When we get the same rate out of less metal that means we are working the metal harder. We are twisting each inch of wire or bar more degrees for each inch of spring travel or travel at the lever arm end.

It turns out that the stress level relates fairly closely to how much energy we want the spring to store: stiffer rate and greater travel both increase stress. One reason those short torsion bars in F1 and LMP cars work is that the cars have very little ground clearance and wheel travel. If the suspension were allowed to move more, the bars would have to be longer. Let's now look at the equation for stress:

$$\tau = T / Z_p = Tc / J \qquad (3)$$

where:

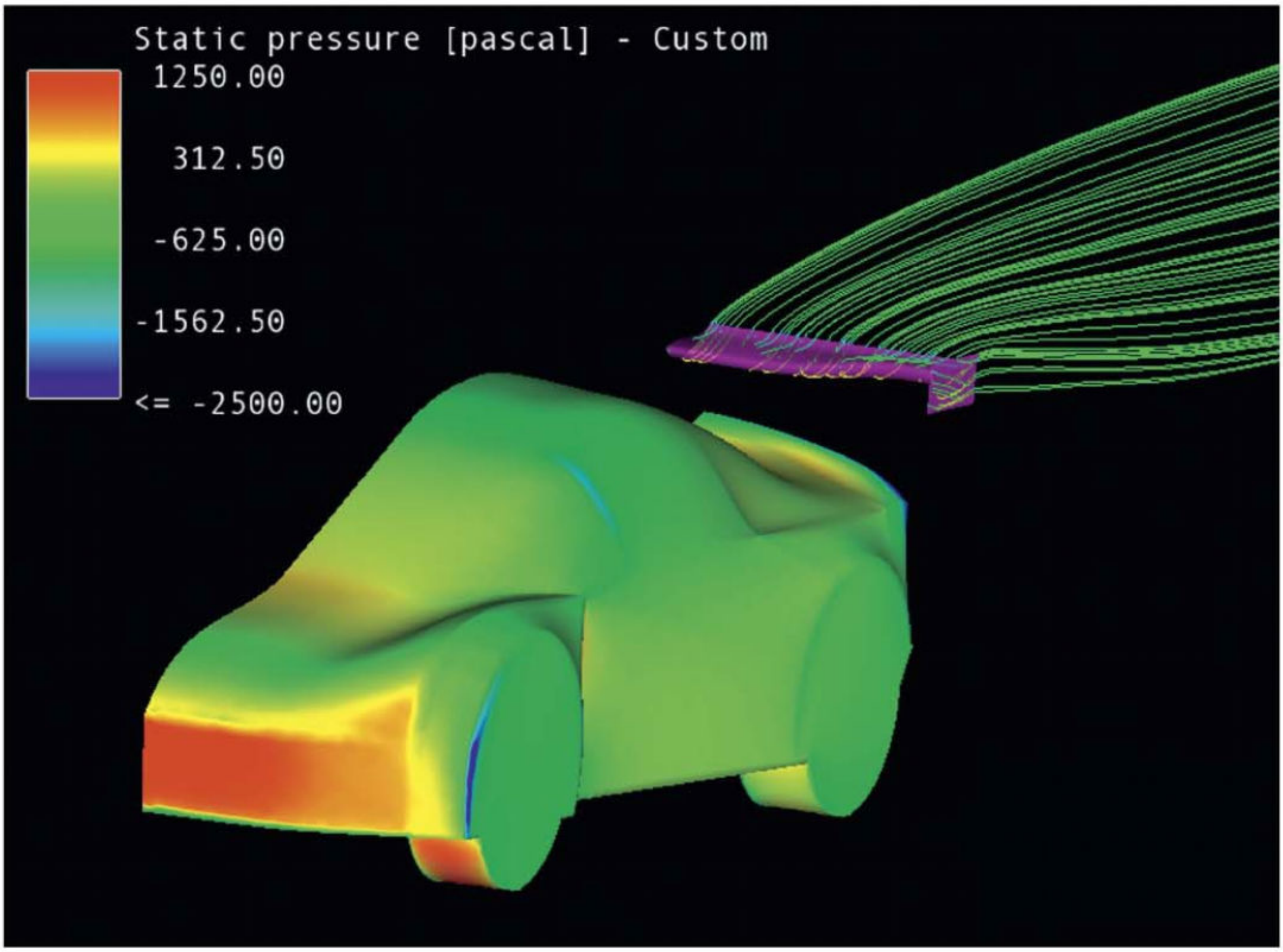
- τ = simple shear stress at outer fibre, lb/in^2
- T = torsional moment, lb in = R times force at arm end
- c = radius of bar, inches = d/2
- Z_p = polar section modulus, in^3 = .196d^3
- J = polar moment of inertia, in^4 = .098d^4

J is also sometimes called the second moment of area, or the torsional moment of area or inertia. It is important not to confuse Z_p and J with Z and I, which are the section modulus and moment of inertia, respectively, for bending calculations. For circular sections, Z and I are half as great as Z_p and J.

Let's look at what happens if we try to shorten the bar by half, and keep the rate and the travel the same. L is half as great, so d^4 is half as great if all other quantities are unchanged. That means d is smaller by a factor of the fourth root of two, or about 1.189 ie about 0.84 times as large. The polar section modulus, Z_p, is about 0.595 times as great. The rate, travel and arm length are the same, so the force at the arm end and the torsional moment T are the same. So the stress τ is greater by a factor of 1/.595, or 1.68. Either the original design had better be under-stressed, or we're going to have to find some vastly superior material from which to make it.

Now let's look at what happens if we shorten the bar by half, but leave the diameter and all other dimensions the same. This time, for a given load, we get the same amount of bar twist per inch, but half the suspension travel, since we have half as many inches of bar. For a given maximum load, τ is the same, but the suspension only moves half as much. S is twice as great, so therefore the suspension is twice as stiff. This, in a nutshell, explains why today's F1 and LMP cars can use short torsion bars that can stand upright in the car.

There are a few tricks that will allow a torsion bar to store the same energy, have the same rate, have the same stress level and be lighter, all at the same time. There are also ways to get a longer length in torsion within a given package length and there are ways to use torsion bars along with tubular shocks, and to get rising-rate suspension with more consistent damping ratios than we could with coilovers. Finally, there are ways that torsion bars can be used interconnectively, to which other types of spring lend themselves less readily. We will look further into these matters and more in part two next month.



Improving your profile

Optimising a wing profile in isolation is one thing, but carrying out the exercise with the wing in its intended location on a racecar must have benefits

BY SIMON MCBEATH

Wings with complex profiles can be seen in many international racing categories these days, from GT cars to Formula 1. Shapes range from a simple twist of a given profile across the wing's span to sometimes quite radical changes of profile and chord dimension across the span. Such shape variations from a simple, straight section across the wing are clearly there for a purpose and, in all probability, this will come down to achieving the maximum downforce for a given drag level, or perhaps the other way around, the least drag for a given downforce level. Whichever requirement has priority will depend on what a team's simulations and / or experience dictate as taking precedence and, of course, these requirements may differ from track to track within a given racing category. Whatever the aim, it is very apparent that computational fluid dynamics (CFD) is a great tool to apply to such a task, either at the design stage or during the development process. Following a request to design a GT2-style wing for a customer, some simple experiments were carried out using Ansys FloWizard to see what possibilities CFD analysis can bring to the task.

As with any development, the extent of your effort depends to a large degree on your resources. A well-heeled team may make use of auto-optimisation for a task such as this, where plug-in software works with CFD software to automatically and iteratively modify and re-test the shape of an item like a wing within pre-defined boundaries.

INITIAL TEST RESULTS

Figure 1

The car model used in these trials, courtesy of Ling Xiao, currently studying for his MSc in Motorsport Engineering and Management at Cranfield University

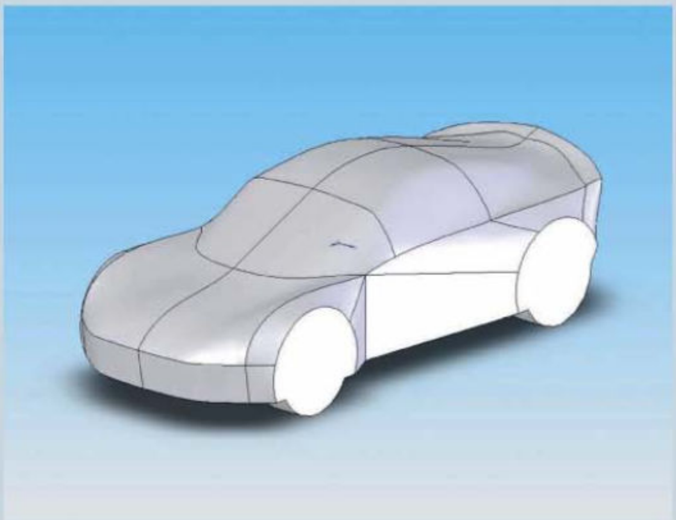


Figure 2

Velocity vectors show the downward flow onto the rear wing at the centreline

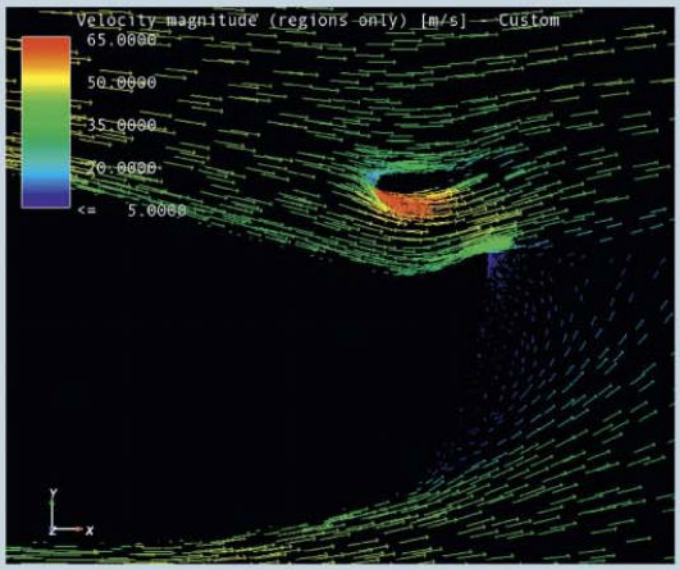


Figure 3

At quarter span distance the flow angle to the wing is shallower than on the centreline

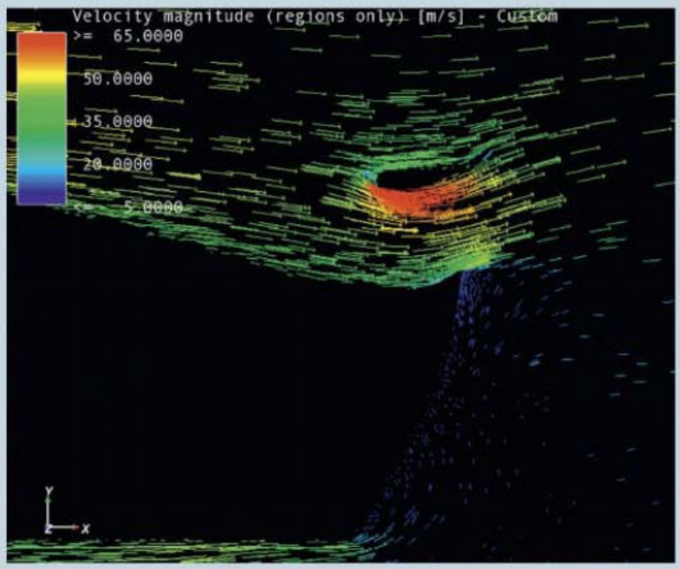
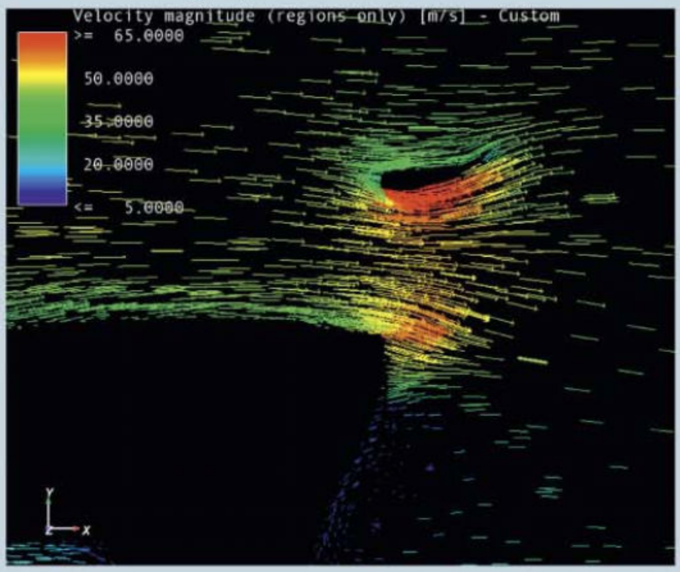


Figure 4

Near the wing tip the flow onto the wing is essentially horizontal and at nearer to freestream velocity than in the centre (note the yellow vectors instead of green)



Optimisation algorithms then seek out solutions that attain a pre-set goal, be that best lift-to-drag ratio (-L/D), maximum downforce or whatever. The 'manudraulic' variations on this automatic method could range from the shotgun approach – firing lots of CFD engineers at the problem – down to a more modest appraisal of some selected options so that a view on worthwhile directions might be formed. Inevitably enough, the approach taken for this article was the latter.

START LINE

The basis for the preliminary project highlighted here was a generic GT car, which in the CAD image in figure 1 above looks similar to a Lotus Exige – a popular choice for racers from grass roots to international level. Thanks go to Ling Xiao, currently studying for an MSc in Motorsport Engineering and Management at Cranfield University, who drew this model in SolidWorks from a set of dimensions, some photos and a request from your writer to keep the geometry simple enough that the model would mesh and solve on the office PC. Detail on the car was therefore deliberately sparse, but the main object was to create a reasonably realistic domain in which the performance of some rear wing variants could be assessed.

The start point with respect to a wing profile was one of the author's single-element designs that has already been used in a range of applications. The aim of this project was to find variations on the simple, straight span-wise profile that might yield improvement by lowering drag, increasing downforce or generating more downforce for a given drag level. Though this project is about studying the wing, inevitably interactions with the car body would be involved in determining overall performance but, because of the simplicity of the model used here, attention has been focussed on the wings.

TWISTED WING VARIANT 1

Preliminary thoughts turned to the variations that could be applied to the shape of the

Figure 5
The first twist variant (variant 1) saw the angle of the centre section reduced relative to the angle at the tips

Figure 7
Variant 1 did not compare favourably with the original straight wing when tested on the car model

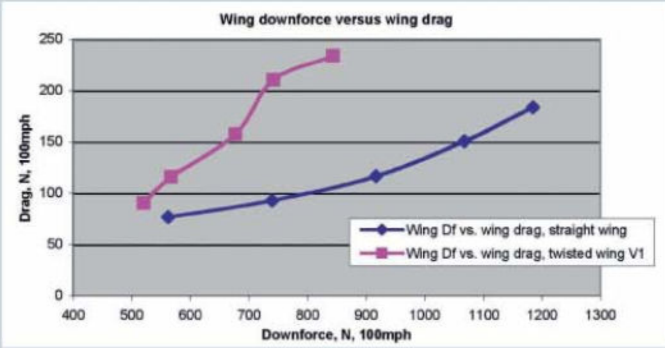


Figure 6
The wing was tested in each case with its highest point level with the roof and its rearmost point directly above the rearmost part of the car

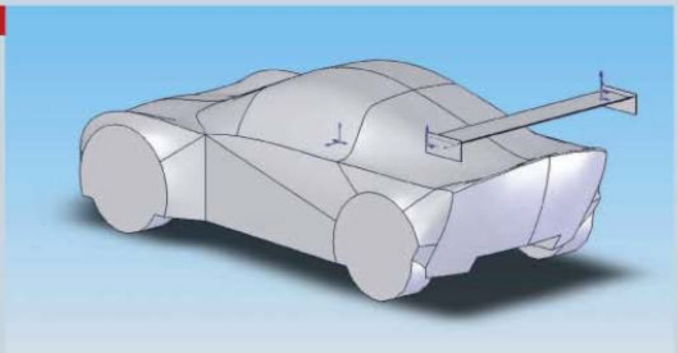
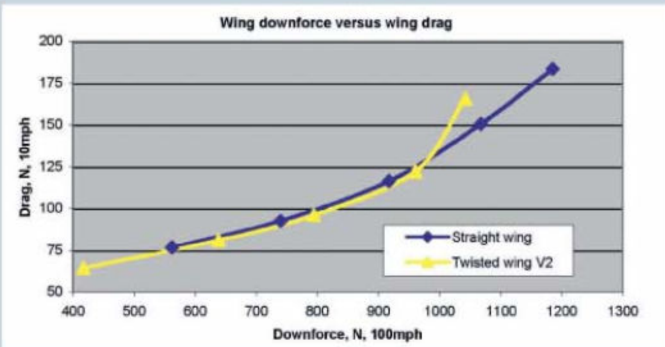


Figure 8
Variant 2 incorporated the opposite approach to V1, the angle of the tips being reduced relative to the centre section

Figure 9
V2 was slightly more efficient than the straight wing across most of the angle range tested



straight wing. One of the most common variants seen on GT cars is the raised leading edge in the central section of the wing, which serves to reduce the angle of that portion relative to the ground. And following initial mapping runs of the straight wing across the zero degree to 16-degree angle of attack range (relative to the horizontal), there seemed to be a certain logic in reducing the angle of the central section relative to the actual onset airflow. Figures 2 to 4 show the airflow direction using velocity vectors near the centre of the straight wing, at quarter-span distance from the centre and near the wing tip respectively. Clearly, the onset flow angle onto the wing varies across the span – by around eight degrees on this model.

From this, it would seem that the purpose of rotating the central portion of the wing 'nose up' is to achieve the same effective angle of attack across the span. But what result would this achieve aerodynamically? Wing variant 1 (figure 5) incorporated eight degrees twist in the centre, but otherwise used the same section profile as the straight wing across the span. The twisted wing was said to be at zero degrees when the centre section was at zero, but with the outer sections eight degrees steeper. And note that in all cases tested, the highest part of the wing assembly was set level with the roof line and the rear-most part of the wing was set level with the rear-most part of the car. (see figure 6).

Figure 7 is a plot of wing downforce vs wing drag calculated by FloWizard with the wing mounted on the car, data points being at zero degrees (relative to horizontal) to 16 degrees, in increments of four degrees. Very apparently, this wing variant seemed to be a good deal less efficient than the straight wing, creating more drag and less downforce across the angle range tested. This poor result may be specific to this particular car shape, but it nevertheless influenced the decision on how to design the second wing variant.

PRESSURE DISTRIBUTIONS

Figure 10

The presence of the wing can be seen to have modified the static pressure on the car's upper surface at the rear. The suction below the wing has reduced the pressure on the tail, shown by less red visible. (Note that only half of each model was tested to reduce CFD run time)

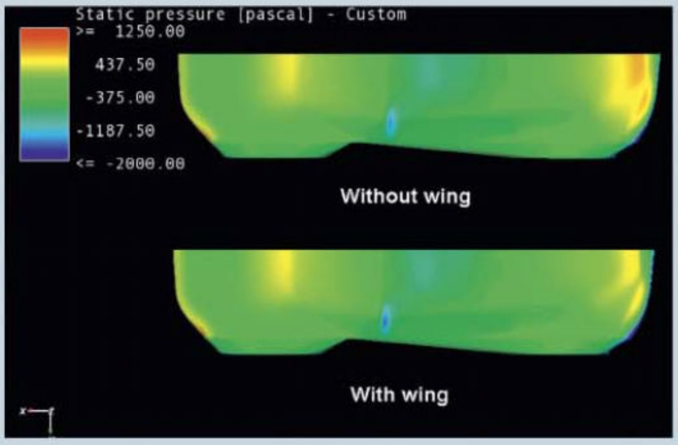


Figure 11

The wing also modified the static pressure on the car's underside, with more low pressure (shown in blue) being visible at the start of the diffuser between the rear wheels (on the right)

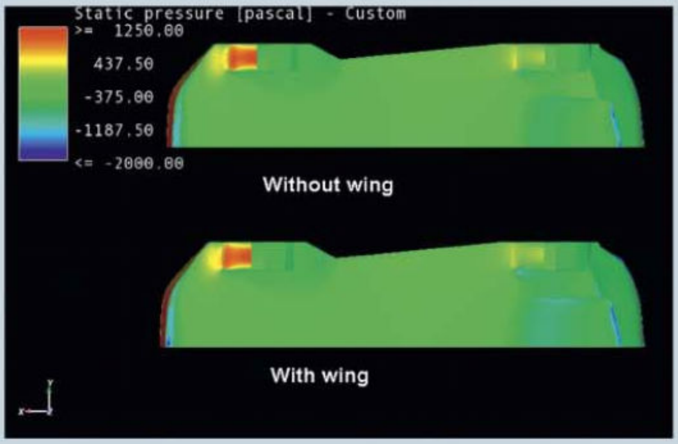


Figure 12

The underside of the straight wing in free stream (top) can be seen to generate the lowest static pressures near the centre (left), and these tail off towards the end plate. On the car, however, the underside of the straight wing generated its lowest pressures near the tip, not in the centre, in spite of the steeper angle the flow encountered the wing at

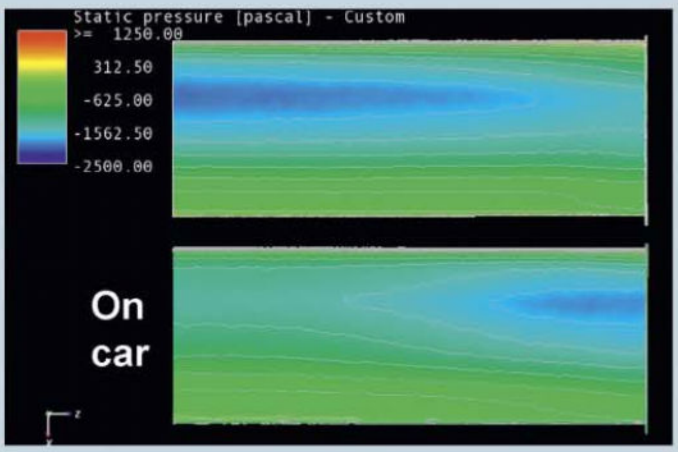
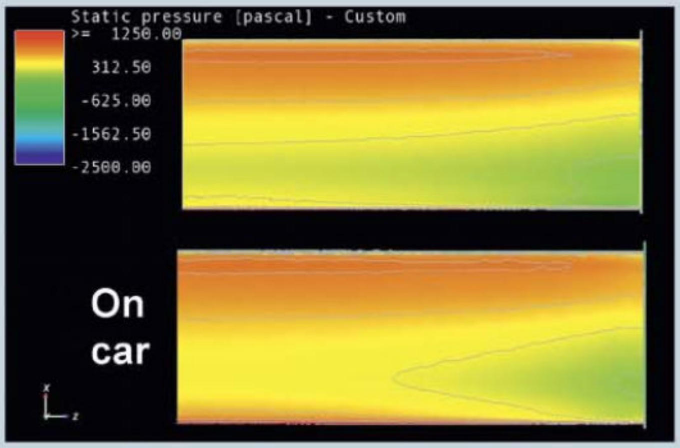


Figure 13

The pressures on the wing's upper surface are also modified by the presence of the car upstream, in this case showing raised pressure (more orange / yellow, less yellow / green) towards the centre trailing edge (towards the bottom) when on the car



TWISTED WING VARIANT 2

If decreasing the angle of the central portion of the wing produced such a poor result, what would be achieved by doing just the opposite? Twisted wing variant 2 (figure 8) featured outer ends that had their angle reduced by eight degrees relative to the centre section, and the angle of this wing was stated as the angle at the centreline. At a stated eight degrees, the outer ends were horizontal. Figure 9 shows variant 2 compared with the straight wing on the plot of wing downforce vs wing drag, and V2 in fact was slightly more efficient than (the curve was slightly below that of) the straight wing. Indeed, although V2 produced less downforce than the straight wing at each angle tested, it also produced less drag, resulting in V2 producing up to about a four per cent better -L/D value between eight degrees and 12 degrees.

At this point, and perhaps belatedly, consideration was given to the pressure distributions exhibited by the wings tested so far. In an ideal world, an efficient wing has what is often referred to as a 'classical elliptical span-wise lift distribution'. This means that the wing generates more lift (or downforce in our context) near the centre of the span than at the tips. This reduction in loading at the tips reduces the strength of the tip vortices and hence reduces the associated vortex drag. By modifying the span-wise profile of the wing we can, theoretically, reduce the drag of the tip vortices still further and increase the lift generated by the centre section of the wing to compensate for the loss of downforce from the tips.

This is relatively simple when considering wings in free-stream air. When a wing is in proximity to a racecar body, however, not only does the onset flow angle vary across the wing span, as we saw in figures 2 to 4, but also the energy of that flow. Air that has passed over the entire car along its centreline, for example, has reduced energy when it arrives at the wing compared with air that flows past the sides of the car and the wing is the first object it encounters. As evidence of this, note the higher velocity of the vectors approaching the wing in figure 4 compared with figure 2. Furthermore, there are also interactions between the wing and the car body that affect both. Figures 10 to 13 show the differences in pressure distributions on the car with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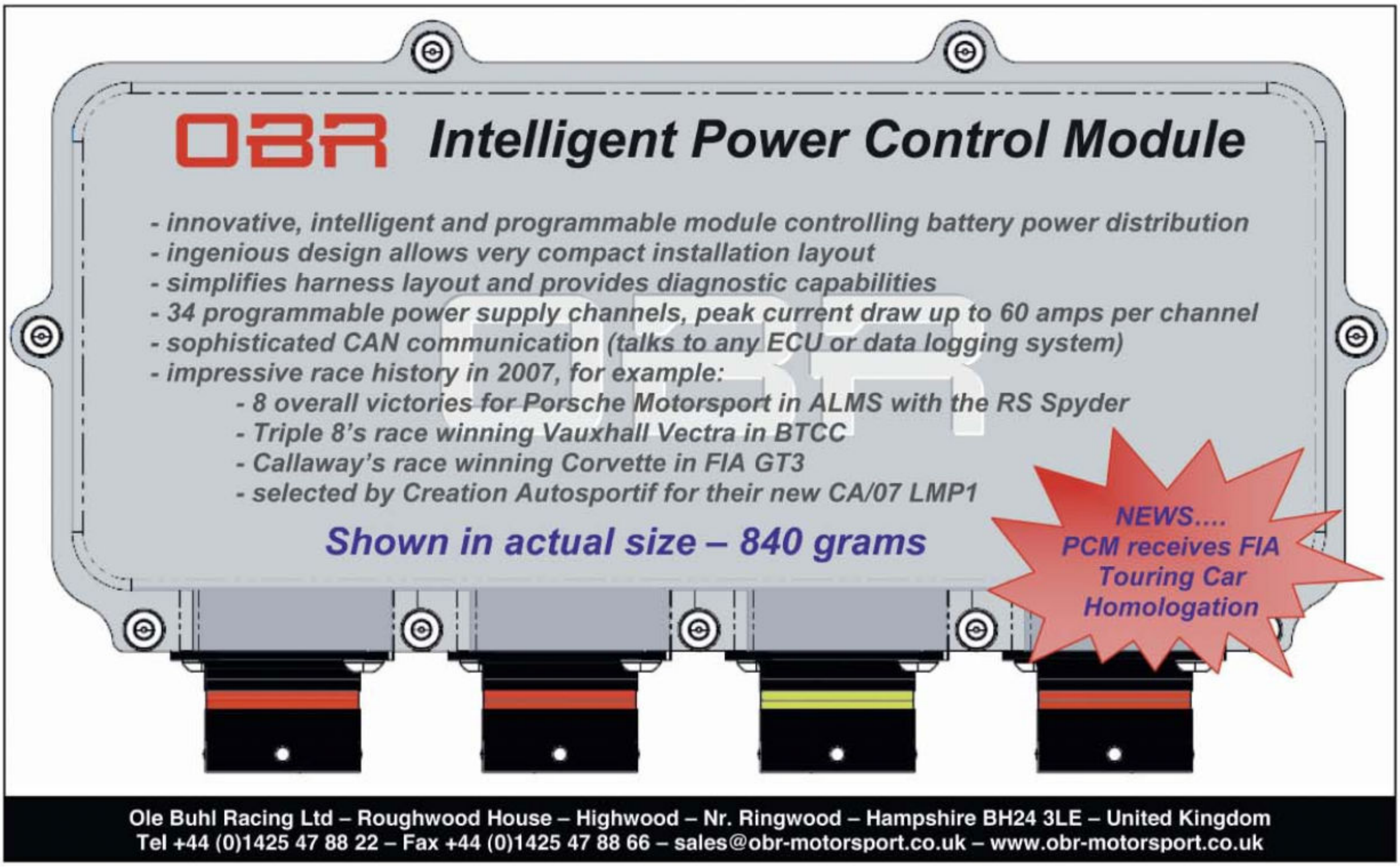
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FURTHER VARIATIONS

Figure 14

Wing variant V3 aimed at increasing the wing's potency in the centre of the span by incorporating more camber

Figure 15

V3 generated more downforce at every angle tested, and higher peak downforce, but also significantly more drag

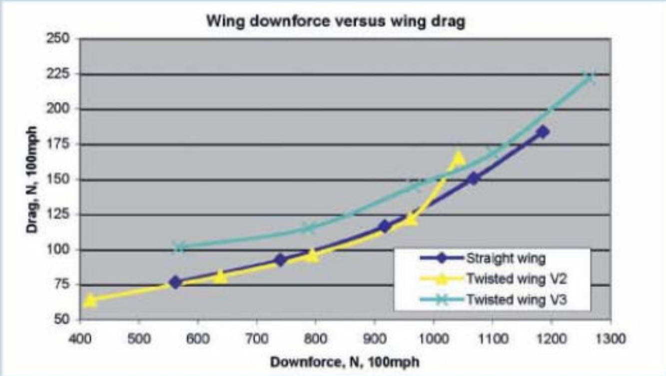


Figure 16

A plan view of variant V4 shows how the chord dimension was reduced at the tips

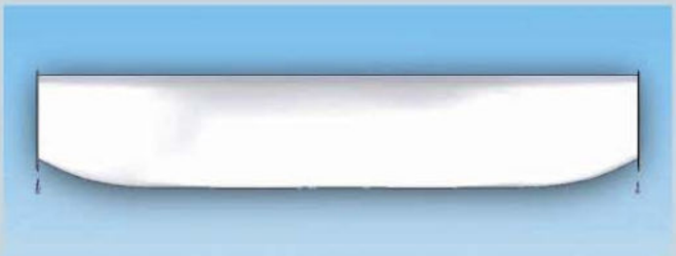
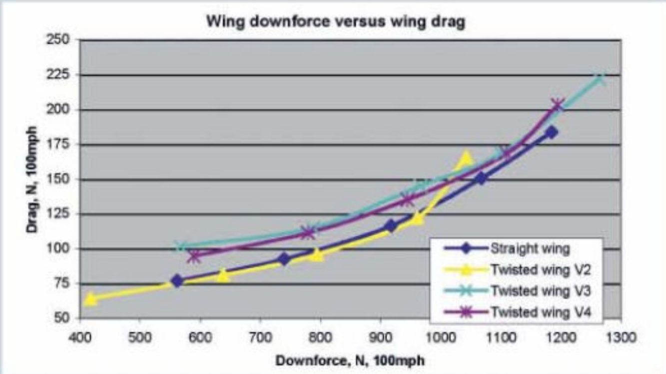


Figure 17

V4 was slightly more efficient than V3, but still short of the straight wing's efficiency



and without the straight wing, and on the straight wing with and without a car. As such, any decisions about how to improve some aspect of the aerodynamic performance of the wing, or the wing and the car together, must take these effects into account.

The options now were either to increase the 'power' of the wing in the centre, in order to generate more downforce from this section, or decrease the loading on the outer portions further, to reduce drag and hopefully improve efficiency (-L/D). The former route was chosen first.

TWISTED WING VARIANT 3

In order to increase the potency of the central portion of V2's span, it was decided to retain the same chord dimension and increase the wing's camber (curvature). A seemingly beneficial side effect of this was that the leading edge of the more cambered wing section was now better aligned with the flow direction coming off the centre of the car's roof. The cambered profile was then blended into the original profile using CAD to produce V3 (figure 14). Figure 15 plots V3's results with the straight wing and V2, and at the steepest angle of attack V3 achieved a 6.4 per cent increase in peak wing downforce over the straight wing. In fact, V3 generated more downforce at every angle tested than the straight wing, but it also generated more drag, so had lower efficiency than the straight wing throughout the angle range. V3 could therefore go forward as a potential high-downforce option, or at least provide design cues for such an option.

TWISTED WING VARIANT 4

So V3 performed quite strongly at the top end of the angle range compared with the straight wing, generating a worthwhile gain in peak downforce, but it was less efficient at lower angles. So would it be possible to increase the wing's efficiency by reducing the loading near the wing tips? V4 was drawn up with reduced chord near the wing tips, as shown in the plan view in figure 16, and again tested at the same five angles in the same location on the car body, with the results shown in figure 17. What we can see is a slight improvement in wing efficiency, and this was born out by the wing's -L/D ratio, which was 11.4 per cent better than V3's at a wing angle of zero degrees, down to 0.9 per cent better at 12 degrees. This improvement still left V4 short on -L/D compared with the original straight wing, however, even though it out performed it on peak downforce again.

PAUSE FOR THOUGHT

Seemingly then, the high-downforce profiles created here did not lend themselves to obvious, simple modifications to improve the -L/D ratio to levels comparable with the straight wing, so an alternative approach was needed. V2 produced a better -L/D up to 12 degrees than the straight wing and less drag throughout the whole angle range but, by virtue of reduced downforce throughout the range, it wasn't as big an improvement on the straight wing as was being sought. Therefore, given that increasing the camber in the centre section of V2 to create V3 generated higher downforce but significantly higher drag as well, it was decided to modify V2 this time by increasing the chord rather than the camber of the centre section, maintaining the same angles of attack of the profiles across the span. The ensuing wing model was designated V2a (figure 18), maximum chord now being 360mm in the centre compared with 300mm previously. Clearly, chord increase would only be a viable option in categories that

Figure 18

Modifying V2 produced V2a, with the central chord extended from 300mm to 360mm

Figure 19

V2a was considerably more efficient than V2 and the straight wing, especially in the middle of the angle range

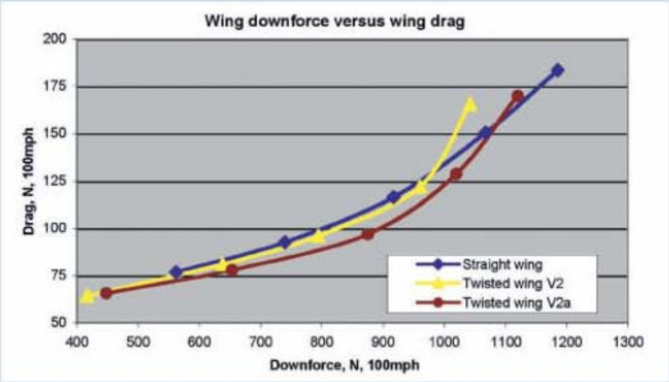
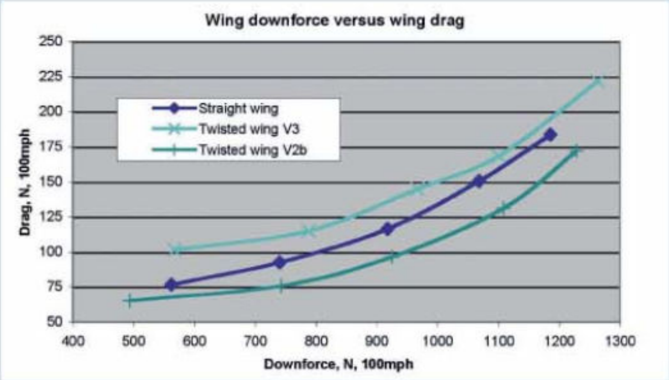


Figure 20

V2b saw the central chord extended to 400mm

Figure 21

V2b produced peak efficiency among the wings tested, but would only be a viable alternative to the straight wing where regulations allowed



permitted it, or where an existing wing was within the specified maximum chord.

TWISTED WING V2A

A test run on the eight-degree model showed promising downforce and drag values compared with both the straight wing and V2, so four further runs were carried out with the wing over the usual range of angles. Figure 19 shows the results gained, and V2a certainly appears to be operating more effectively than the original straight wing across all of the range that would likely be used. In fact, V2a produced the same downforce for up to 10 per cent less drag than the straight wing.

Clearly, V2a pointed at a direction worth pursuing further, so a third iteration, V2b, was drawn up, this time with a 400mm chord in the centre, blending slowly back to a 300mm chord at reduced angle at the tips (see figure 20).

TWISTED WING V2B

Again, an initial test run at eight degrees showed V2b to have achieved a significant improvement over the straight wing at this angle, so the remaining four angles were tested to build up a better picture. Figure 21 plots the results of just three wings for clarity: the original straight wing, the 'higher downforce' variant 3, and the 'higher efficiency' variant V2b. Not only does V2b generate significantly less drag at the same downforce levels than the straight 300mm chord wing, but it also appears to offer higher peak downforce at the steeper angles than the straight wing, and than the 'high-downforce' V3 wing at 12 degrees.

Of course, this begs the question, 'Wouldn't it just have been easier to have made a bigger chord straight wing in the first place?' Perhaps, but would such a wing that didn't benefit from the efficiency-enhancing reduction in loading at the tips perform as well? Those questions will be left hanging for now, as the purpose of the exercise here has been to illustrate how even a simplistic approach with CFD software enables the rapid evaluation of potential options.

CONCLUSIONS

This project has shown that model wing designs can be meaningfully compared with a basic CFD approach if they are located in an environment akin to their real working environment on a model racecar. Furthermore, the model does not necessarily have to be fully detailed as long as the part of the domain in which the wing functions is representative. It seems reasonable therefore to presume that this type of evaluation is more realistic than evaluations of wings in isolation, especially when the wings are being tuned to a particular car shape.

It has also been seen that unloading the wing tips by reducing their angle and their chord reduced wing drag on the back of a GT-style car. Increasing camber in the centre of the wing increased wing downforce, but at the expense of increased drag. In addition, it was found that increasing the chord in the centre of the wing increased wing-generated downforce but with minimal extra drag. It might also reasonably be stated that the original straight-wing design was apparently operating pretty efficiently at the outset and, on the basis of these few trials, its efficiency could only be bettered by a larger chord wing.

There are obviously many more options that could be evaluated, but the project served its purpose by focussing ideas on potentially beneficial directions that could be explored further with modest resources.

Thanks to Ansys UK and Ling Xiao at Cranfield University.

Safety stop

Photos: Andy Willsheer

A fatality in NHRA Funny Car racing last year has prompted a revolution in top-level drag racing safety

BY ANDY WILLSHEER

The world of drag racing was stunned last summer when veteran Funny Car driver, Scott Kalitta, succumbed to injuries suffered during a qualifying run at the Lucas Oil NHRA SuperNationals at Old Bridge Township Raceway Park in Englishtown, New Jersey. His high-speed crash led to America's largest motorsports sanctioning body, the National Hot Rod Association (NHRA), reviewing safety measures for the supercharged, carbon fibre-bodied machines that can cover the quarter mile in under five seconds and attain terminal speeds in excess of 300mph.

This is just the latest in a series of driver safety improvements introduced recently in top end drag racing: the HANS device; neck braces; arm and helmet restraints; formed seats; fire-resistant clothing; seven-point harnesses; rollcage helmet shrouds; oil-retention blankets; supercharger shrouds and chassis skid plates are now all standard requirements but, following Kalitta's accident, Graham Light, NHRA senior vice president of racing operations, reduced the universally recognised racing length of 1320ft to 1000ft for both the Top Fuel and Funny Car classes, with that regulation currently still in place.

Soon afterwards, Dave Leahy, proprietor of Delaware, Ohio-based Electrimotion, began work on a project he felt could fulfil the requirement of slowing and stopping a speeding racecar in the event its driver was, for whatever reason, unable to shut it down manually. Just one month after the SuperNationals incident, Leahy had a working prototype of a system he felt would do the job. A month after that, at the US Nationals in Indianapolis, Electrimotion's new safety shut-off controller kit was fitted to the entries of long-time Funny Car campaigners Jim Head and John Force.

> "easily installed, cost-effective system"

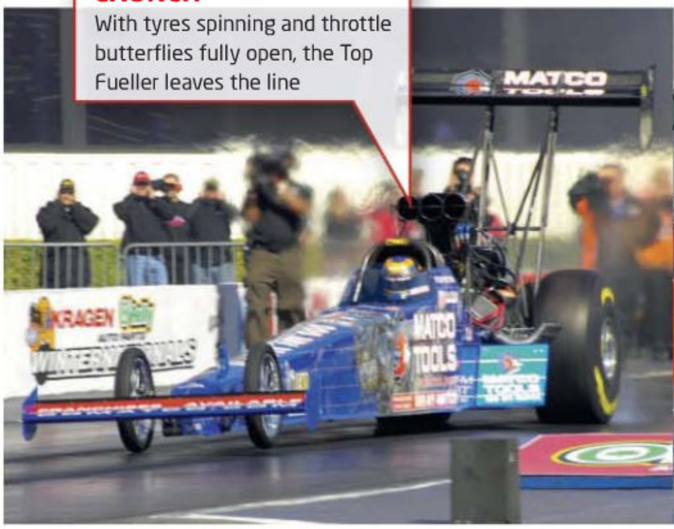
This easily installed, cost-effective ($375/£255), excluding air-activation cylinders) system employs sensors that monitor a number of the car's operating parameters during the course of a pass, with any malfunction – such as, for example, a supercharger backfire – initiating instantaneous fuel and ignition shut off, together with parachute deployment. Variations of the Electrimotion kit include a pressure sensor attached to the sump, which triggers the shut down process when a specified threshold is exceeded.

Some teams also employ a timing system, whereby the shut-down procedure is activated after, say, 4.8 seconds of a run have elapsed. In this case, should the driver be rendered unconscious or disabled for whatever reason, the car will not carry on at full throttle until it strikes the end-of-track gravel pit and catch netting, as happened in the Kalitta accident. In addition, the driver has the option of manually activating shut down, simply by pressing a button.

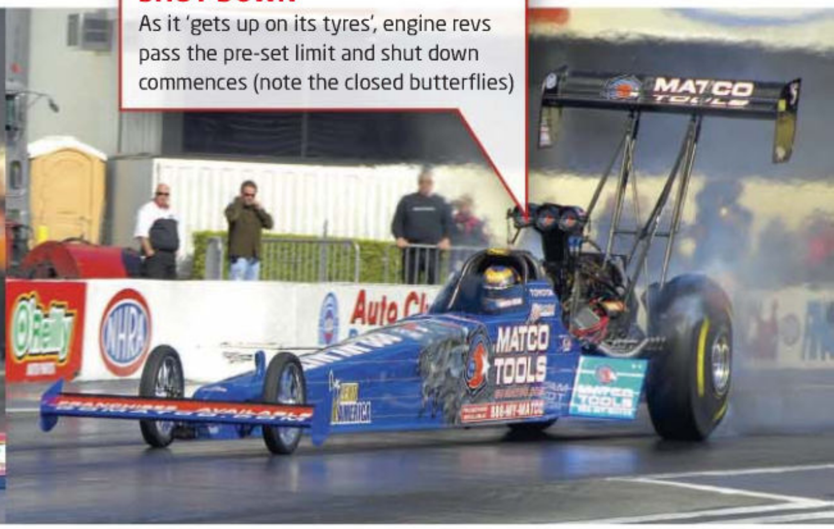
Electrimotion was gratified when its safety shut-off

> "mandatory in the Funny Car class from the end of October 2008"

LAUNCH
With tyres spinning and throttle butterflies fully open, the Top Fueller leaves the line



SHUT DOWN
As it 'gets up on its tyres', engine revs pass the pre-set limit and shut down commences (note the closed butterflies)



controller was made mandatory in the Funny Car class from the end of October 2008 and, following positive feedback from some of the sport's top names, also became a requirement for Top Fuel cars from the season-opening Pomona Winternationals, in February of this year.

So how well does it work? Funny Car driver, Robert Hight, who's a member of John Force's front-running team, was impressed when he instinctively reached for the fuel shut off and parachute release after the supercharger on his car's engine exploded at the US Nationals, only to realise the Electrimotion system had already instigated the shut down a split second after the SFI-Spec 23.1 burst panel ruptured.

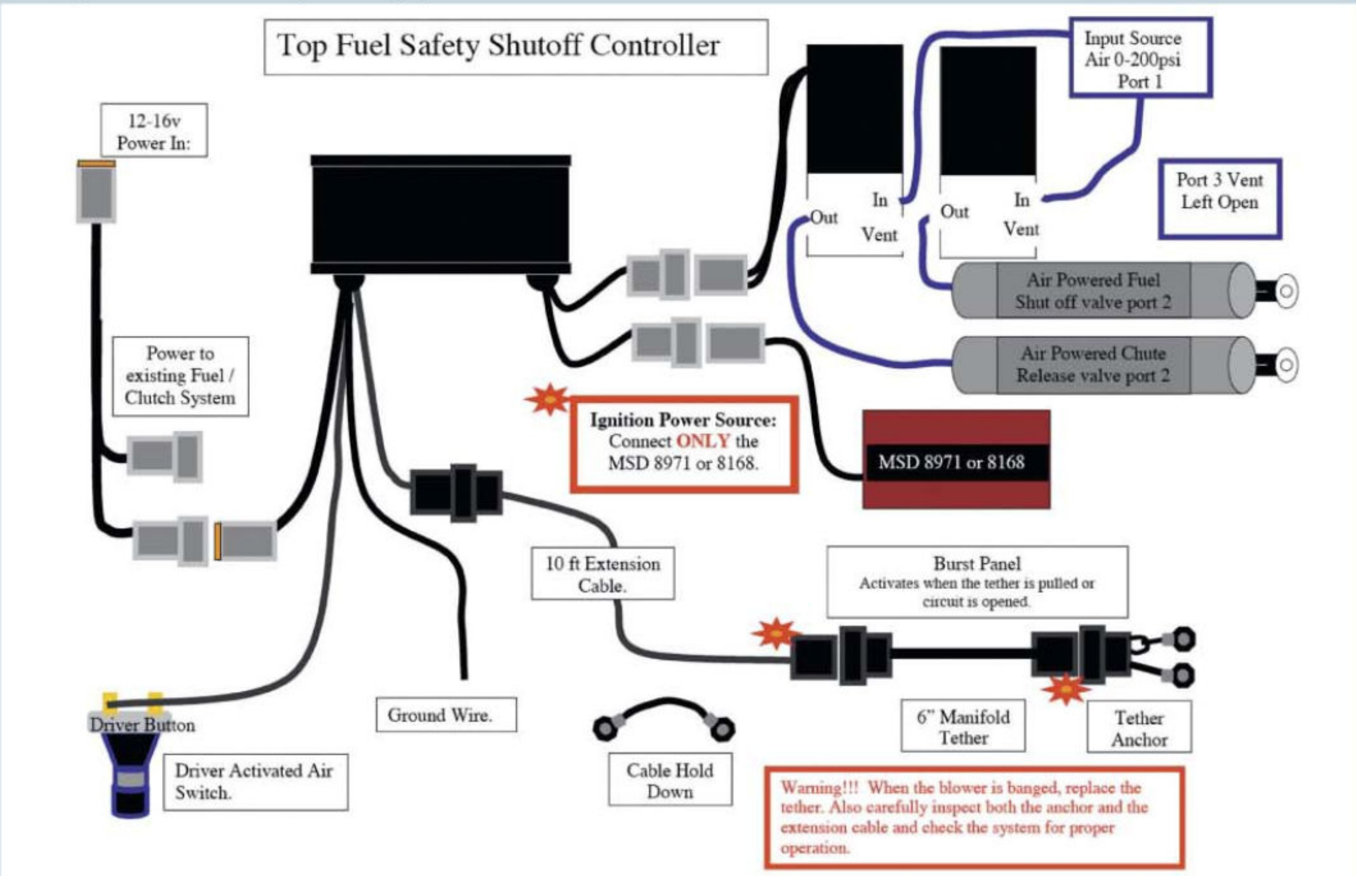
> **"shut down a split second after the burst panel ruptured"**

Another example of the effectiveness of the arrangement occurred earlier this year, when Antron Brown's Top Fuel car overcame available traction at the start of Pomona's Parker Avenue strip during an uncontested elimination pass. The combination of the engine's

HOW IT WORKS

Figure 1

Various sensors monitor the engine's vital functions. If any pre-set limits are exceeded, the shut down process is automatically initiated. It can also be set to go off on a timer or brought into play by a separate driver-activated switch



PARACHUTE OUT
Immediately after engine shut down the drogue parachute is deployed

SAFE STOP
With the fuel and ignition shut down and the parachute deployed automatically, the Fueller comes to a safe stop under complete control

prodigious power output and timing for the multi-disc clutch pack being overly ambitious for the conditions led to engine revs rocketing skywards as the slicks scrabbled for traction. This, in turn, caused excessive pressure build up in the intake manifold, leading again to the burst panel rupturing and setting in motion the cut-off procedure that had the engine silent and the parachute deployed well before the car had reached the halfway point of the track.

Accepting the fact that any form of motorsport includes an element of risk, the NHRA decision to reduce the racing length of the drag strip for its two top nitro methane-burning classes, thereby providing an extra 320ft of stopping distance at national event races, combined with compulsory use of the Electrimotion automatic shut-down system, will certainly provide some very useful extra margin for the drivers of these land-locked missiles. Should circumstances deem further action necessary, however, it's odds-on that the sanctioning body will look next at existing power levels in these classes, with a view to reducing them from the 7000bhp plus outputs that are currently the norm in the Top Fuel and Top Funny Car classes. Only time will tell...

When the controller is activated, one air-powered shut-off valve cuts off the fuel and ignition simultaneously

While a second valve automatically pulls the braking parachute

Also included in the system is a manual driver shut-down button

A sensor is attached to the supercharger burst panel, while others can be fitted to the sump or other critical monitoring points on the engine

The rig guru

For more than three decades, Dave Williams has tackled the dark arts of racecar suspension and now enjoys a uniquely privileged perspective

BY CHARLES ARMSTRONG-WILSON

The idea that he may be a legend in suspension circles is one Dave Williams dismisses derisively. He's a quietly spoken man in late middle age whose self-effacing manner mostly manages to conceal his enthusiasm and pride in his work. Yet his knowledge is revered in the industry and his reputation among those in the know is immense.

'I know a bit about certain areas,' he says modestly, 'but there are big gaps in my knowledge. I don't have the whole picture.' But when you talk to him about those areas he does profess to understand,

Ferrari F430 GT2 car on Multimatic four-post rig, which incorporates two pneumatic actuators to add aero loading

you realise why his time is in demand from race teams all around the world. Currently, much of that time is taken up with working as a consultant to teams at the Multimatic test rig in Thetford, not far from Lotus, where he was first drawn into motorsport.

Williams created what he thinks was the first suspension test rig at Cranfield in an attempt to understand the active suspension he created for Lotus. 'It was my idea, I suppose. The rig came from Servotest, who did the actuators and hydraulic power supply, while the controller for it was ours [Cranfield's]. It was an active suspension controller.

'Some five years later, someone came along from Reynard and asked if they could use the rig to help set up passive suspension, which hadn't occurred to me at all,' recalls Williams. 'I was a spectator for the first few tests, then started getting interested technically and began thinking, "What could you learn about a car with very simple bolt-on instrumentation?" From that starting point, things have developed and grown right through to now.'

> **"Reynard asked if they could use the rig to help set up passive suspension, which hadn't occurred to me"**

METHOD MAN

Over the 20 years he has worked with suspension rigs, Williams has developed his own methods and tools for analysing racecar suspension. Most people who use suspension rigs, notably Formula 1 teams, tend to focus on running track-derived data to optimise the car. Williams acknowledges this has its uses, but he also recognises its limitations. 'It's a tool, it plays a part, but I don't think it is the only tool by any means, because you throw away so much of what you can find out. There are a number of issues, like you can't load the car laterally so the tyres aren't in the same state. Nevertheless, the optimisation methods they have developed are really quite sophisticated and work remarkably well in the sense that I've seen data from the track and data from the rig where you can't see where two lines deviate. They really can be very accurate.

> **"I've seen data from the track and data from the rig where you can't see where two lines deviate"**

'If you want to set up dampers and springs with dampers, it is definitely not the best way to do it. The sort of sine sweep studies I do here is, I think. I have been working with F1 teams where they have been doing their thing and I've been doing my thing on the same car on the same rig and been comparing notes and data over a race weekend with the car at the track, so it's a fairly immediate loop, and that's very illuminating. It shows what the two types of study do and don't say about how the car behaves.

'Track simulation doesn't help you understand very much about the vehicle. That is the issue. You throw away a lot of the potential information because it is a track simulation. You can't deduce the tyre stiffness or the installation stiffness. You see the end effect, but you can't deduce how it is made up. In simple tests like I do, you can unravel this and deduce what the real issues are, and I think that's the real power of it. The fact that it can often help a car go round the track quicker is incidental. The teams don't think so, but I tend to think it is.

'Although racecars are generally quite well designed, on occasions they aren't. For instance, there was one Formula 1 car where the best damper turned out to be the engine. Because the unit was not a monolith but was flexing, and was full of oil and bits that rub against one another, it became a very effective damper. It was actually absorbing 40 per cent of the energy input into the chassis.'

The rigs Williams uses at Multimatic in the UK and Canada are not the most complex incarnations of the concept. They would normally be described as four-post rigs with four hydraulic actuators for the wheels, but with the addition of two pneumatic actuators to add a steady aerodynamic load. In the world of seven-post rigs, many would regard the Multimatic versions as limited, but Williams insists they actually have practical advantages.

'The cars they [F1 teams]

LAT

One of Williams' first assignments was developing the active suspension used by Lotus on its racecars in the 1970s, in particular the troublesome Lotus 80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Williams always prefers to work with real racecars in race trim as items such as anti-roll bars, which may be left off, can have a dramatic effect on set up

usually put on their rigs are not race vehicles. They have slave engines and they are usually out of date. In fact, you could not put a racecar on a seven-post rig because you need to make a structural connection between the sprung mass and the hydraulic downforce actuators.' Normally, that would render a racecar as scrap.

'I like to try to get a real car here. It's something I would hate to lose, and if that means we are stuck with pneumatic downforce, then I'm happy with that. It means an F1 team can bring its car in here before they can get it on their own rig. Normally, they have to build a rig car and it's usually quite a way into the season before they get that.'

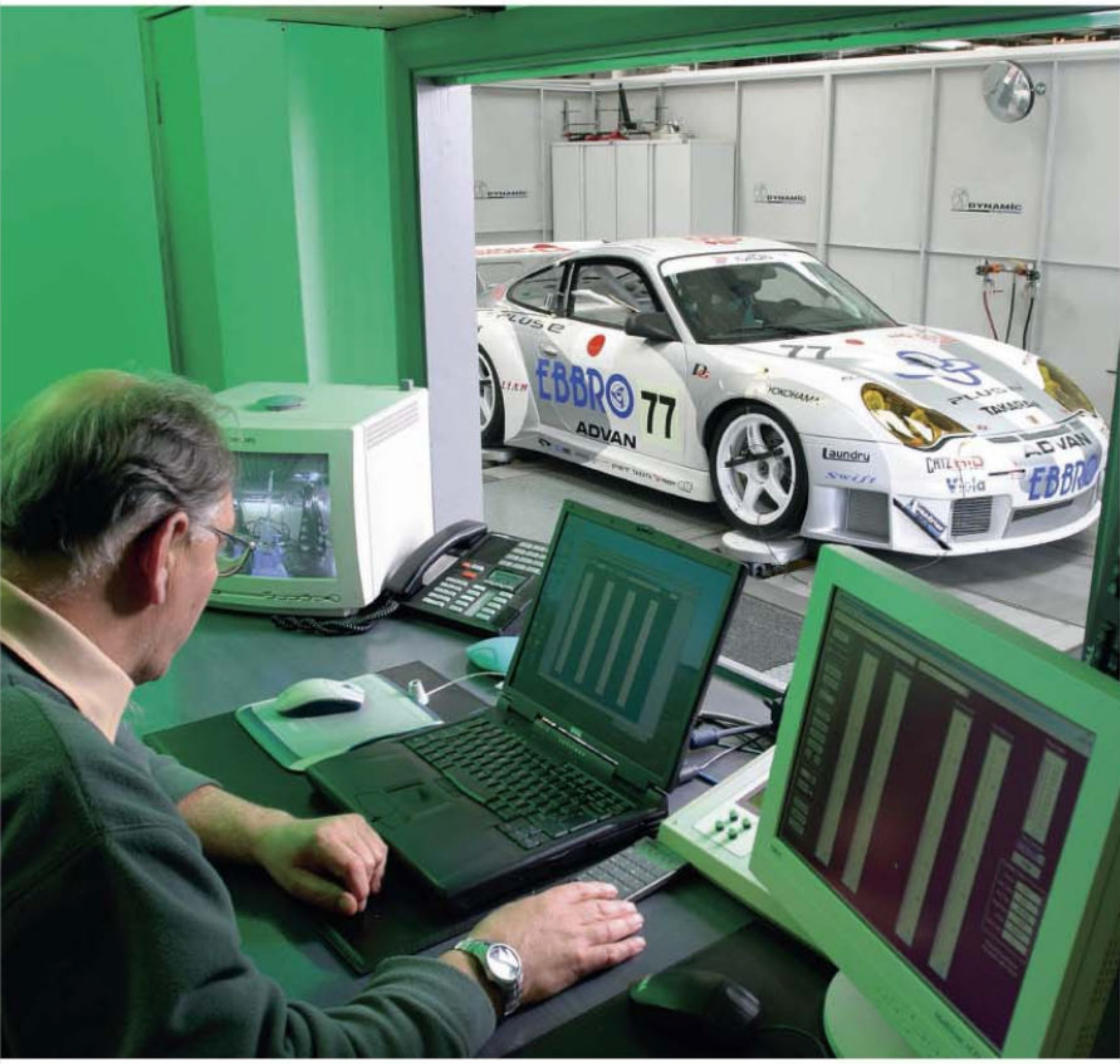
One of the reasons Williams is so keen to work with real racecars, as opposed to mock ups, is because assumptions can mask real problems on the vehicle. Generally, customers bring their cars in to get the suspension and damper settings in the right ballpark to then be fine tuned at the circuit. 'We will get an optimised set up, get a balance between tyres, springs and dampers, but you'll always find something else that you weren't necessarily expecting. Anti-roll bars are a classic one. They will find in their test there is a stiffness across the axle, so we do a sweep of the roll bar settings – the number of times that it can get softer as they set it stiffer,' he explains. Suspension roll stiffness is sometimes increased by loading a torsion bar connected to suspension rockers by 'drop links'. The arrangement works well when the drop links apply pure torsional loads to the bar, but often the torsion bar will deflect in both bending and torsion. This can produce counter-intuitive effects when bar settings are changed. For example, the overall roll stiffness can actually reduce when settings are [logically] increased. A rig is a cheap and effective way of understanding issues like this.

> **"I give a car what I call its symmetry rating"**

Williams says he also finds many suspension rigs, particularly seven-post rigs, are misused. 'Often, when I go to a customer, the most effective dampers in the room are the hydraulic downforce actuators. So we find we have to re-optimise the controllers. When a car has been developed on a seven-post rig, usually the first thing we see when it goes on our rig here is it is under damped.'

COST FUNCTION

Williams describes this as: 'Where you have a number of variables and you would like to optimise all of them at the same time, but that's not always possible. So what you would like to do is get a good compromise between things that sometimes pull in opposite directions. The way you do that in a control system is to use what is termed a cost function. By taking each of the parameters that describe different elements of set up and weighting those parameters, then adding them together, you are producing one number which describes what you think is a good compromise.'



Customers are given a summary of every run that is done on the rig, and the car is then given a performance index

PERFORMANCE INDEX

Over the years, Williams has developed his own techniques and own tools for the job, most notably his racecar performance index, a mystical term often whispered around the race paddock. He relates where this came from, recalling his early days of rig testing: 'The starting point would be when a team came in with a car with springs and 'bars that they chose and they would go away with damper settings that work with those springs. And we would do that for maybe four or five springs selections. To begin with, what I did was almost finger the wind and, with time, it became obvious to me that I was better at doing that on some days than others. So I started thinking about how I could achieve some consistency and I used the idea of a cost function, which is used widely in control engineering. I put one together and started playing with it, manipulated it, and changed it so that I became more comfortable with it. But it wasn't a deliverable for well over a year. Then one of my Touring Car customers said, "Can I have a copy of that?" He took it away and a while later, during conversation, said, "you know, I tried half a dozen of your set ups at the track and it ties up well with lap times."

"All I was trying to do was optimise the control of the car"

So it was actually a customer who told me that it worked, rather than me thinking in a vacuum. All I was trying to do was optimise the control of the car. At that point I thought maybe that's a deliverable and it kind of developed from there. So now customers get a summary of each run, including all the parameters that I've calculated and used or might have used to put together that description and the cost function, which I now call the performance index [PI].

'And that has developed into different things. So I give a car what I call its symmetry rating, which describes numerically how symmetrical the car is. If the car is not symmetrical, when it is subjected to vertical inputs it actually changes balance. The rig is good at spotting mis-adjusted dampers where the mechanic has slipped and gone up on one side and down on the other. That happens a lot.'

PROBLEMS OF PERCEPTION

An undesirable side effect of this is an unhealthy obsession with PI figures in the paddock.

DAVE WILLIAMS

Starting his career as an apprentice at British aircraft manufacturer De Havilland gave Dave Williams a thorough grounding in aeronautical engineering. It also made him curious about aerolastics – the study of vehicles as flexible structures and how they interact with aerodynamic forces. This took him to Cranfield University to study aircraft response in turbulence. Throughout this time he also worked as a freelance engineering consultant and his work with small measurement systems used in aerobatic aircraft came to the attention of Peter Wright at Team Lotus. At the time, the team was trying to understand more about the dynamics of its grand prix cars and, in 1976, Williams started consulting to Lotus.

He gradually became sucked into the various problems the team was tackling, culminating with the problematic Lotus 80. His experience on this car led to him proposing and developing active suspension for the team and for the road car consultancy, Lotus Engineering.

Leaving Cranfield in 1997, he remained a freelance consultant, and today much of his time is taken up with work for Multimatic on its suspension rigs in Norfolk, UK and Toronto.

INERTERS

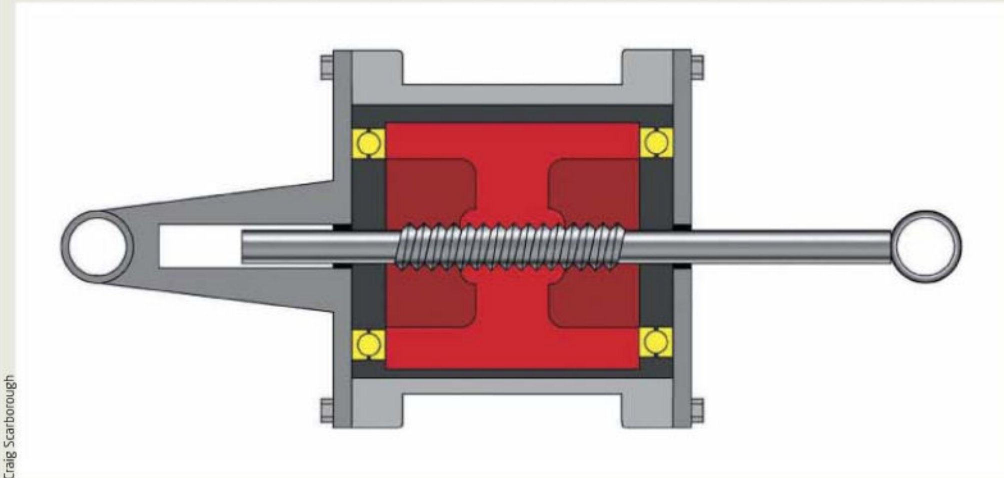
Williams regards inerters as 'the biggest change in suspension dynamics in years.' His experience on the rig of the technology that has swept through Formula 1 in the last couple of seasons is very enlightening. A couple of years ago the teams were bringing them to his rig for blind testing because, although they thought they worked, they were not entirely sure about their effectiveness. However, the iterations the teams produced for the last season were, in his experience, much better. 'If you set them up correctly you can double the minimum load under the tyre,' he observes. In other words, they markedly reduce the load variation in the contact patches of the tyres, both improving grip and generating less heat in the compound due to vertical load cycling. He also notes that in some ways it is better than active suspension.

The different ways teams are using them is also rather surprising: 'They have bad characteristics as well as good ones, and I've seen some teams use them to beat the hell out of the front tyres to get them up to temperature. The rig can tell you how much the tyres are being heated and it does significantly change the heat in the tyres.'

"Renault's dynamic absorber arguably has no more aero influence than an inerter"

Williams is also able to divulge why he thinks there have been a number of inerter failures, resulting in spectacular accidents. He puts it down to the use of different metals without allowing for the differential expansion rates. While an inerter in operation on its own generates very little heat, they are usually mounted in high temperature locations like just above the gearbox. Once the clearances disappear, the unit locks, removing the freedom to jounce from that end of the car.

His comparisons with Renault's mass dampers, or dynamic absorbers, are revealing and, in particular, why he thinks certain teams failed to make it work. 'Some teams got it wrong by tuning it to the pitch mode of the car, when you need to tune it to the frequency at which it will porpoise.' His point is the purpose is more to do with the tyres than the suspension and observes that, 'Renault's mass damper would be most effective when the suspension was locked.' An inerter, however, does nothing if the suspension is locked. For this reason, he notes wryly, despite being banned due to its aerodynamic influence, Renault's dynamic absorber arguably has no more aero influence than an inerter.



Craig Scarborough

Above: cross-section through an inerter. Flywheel (in red) spins in the bearings (yellow) to absorb and release kinetic energy

XPB

Left: 2008 Renault F1 rear suspension incorporated inerter. Such units must be carefully tuned to the chassis

To the point that customers have been known to ring Multimatic complaining that a competitor has revealed that their car's PI is 0.24 when the customer's car is 0.4. The response is usually to point out that nobody is racing PI figures, and that anyhow the competitor is lying. Another exasperating phenomenon is the trade in set ups. 'I had a car on the rig and I said [to the customer] well, I think you want to change the dampers and he stood back and said "why?"' Dave told him they were not quite optimised, and the surprised customer replied, "Well, I bought this set up from somebody who told me it was your set up."

"Some think of it as bolt-on speed... It's not"

This is where there are problems with the perception of what it is that Williams actually does. 'Some think of it as bolt-on speed,' he muses, 'but it's not.' An example of this is his work with IRL teams. Multimatic has a very strong relationship with Newman Haas. However, many teams turn up at the rig in Toronto saying, "Give us the Newman Haas set up." Williams explains the absurdity of this request: 'We tell them it's not relevant, and it's true. In the set up of a car there's probably 100 plus variables, and I am maybe changing five of them. Where I go with those five depends on what they've done with all the others.'

More than 30 years down the line, working on the rig at Multimatic still excites Williams. 'If everything was the same it would quickly become boring, but there's always something new.' Reflecting on his own role, Williams is typically modest. 'In a sense we don't do anything more than a good test driver would at the track, with one or two exceptions. And one of those is if the car starts off in the wrong ballpark, then an engineer will probably never make a big enough change to get into the ballpark. On the rig, you'll see it straight away.'

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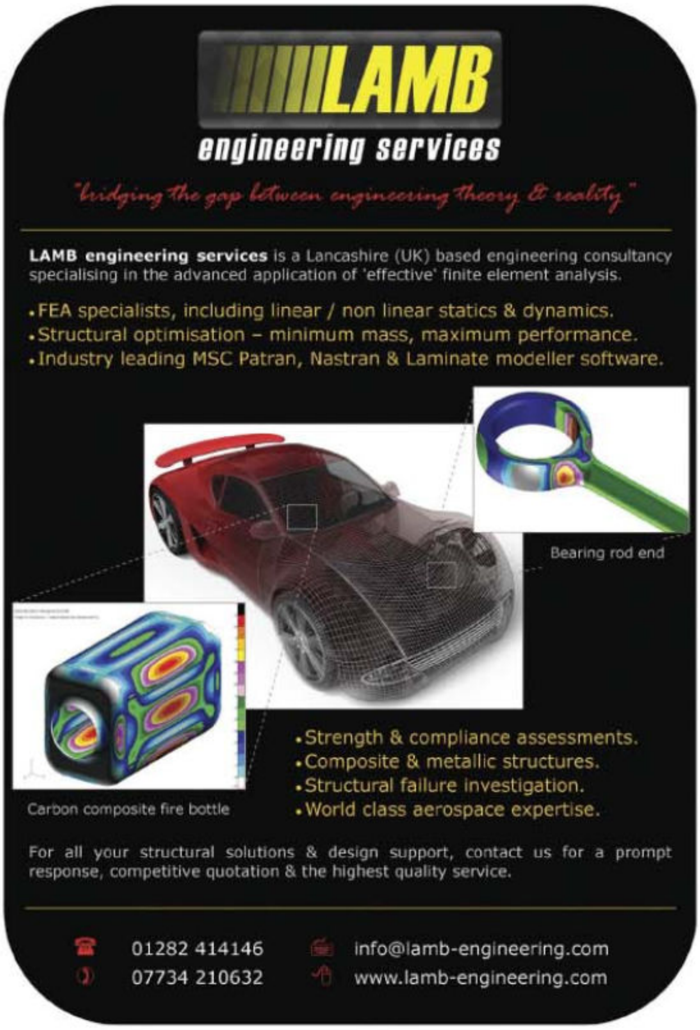

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LAT

NASCAR 2009 AD

NASCAR engineers are being forced to adapt. *Stockcar Engineering* talks to Jimmy Makar of Joe Gibbs Racing to get the inside line on the new way

JONATHAN INGRAM

During the NASCAR test day at Charlotte last Fall, small seas of engineers were seen huddled at various tables throughout the garages, poring over computer screens, rather than the more traditional pose of leaning into engine bays.

Jimmy Makar easily moves between the three Joe Gibbs Racing (JGR) Toyotas and between two long tables lined with laptops, each manned by one of the team's engineers. A fabled mechanic, crew chief and now technical guru, Makar's presence and his movements between the cars, drivers and engineers serves as a fitting metaphor of how NASCAR has changed.

When he first began working in what was then called the Winston Cup, the tools available were limited. Wheel alignment was done by string, scales were something a car ran across prior to a race to check it was up to minimum weight and telemetry was something you might have seen on *Star Trek*. You put your engines on a dyno, not your shocks, and nobody referred to shocks as dampers.

> "success or failure on the technical side still comes down to brain power"

Ultimately, success or failure on the technical side in modern-day NASCAR still comes down to brain power, despite all the sophisticated telemetry equipment the sanctioning body now allows teams to use (though notably only during tests), and that's why a savvy guy like Makar, who was a car chief for Rusty Wallace and the Blue Max team when it won the championship in 1989 and saw out three championship seasons at JGR in 2000, 2002 and 2005, has continued his upwardly mobile path.

Makar's current job is to coordinate the old-fashioned methodologies long familiar to the good ol' boys of NASCAR with today's newfangled engineering approach. Get the balance wrong, and have too much engineering and not enough NASCAR experience, and you'll be missing a trick. Likewise, cast wary glances toward the more sophisticated approaches at your peril.

SIGNIFICANT CHANGE

Makar, now a senior vice president, is the man who has maintained this crucial balance between the old and the new for Joe Gibbs Racing in recent times. It's all a long way from the days when the New Jersey native travelled south to help crew his father's short-lived entry into NASCAR in 1976. And who, when the family car was crashed and damaged, worked on it at the Charlotte shops of Robert Gee, who offered him a job a short while later. At the time, Gee was considered an artist when it came to hanging bodies on cars to achieve the best performance – a process that back then was done by hand, eyeball and experience.

'There's light years difference,' said Makar, when asked about the changes he's seen in the years since. 'What we're doing today is tremendously different even to what we did 10 years ago. You don't even have to go back to the mid-1980s to see the difference. Certainly, things have changed significantly in the way you tune the car, the parts you tune on, and the parts and pieces you use on the car are all very different.'

This has brought about a different sort of relationship between teams and factories. Prior to the vast increase in budgets brought by TV coverage, crew chiefs and drivers were loathe to consider sharing information with a factory engineer, much less heed any advice. But at the recent Charlotte test, Makar also moved not only among his team but traded notes with the engineers at Toyota Racing Developments.

Using a hauler that is off limits to journalists, the four TRD engineers have immediate access to computers at various locations around the country during tests, and possibly Japan, too. A team can present a problem to TRD during a test and expect to have a simulation done within an hour, or perhaps even a shaker rig test executed back at headquarters, much like F1 teams on race weekends (this is only speculation mind, given that this type of information remains closely held by TRD).

Naturally, the relationship over the course of an entire season is also very close between NASCAR teams and the manufacturers these days. 'TRD and Joe Gibbs Racing work hand in hand on a lot of different aspects,' said Andy Graves, vice president of chassis engineering at TRD, continuing, 'We have a lot of simulation programmes for the chassis to develop different parts and figure out where we can get the biggest bang for the buck.'

OPINION
'There's light years difference', says Jimmy Makar, senior vice president Joe Gibbs Racing

CAR OF TOMORROW

At the test in Charlotte, gleaning information on the Car of Tomorrow was order of the day. 'The notebooks are not very thick on the CoT,' explained Makar, referring to a crew chief's time-honoured record keeping system.

> **“The notebooks are not very thick on the CoT”**

'People aren't sitting here with notes on a style of car they've been using for 20 years. A couple of years of notes is all we have for things to try, so there's still a lot of unknowns. We're trying really hard to figure out what makes the car respond. I think we're all in the same boat though. It's a process of elimination and it's just going to take time. You can only hope to get it before somebody else does.'

The case of the good ol' boys doesn't seem to be that different from other series that have undergone an explosion of budgets, which are now approaching $100 million annually for the major NASCAR teams. The money trail is followed by ever more engineers and a bigger emphasis on computers, wind tunnels and materials. Where NASCAR differs from other leading formulae though is that the emphasis is on close competition among a wide array of teams – a concept long underpinned by the relatively ungainly, primitive aspect of Stock Cars.

The CoT continues this tradition – a tradition that lies at the root of the sanctioning body's ethos. It's a purpose-built box where teams are limited on aerodynamics by a fixed body and limited on the tube-frame chassis by a standard design that must undergo a laser scan to be approved. In addition to safety, the idea was to save the cost of changing cars for each type of track, and to limit the richer teams' ability to find advantages.

'The biggest problem built into the car,' said Makar, 'is the higher centre of gravity, which results from a taller greenhouse. In addition, the CoT is wider and carries more weight on the right side compared to its predecessors, due to re-routing the exhaust and adding crush panelling and steel bars to the passenger side door.

'Because of the way they've done the car, the higher centre of gravity has become significantly more important,' he continues. 'If you can move it, it really changes the way the car drives. The problem is there are not a lot of things on the chassis or the body you can move around, so a lot of it has become components. Literally, every single component on the car is analysed to try to make it lighter.'

Materials technology in the chassis has now become a crucially important arena for the manufacturers. 'We can afford to invest in and evaluate some cutting-edge technologies that a race team could not take the time to do or have the resources to do,' explained Graves.

DRIVING STYLE

The second and far less technical option is to find a driver whose style better suits the higher centre of gravity and the increase in right side weight. The Joe Gibbs Racing team found just such a driver in Kyle Busch, who stunned the NASCAR crowds with his eight victories before the 2008 Chase for the Championship began.

'We do the same things with all our drivers,' said Makar of the Gibbs team, where Busch, Tony Stewart and Denny Hamlin handle driving chores. 'Some of them just adapt better. Although Busch complains bitterly about the way the car drives, the CoT fits his style better.'

That style means a corner entry that may not invite oversteer, but tolerates a looser condition better. The same would also be true for mid-corner handling on banked ovals. Others who take this approach are Carl Edwards of Roush Fenway Racing and Jimmie Johnson of Hendrick Motorsports.

AERODYNAMICS

'With the traditional cars, crew chiefs had more options to adapt a car to a driver,' said Makar. 'Most of it had to do with body offset, the way the roof, the tail and the quarter panels all interacted, even with the way the nose was offset,' he said. 'How all that interacted from bumper to bumper made a big difference. It usually affected the side force and the downforce and, once you figured the puzzle out, you knew which way to go with it. You now change certain parts of the car to get more downforce or more side force, less downforce.'

That's no longer the case though. The templates for the CoT are like an iron maiden, and much of the side force now comes from one of two choices given to teams for end plates on the rear wing. 'There's really not a lot of adjusting to the aerodynamics any more,' said Makar. 'There's little you can work on the underbody either. There are a few places – ductwork and taking air in through the car for example – but we try to limit that and use that to our advantage. They're not big things any more.'

What's also difficult for teams is the change in the centre of aerodynamic pressure on the CoT, which has far longer rear quarter panels than the front. By design, this makes it easier for drivers to correct slides, but the design has drawbacks as well. 'You're handcuffed with what they given you for an aero balance,' explained Makar. 'We're learning different things we can do to try to change the balance a little bit. But really what we're doing is trying to find little bits here and there, rubbing on different parts of the car, trying to get some downforce back. We're not looking for a hundred pounds of downforce, we're looking for 10 or 20. And it's a good day if we find that.'

At the track, the problem with the new car is balance in traffic. 'We found that you could work out the aero balance with the chassis. You could do it by yourself [on a solo lap] and find the balance but, as soon as you disrupt the aero balance by being around other cars, it went away. That's something we've worked really hard on.'

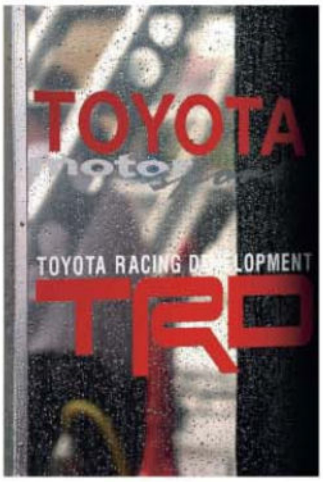
WIND TUNNEL WORK

The chief resource for sorting aerodynamics is JGR's scale model wind tunnel programme, directed by Nelson Cosgrove. He can often be found in the Penske Technologies 40 per cent scale model tunnel in Mooresville, gathering data for CFD calculations and simulations.

'Our aero department has got a significant amount of knowledge and data,' said Makar. 'We're working pretty hard to try to find something. Like I told everybody on our team last year, aero is one area NASCAR decided they wanted to limit us on developing. But we couldn't roll over and say, "They got us now because of the templates." So far it's been fruitful and worth the time and effort we've put in.

'But CFD points us in different directions. That's probably where we find most of our ideas and we spend a significant amount of time. We work on the tools that work for our aero projects, then go to the full-scale tunnel basically for cataloguing cars and tuning cars to make sure they're where we want them.'

TRD has an extensive database for aerodynamics as well – one that all its teams contribute to when they take full-scale cars to the wind tunnel on Toyota's time. But when teams bring their own data to work on CFD and simulations for the Camry, that information remains proprietary, explained Graves.



> **"every single component is analysed to try and make it lighter"**

In general, Graves said he tries to keep teams abreast of what types of numbers are being generated overall by the Toyotas. 'We try to let all the teams know where the goal posts are, whether it's horsepower, the grip platform or downforce/drag numbers.'

One of the significant processes is predicting the ride height of the front splitter, which will self-destruct if it makes contact with the tarmac. NASCAR's goal in introducing this was to force teams to use their front suspensions instead of coil binding springs, which put the nose of the car on the pavement in the corners. Alas, the genie now won't go back into the bottle, and teams have switched their emphasis to bump stops – a process that began with coil binding. 'We used to want to know if the front splitter travels 100th of an inch,' said Graves, 'but now we want to predict it within 10 to 20 thousandths.'

SUSPENSION TRAVEL

At least there's still a matrix of choices when it comes to suspensions now and teams can modify the front clips as well as suspension geometry, just like the old days. What's new is this emphasis on dampers and bump stops.

'The splitter is what it is,' said Makar. 'You want to get it as close to the ground as you can. We've done work in the tunnel to optimise what's there and understand that, and once you're there, you're there. How harshly you limit the travel is significant though. Now you're into a rubber spring of sorts that stops the car from travelling and also has to act like a spring rate. You can't just go down solid and bounce it like a basketball. There's a lot of give and take as to how you get there and how harsh you are on rubbers and springs.'

As you might expect, they have become an area of especially intense study on the 1.5-mile tracks. 'There is a lot of tuning going on there, but also a lot left to be learned in that area for everybody.'

So, is it all bump stops on the intermediate tracks? That depends. 'Are you using them as your suspension in the corner or are you using them to cut the tops of the bumps off? Or is it half spring and half bump rubber? There's a lot of combinations there and they all drive differently.'

Like their predecessors, the CoT is hard to adjust mid-race, particularly on the intermediate speedways, because of the reliance on such a relatively harsh ride in the corners. 'You can fall on either side of good,' said Makar, 'when a guy hits it, you see him run away from the field, but it's so inconsistent – one minute you're tight, next you're loose. It's not a nice, broad band you fit into so that you can tune the car as the track changes. It's more of a knife edge.'

OLD-FASHIONED WAYS

Although he can be like a kid at Christmas when he goes to the wind tunnel, at times Makar regrets the onslaught of technology. 'There's less of a chance these days that a mid-level team can come up with something that allows a driver who may not be considered one of the top drivers to win a race,' he says.

But at least one old-fashioned methodology continues in a sport where teams must park side by side in the garage – crew members still constantly purloin what they see and hand off what they learn to crew chiefs, themselves known to eyeball the competition carefully.

'Once a team finds a thing that works well and brings it to the racetrack, everybody else either catches up or finds the same thing. That's one thing about our sport, it's kinda hard to keep a secret around here...'

LAT

STOPPING AT SPEED

Contrary to popular opinion, Stock Car racing isn't just about outright speed, how quick a car slows as well can make the difference between getting to victory lane or not

Flat out blind at 200mph, racing a Stock Car on a superspeedway might seem to be all about the grunt of the engine and the aerodynamic efficiency but, if you are travelling at such high speeds, at some point you are also going to need to stop. 'There have been many races in the past couple of years that have been won or lost by the driver's ability to get the car slowed down and to get on pit road and get back out again,' explains Jason Novy of Performance Friction. 'And having that power to get the quickest stop when it's a green flag lap can really get you to the front.'

And they've got the experience to back these comments up, as the South Carolina-based firm's products have been fitted to seven out of the last eight race winner's cars on superspeedways. According to Darrick Dong, director of motorsports at the firm, it is because their brakes give the teams a competitive advantage. 'We have a lower drag system and that starts coming from the tolerances we have on our discs – 1.7 microns of thickness variation and under 10 microns of run out on the flange,' he explains. 'So as soon as you spin up the disc it runs free and minimises any deflection or distortion you have on your disc, which is going to have to be taken up by seal roll back or pad retraction in the caliper. The fact we have minimised that allows us to have a better pedal with quicker release. It's just more responsive, so that when you release the brake you feel that pop, that free spin immediately. We have just enhanced the pad retraction too, so there is no drag whatsoever on superspeedways.'

> **It's the cheapest horsepower you can buy!**

Don Burgoon, owner and managing director of Performance Friction, continues: 'That's really one of the unique features of our speedway caliper. There are other people doing different things, like trying to attach pads to the pistons, but that will generally cause the calipers to leak. Others try things like wiring or springing the pads, but a spring means the more wear you get the more retraction you get and, as a result, more pedal travel.'

'Some teams have actually done chassis dyno comparisons on the rear package alone and we have picked up as much as 4bhp over another brand,' adds Novy, 'so it's basically the cheapest horsepower you can buy!'

The pad retraction system used is said to improve driver feel and give better consistency during a long race or test run, especially if the cars are running in a pack. 'With the CoT, because the cars are so big, and the way they suck up in the draft, you are constantly battling traffic,' explains Dong. 'One of the problems we hear of out in the field is that it's the inconsistency of the braking while in the pack that makes the drivers feel very uncomfortable. But our pad retraction device is self-adjusting, so makes up for pad and disc wear. The other systems cannot do that and the difference is the torque is being taken out of the pad, which means they wear flat. On a lot of the components that are out there today the pads always wear at a taper.'

For this season, the South Carolina-based brake specialists have introduced a new range of brakes specifically for NASCAR, which they have quietly been developing in a unique way. 'We do it a bit differently to the competition,' explains Dong. 'We look at dynamic thermal imaging on the dyno and feed that data back to our FEA models. Then we shape optimise from there. From there on, it's an iterative process of testing and shape optimising from what the computer says and what the testing says.'

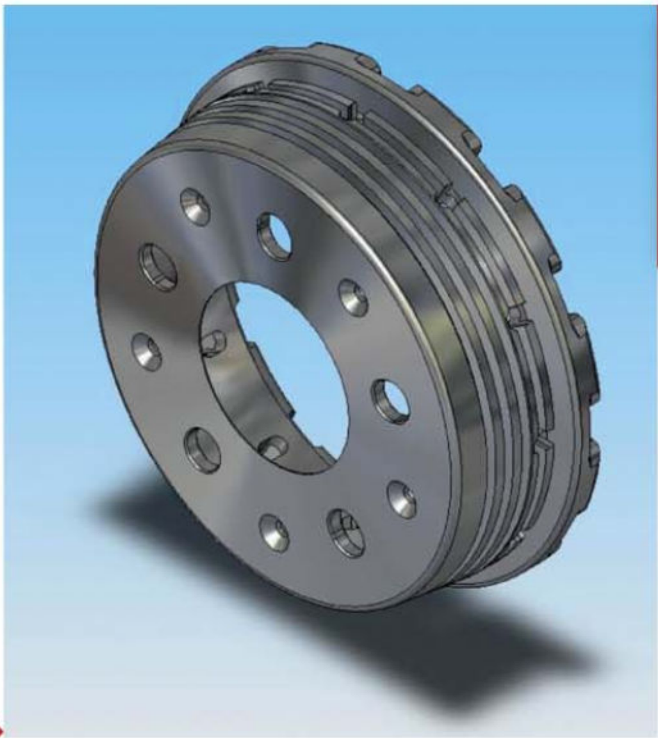
Unusually, for a brake manufacturer, Performance Friction makes the whole hot-end package, including the friction material, and that has an influence on its design ethos. 'What we do is look at what optimises the brake pad performance and then build the components around that. It's like building a racecar around the tyre you are going to be racing on,' explains Burgoon. 'Many of the strategies we use in our design and componentry are unique because we don't look at it from the architecture of the caliper inwards, we look at it from the angle of the friction materials out.'

Another things we do is torque balance the packages toward the venues the cars are racing at, and we can do that because we know what the torque balance needs to

LATE MODEL CALIPERS

As well as revealing the new range of brakes for the top end of Stock Car racing, Performance Friction also showed off its new Late Model caliper at the PRI Show in December. The forged monobloc design is claimed to use the same technology as the NASCAR versions, but in a less expensive form, as Don Burgoon explains. 'The machining technology is not as high, the finish is not as good as it is on the Cup brakes and the coating is not the same. The alloy is slightly different too, but it still gives you the rigidity and durability of a monobloc caliper and the associated strength. It doesn't have all the lightening the higher-level calipers do so we sacrifice a bit of weight there but we also save weight because it doesn't need to have the thickness of the pads, so it's a physically smaller caliper.'

CROSS POLLINATION
Same, same but different. And it's physically smaller, too



COOL HAT
This ducts air across the inside of the disc face and forces heat energy out through the spindle duct

be for each specific track. NASCAR is a very complex series and most people don't give it a lot of credit because they don't understand how different each racetrack is and how different each component that influences the balance of the car has to be, but we make point of knowing that.'

Tuning the brakes for each circuit would suggest that teams need a large inventory of calipers, pads and discs, but in fact the opposite is true, as Dong explains: 'We have done a lot of study on how to optimise and simplify the components the teams have to have in order to outfit the cars. Instead of having 10 or 12 calipers to do the same thing, we have four. Instead of having 15 or 20 front discs we have four. What we have done is looked at the complexity of the challenge in NASCAR for both the teams and the series to minimise all the variations.'

"We do it a bit differently to the competition"

KEEPING COOL

Keeping brake temperatures under control is also a critical factor on many circuits, most obviously for the aerodynamic advantages of running smaller ducting. But there are also reliability implications when it comes to tyres. Novy: 'We have seen this past season where other firms' calipers have overheated and seen tyres explode during the race as a result. That was purely due to the caliper being used as a heat sink to take the heat away from the disc. Some firms' NASCAR calipers exceed 500degF on a regular basis, so because they are being used as a heat sink, sure the disc is running cooler, and that's what they tell people to look at. When people look at the brake system, a lot of the time they do just look at the disc temperature but, if you really want to compare temperatures in the brake system, the thing you really want to look at and is important to keep cool is your caliper. That's where your fluid is and it's the closest part to the tyre bead itself.'

As a result Burgoon's engineering team have put a lot of effort into cooling the calipers and brakes in general. All its new range of calipers are fitted with the company's rocket nozzle insulators on top of the pistons, which are claimed to allow the caliper to run 100-150degF cooler. 'Another new product we have for NASCAR is the cool hat,' adds Novy. 'We have reduced the temperature further by designing the hat to allow it to duct air through and up to the outboard pad across the inside of the disc face. It both cools and allows the hub to run cooler because the hat is absorbing so much of the energy that it's actually working as a heat soak in the hub.' In order that this doesn't have an adverse effect on the bearing, the new hat design forces the energy out through the spindle duct, which in turn helps keeps the bearing package cool.

'We have been seeing a reduction of hub temperatures of a minimum of 50degF or more, depending on the venue, which is obviously a major advantage. The cooling fins that are designed in actually allow some of the airflow to move within the wheel, too. To prove that, take a look at any race and you'll see that all of the brake dust is staying inside the wheel until the pit stop, so being able to finally move some air inside the wheel will also help in a reduction of build up in tyre pressures.'

Currently, it appears that the new designs are locked into Sprint Cup and the NASCAR series for three years, during which time a number of the firm's customers will undoubtedly be using the technology behind these brakes to go faster.

ZR34 SPEEDWAY FRONT / REAR CALIPER
Uses: NASCAR Sprint Cup series

ZR22 CALIPER
Uses: NASCAR Sprint Car, Nationwide and Truck series

ZR41 SUPERSPEEDWAY FRONT CALIPER
Uses: NASCAR Sprint Cup series

ZR38 CALIPER
Uses: NASCAR Sprint Cup series

ZR49 CALIPER
Uses: NASCAR Sprint Cup series (evolution of ZR22)

ZR43 SUPERSPEEDWAY REAR CALIPER
Uses: NASCAR Sprint Cup series

TECH SPEC

PERFORMANCE FRICTION NASCAR CUP BRAKE RANGE

Superspeedway (ie Talladega)

Front caliper: ZR 41 4-piston with self-adjusting pad retraction

Disc sizes: 309mm x 32mm (40mm swept), 323mm x 32 mm (40mm swept)

Rear caliper: ZR 43 4-piston with self-adjusting pad retraction

Disc sizes: 284mm x 19mm (35mm swept)

Light intermediate (ie Atlanta)

Front caliper: ZR 49 4-piston

Disc sizes: ZR 49 4-piston

Rear caliper: ZR 20 4-piston

Disc sizes: 284mm x 19mm (35mm swept), 284mm x 32mm (35mm swept), 309mm x 32mm (40mm swept)

Heavy intermediate (ie Pocono)

Front caliper: ZR 38 6-piston

Disc sizes: 323mm x 32mm (62mm swept), 323mm x 35mm (62mm swept)

Rear caliper: ZR 20 4-piston

Disc sizes: 309mm x 32mm (40mm swept), 323mm x 32mm (40mm swept)

Short track (ie Martinsville)

Front caliper: ZR 38 6-piston

Disc sizes: 323 x 35mm (62mm swept), 323mm x 40mm (62mm swept), 323mm x 42mm (62mm swept)

Rear caliper: ZR 49 4-piston

Disc sizes: 323mm x 29mm (46mm swept), 323mm x 32mm (46mm swept)

STANDING UPRIGHT

Re-designing a component that has been in use for half a century calls for some serious application of technology. Italian firm CRP Technology believes it has the answer

In each issue of *Stockcar Engineering* we will aim to highlight products or services available from European motorsport suppliers who are moving into the Stock Car racing market. The first of these is Italian supplier CRP Technology.

Over the last 30 years, suspension uprights in NASCAR have undergone very little change from a design standpoint. Even today, the part most widely used is a facsimile of an OEM component that Detroit produced in the early 1960s.

But that is over simplistic; today the uprights used in Cup cars are every bit as advanced as the rest of the car. One of the latest F1 derived technologies to influence the design of these parts is near net shape investment casting, and the company that has focused its attention on NASCAR uprights using these techniques is CRP Technology.

NEW TECHNOLOGY Example of a CRP manufactured upright

The Italian company, which has been one of the foremost names in European motorsport for many years, is now applying the knowledge it has gained in disciplines as diverse as Formula 1 and the World Rally Championship to NASCAR. 'The approach of CRP Technology is unique,' explains a company source, 'and is made possible in large part due to a commitment to the integration of rapid prototyping and rapid manufacturing from the earliest stages of component development. Since 1996, CRP has pioneered many of the technologies involved. It has also developed its own line of rapid prototyping materials, most famously Windform. These have already been used in NASCAR, with Penske among others (see *SCE*1). This, in turn, has broadened the scope of available finished product materials that the company can offer to its customers and, by extension, has opened up the traditional material property constraints for designers. 'Investment casting also adds the benefit of uniform isotropy for high load components with complex geometry. CRP's experience and unique manufacturing methods have the company perfectly positioned to usher in a new era in manufacturing Stock Car racing components.

'Stronger, lighter, cost-competitive designs, with the added value of combining time compression and mass customisation technologies allow CRP Technology to be in a better position to address the unique challenges of its motorsport partners.'

HARDWARE
Z corporation produces both the printer (main) and scanner (inset)

PERFECT 10s

A company in Mooresville is now offering race teams a way to get the perfect Stock Car body time after time

In a racing class as close as Sprint Cup, precision matters. With 43 cars crossing the start / finish line in just a handful of seconds it has to. But on hand built, panel-beaten cars that share a design ethos with a 1950's truck it's not always that easy to achieve.

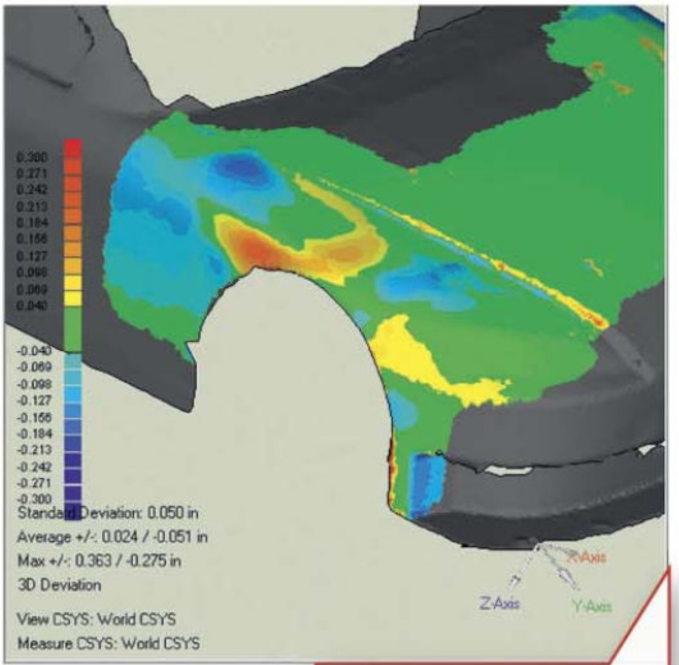
Laser scanning is nothing new in Europe – you see it in use almost daily in a mind-boggling range of applications, including archaeology, tunnel monitoring, reverse engineering and espionage, but its use in motor racing is less common. Initially, it found limited use in Formula 1 but, as the technology became cheaper to buy, Formula 3 and racing saloon teams started to hire freelance scanners to try to get that extra edge. In NASCAR, however, until very recently, this technology has been the preserve of the very top teams only.

In early 2008 a team went to the Aerodyn wind tunnel in Mooresville as part of its Daytona 500 preparations to run back-to-back tests on apparently identical cars. They were staggered and confused to find 15lb difference in drag between them and, as a result, turned to two representatives of Z Corporation in Mooresville, NC – Kevin Outz of Matrix CAD Design and Bill Watson of Anvil Prototype. 'They should not be that far apart, but the team did not know where the difference was,' explains Outz, 'so we came in, scanned the cars and overlaid the data onto a model that allowed the team to visualise with the colours where the dimensional differences were. They could then go back and change the body panels to improve the car's performance.

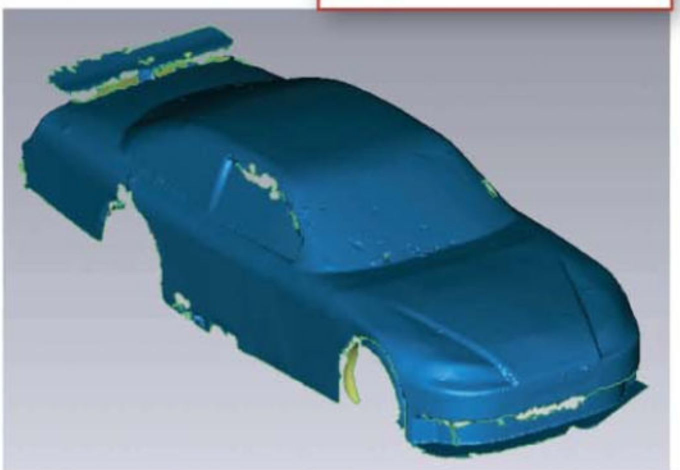
> "Digitising the cars' bodies makes performance more repeatable"

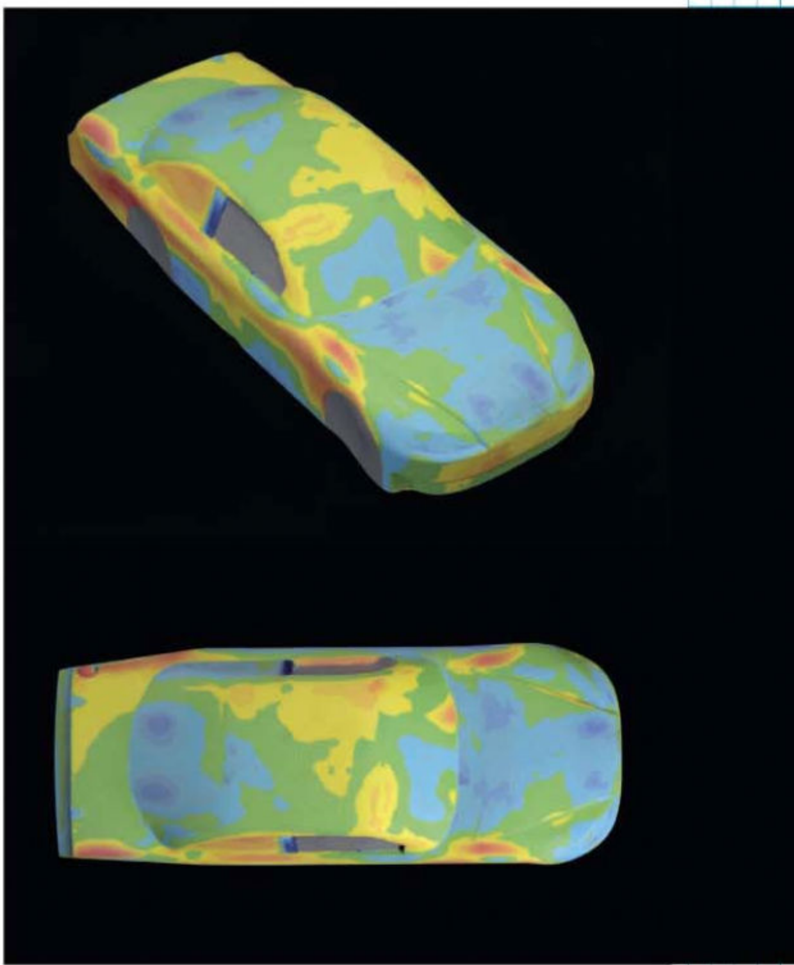
'The models we did for them varied in ranges. With our kit you can set your tolerances and colour spectrum to see as small as 5000th or even 1000th of an inch, but typically they wanted to see every 30,000th of an inch (1/32nd of an inch on a tape measure). They are more likely to hold about a 16th of an inch to hand work sheet metal as you just can't get to a 32nd, but they still wanted to see it in increments of 30,000th of an inch.'

These models allowed team engineers to guide the panel beaters with an unprecedented level of precision, but transferring this technology to the guys doing the work had to be done in logical iterations. 'The way we started was just with two-dimensional



SOFT SHEET METAL
The raw scan (below) can be used to make a hieght map





SAVING TIME AND MONEY

Compared to Formula 1 teams, Stock Car teams have tiny budgets, yet are equal in their levels of ingenuity. Some of the larger Cup teams have invested in millions of dollars of high-end rapid prototyping equipment, but now lower cost printers are hitting the market and making the technology available to all.

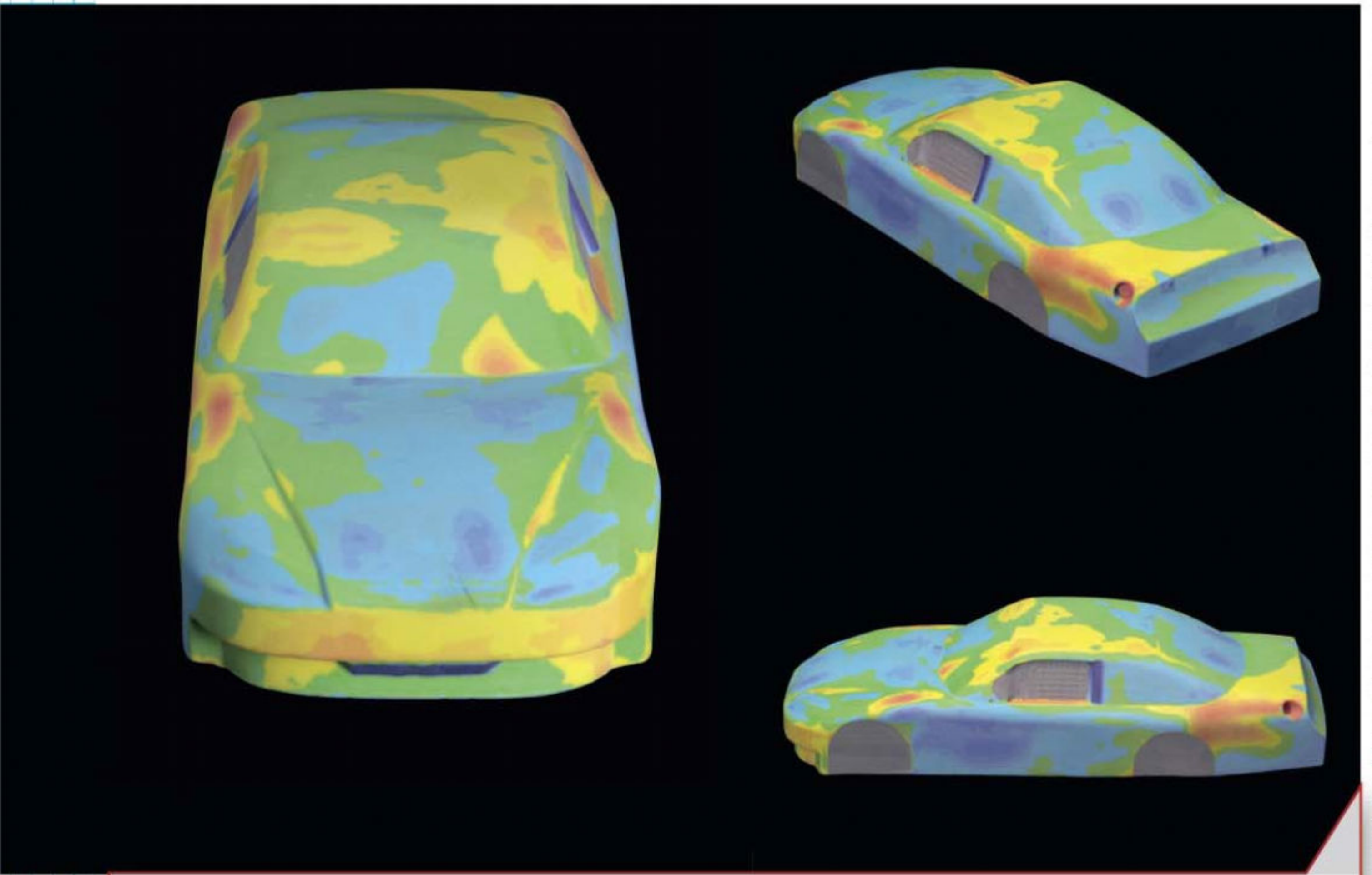
'A piece of equipment that is only $40,000 (£27,000) can now be 10 times as fast at a 10th of the price,' claims Bill Watson of Anvil Prototype. 'It allows us to do a lot more parts quickly and, when we are talking about the larger teams that already have SLA equipment, we can generally clear a week-long backlog on an SLA in a weekend. You take the parts that are massive and take a long time on the expensive equipment and use the less expensive equipment to clear the backlog. This means you can ensure that the critical surface finish parts can be made on the high dollar equipment faster. It also helps you design and prove parts faster. If your engineers are having to wait for parts, then there is a bottleneck and those are vital days between now and Daytona that you have wasted sitting around waiting for parts.'

paper reports, because the sheet metal fabrication guys were not used to seeing three dimensions in a two-dimensional layout and initially there was some confusion. That sparked the interest in taking the CAD file with some colour in it and rapid prototyping it to help as a communication tool. That's how the combination of both products came about,' explains Outz.

These models allowed the fabrication shops to figure out how to manipulate the surfaces to the maximum degree allowed within the rules. 'You do have some play between the templates, even with the 'claw', so you can improve on that gold standard version, which is legal but only average. But racing is not about being average, it's about winning. Using the models allows the guys to make the cars quicker.' Digitising the cars' bodies makes the cars' performance more repeatable, too. 'If you win Daytona you better know exactly what that car looked like, so you can repeat it,'

When NASCAR introduced the 'claw' template, along with the CoT, it was meant to stop a lot of the manipulation of the grey areas between the templates but, as Outz explains, there are still areas that can be optimised. 'You have 15-18in between each cross section, and within one of those you have the gap right behind the front tyre well area, or the c-pillar. That's a really shaped area, not a flat panel that's easy to change and work to the desired shape. There are a lot of differences in that area but, until now, teams could not dimensionally check and know where they were. Having digitised bodies lets them do just that.'

One of the areas Outz and Watson pride themselves on is the speed and ease of using this technology – both the scanner and the 3D printer are cost effective and fast. 'We are known around here for being able to do the fastest



VISUALISING DIGITAL REALITY
Once the car has been scanned and a height map produced, with red denoting high areas and blue low, the model can be created using the Z-Corp 3D printer. Some teams have found that using these models to communicate with the sheet metal workers highly effective.

full colour rapid prototypes, which is the fastest way to make a solid model and is key for racing – it's all about speed and designing things faster. We are about 10 times faster than the FDM process, two or three times faster than traditional SLA and about 10 times faster than SLS. For us it is more of a do-it-yourself design aid that helps people get parts in their hand or into the wind tunnel quickly.'

SELF-POSITIONING

The Z Corporation scanners used by Matrix CAD Design are claimed to be the only ones that are truly hand held and portable. 'There is no expensive tripod or portable CMM arms to attach to it. It's unique because it is self-positioning, which means it references the part for its position, so it allows you to rotate the part as you are scanning it. We have even scanned cars as they are being built in the workshops.'

It takes eight to 10 hours to scan a whole Stock Car but, according to Outz, that's not time when the car is out of action. 'We don't tie up the surface plate and we don't tie up the car whilst we are scanning. A mechanic can come in, undo the window net and get in the car and it doesn't matter. You can even be rolling it across the garage floor when you are scanning. You can scan the fender straight after they hang it on one side whilst they're still hanging the other side – that way you can tell the body guy before it is too late if it's out [of shape].'

The scanner outputs in a .stl format, which can be fed straight into CFD software or a 3D printer with very little post-processing needed as it already has a polygon mesh, rather than just cloud points.

Of course, as with many new technologies, it all sounds horribly expensive, but there's the next surprise. Teams can hire the scanning outfit to come to the race shop and scan a car for around $2500 (£1700) for data collection and comparison against another scanned surface. What this means is that it's now a realistic option for Nationwide and even Truck teams. In practice, Outz and Watson generally try to persuade teams to buy in their own equipment so they can get a handle on it themselves and because they are not always available, such is the demand for the service.

> "30 minutes of training and you are up and running"

'Five years ago you needed to have a million-dollar budget to do scanning and rapid prototyping. Now we are talking in the region of $100k (£67,500) and you have the full thing and are ready to go. You don't have to be an engineer to know how to use it either – 30 minutes of training and you are up and running,' says Outz enthusiastically. As if to back this up, teams have been clamouring to buy the kit already and Outz is brimming with confidence for the season ahead: 'The teams that do it are gonna win races,' he says. 'We are very excited about a couple of clients in particular that we are working with and we expect them to be winners this year because they are using this technology. The folks that don't have it are gonna lose races because they are missing out...'

LAT

LIVE AID

Getting to grips with live axle toe steer and anti-squat

DANNY NOWLAN

A number of issues ago I wrote about force-based anti-dive and anti-squat. In the piece I suggested a number of things that went against the grain of traditional thinking, but nonetheless it filled in a few blanks. The focus of this article will be taking the principles outlined in that article and applying it to explain the behaviour of a particular set up used on a live rear axle car.

One of the nice things about what I have done with ChassisSim is that from time to time one of my colleagues or customers will ask me a really good question. The question usually goes along the lines of we tried this, and it solved this problem because of this. However, as you start to dig, it quickly becomes obvious that what you thought was going to happen didn't necessarily transpire. The downside is you spend a couple of hours, or even days, being utterly confused. The upside is that once you have solved the problem you have actually learned something. This article was inspired by such a problem.

> "how to use the radius rods to adjust understeer/ oversteer"

What we'll be discussing in this article is live axle toe steer and anti-squat. In particular, our discussion will revolve around a racecar in which the body movement isn't that extreme. Fortunately, this will cover most motorsport applications. The only application that won't be covered is extreme all-wheel drive vehicles, where you could drive a Mack truck through the suspension deflections, metaphorically speaking. Of more relevance here though is the application of this thinking to V8 Supercars and NASCAR racers.

Before I discuss the problem though, let's define what the rear live axle geometry looks like on one of these cars. This is illustrated in figure 1. As can be seen, the points on the axle are connected to the points on the chassis by pushrods running down the length of the car. These are referred to as radius rods. It is these radius rods that not only translate the longitudinal forces to the chassis but also roll the axle as well. Typically (but not always), the pushrods are equidistant from the centreline of the car on either side.

The problem that was discussed was how to use the radius rods as a tool to adjust the understeer / oversteer characteristics of the car. In particular, where radius rods are equal in length and parallel to each other. Usually, in order to tune to improve the car's characteristics the radius rods on the axle are dropped to improve understeer and raised to improve oversteer. This situation is illustrated in fig 2.

However, when discussing this situation with one of my peers there was some confusion as to what the primary driver here actually was. Was it toe steer on the live axle or was it anti-dive and anti-squat effects?

THE BASICS

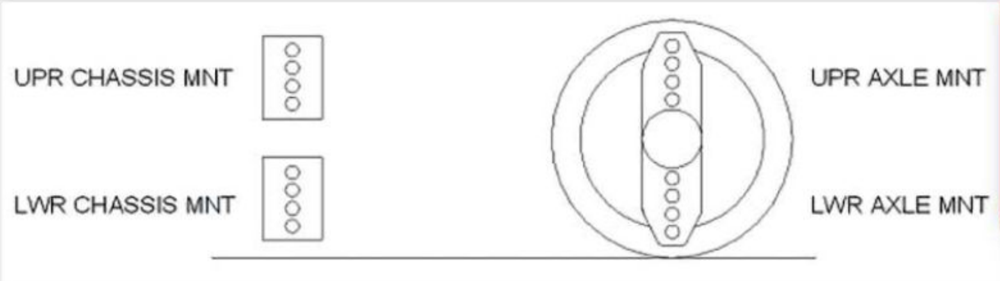


FIGURE 1
Rear suspension arrangement for a live axle car

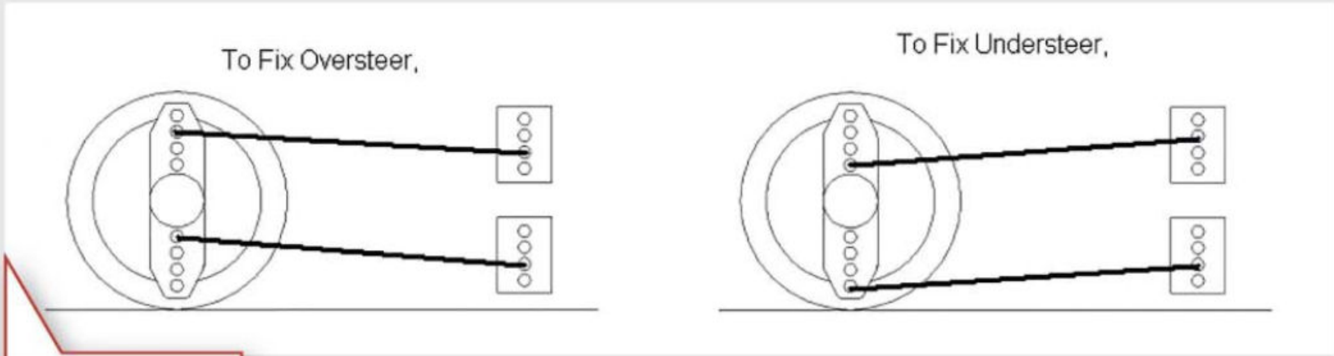


FIGURE 2
Tuning for oversteer and understeer

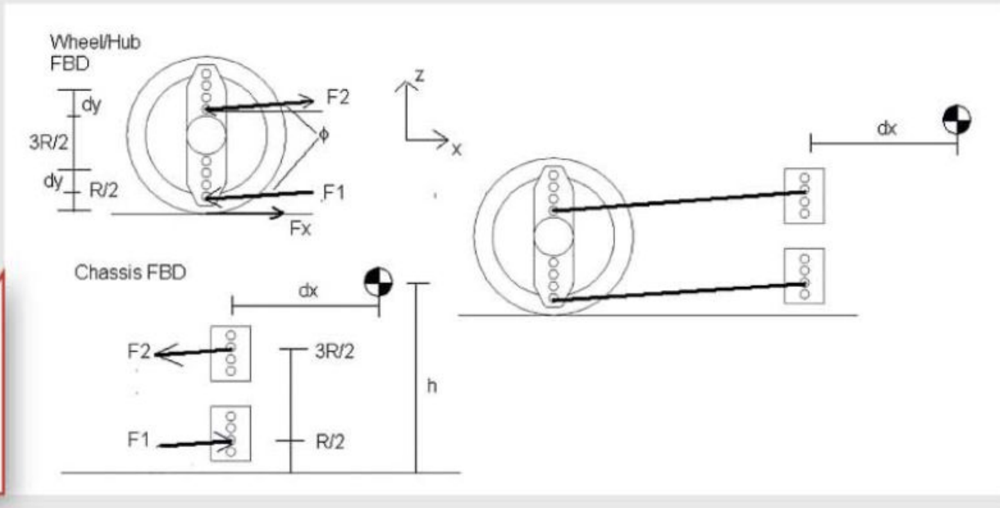


FIGURE 3
FBD of parallel radius rods at an angle

To better understand, let's consider a free body diagram (FBD) of the suspension system components. To aid in our discussion we'll assume the radius rods are mounted at a height of R/2 and 3R/2 from the ground, where R is the rolling radius of the tyre. I could have assumed some other numbers but I've simply put it here to make the maths easier. Now let's drop the rear radius rods by a height denoted as dy. This is shown in fig 3.

Taking a FBD of the wheel and axle line, using the approach we discussed in force-based anti-dive and anti-squat, it may be shown as follows:

$$\sum F_x = 0 = F_x - F_1 \cdot \cos(\phi) + F_2 \cdot \cos(\phi)$$
$$\sum M_0 = 0 = \left(\frac{3R}{2} - dy\right) \cdot F_2 \cdot \cos(\phi) - \left(\frac{R}{2} - dy\right) \cdot F_1 \cdot \cos(\phi) \quad (1)$$

Then, using the two equations shown in (1) it can be shown,

$$F_1 = \frac{F_x}{\cos(\phi)} \cdot \left(\frac{3}{2} - \frac{dy}{R}\right)$$
$$F_2 = \frac{F_x}{\cos(\phi)} \cdot \left(\frac{1}{2} - \frac{dy}{R}\right) \quad (2)$$

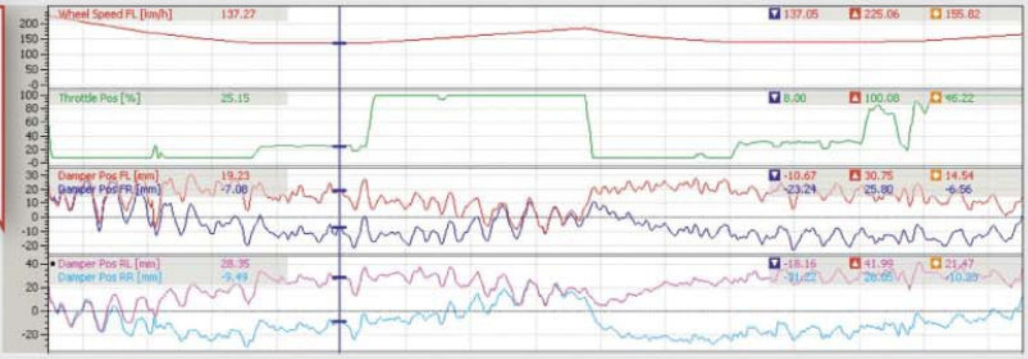
Looking at the chassis and taking moments about the c of g it can be shown that,

$$\sum M_{cg} = F_1 \cdot \cos(\phi) \cdot \left(h - \frac{R}{2}\right) - F_2 \cdot \cos(\phi) \cdot \left(h - \frac{3R}{2}\right) - F_1 \cdot \sin(\phi) \cdot dx + F_2 \cdot \sin(\phi) \cdot dx \quad (3)$$

Substituting (2) into (1) and doing a bit of algebra it can be shown,

THE DATA

FIGURE 4
Suspension movement of a V8 Supercar through a high speed turn



$$\sum M_{cg} = F_x \cdot \left(h - dy - dx \cdot \tan(\phi)\right) \tag{4}$$

Having a look at the geometry it can be shown that,

$$\begin{aligned} dy &= (b - dx) \cdot \tan(\phi) \\ &= (wdf \cdot wb - dx) \cdot \tan(\phi) \end{aligned} \tag{5}$$

Subbing (5) into (4) it can be shown,

$$\begin{aligned} \sum M_{cg} &= F_x \cdot \left(h - wdf \cdot wb \cdot \tan(\phi)\right) \\ mom\_arm &= \left(h - wdf \cdot wb \cdot \tan(\phi)\right) \end{aligned} \tag{6}$$

€

Now let's try and quantify this by adding in some numbers. To start, let's consider a radius rod height change of, say, 20mm from the radius rods being parallel, working with a radius rod length of 700mm. Substituting some typical numbers for a V8 Supercar, which would have a wheelbase of 2.8m, a c of g height of, say, 450mm and a weight distribution of, say, 52 per cent, applying equation (1) it can be seen that:

$$\phi = \tan^{-1}(20/700) = 1.63^0$$

$$mom\_arm = 0.45 - 0.52 \cdot 2.8 \cdot \frac{20}{700} = 0.4084$$

This equates to an anti-squat of almost 10 per cent. For a 20mm change, this is a very big adjustment.

To put this into perspective, let's now consider a brief hand calculation of the toe steer due to the change in movement of the axle. Using the numbers above, to achieve a 20mm drop in the radius rod location you are looking at a radius rod length of 700.3mm. Now consider the bit of V8 Supercar data shown above in figure 4 that shows the car rolling in a medium-speed turn. From this it can be seen that the roll at the rear is approximately 40mm. The true roll will actually be a little bit more than that because in roll the dampers are mounted slightly inboard but, as an approximation so we can get a feel of where the numbers go, let's take these numbers at face value. As an approximation the radius rod on the outside will increase in length by 0.3mm and decrease by 0.3mm on the inside. It will increase on the outside because the radius rods straighten themselves out while the radius rods on the inside are contracting. This gives us an effective toe in. To calculate this toe in, assuming a tyre radius of 300mm, we have,

$$\partial\varphi = \tan^{-1}(0.3/600) = 0.0285^0$$

$$\delta toe = 300 \cdot \sin(\partial\varphi) = 0.15mm$$

This was done assuming the radius rods are mounted 0.6m from the centreline. This is a differential length of about 0.3mm measured rim to rim.

Now let's take a deep breath and see what components are doing what. First, let's consider the effect of the toe steer. Does this help with the understeer? Absolutely, because the rear axle is rotated in the path the car is turning in. However, the effect is very minor. The reason for this is most race tyres have peak slip angles of six degrees. So, by doing a very basic hand calculation and assuming peak slip angles, the axle steer is contributing 100*(0.0285/6) per cent of the slip forces, or about 0.4 per cent. It helps, but really it's the cherry on top.

In contrast, dropping the rear radius rods 20mm at the rear axle line gives an increase of nearly 10 per cent in anti-dive / anti-squat at the rear. This has massive implications for chassis movement, and is further amplified by the fact you're transmitting some 600bhp at the wheels, and even more for a NASCAR Cup car. This is going to mean the rear is not squatting as much under balanced throttle, and the implications for this on understeer and oversteer are pretty obvious.

For those of you who still think I'm off base in placing the force line under traction at the tyre, instead of the axle centreline, let's re-do this analysis assuming the force application line is at the wheel centreline. Keeping all our other variables constant, the moment equation expressed in (1) becomes,

$$\sum M_0 = 0 = \left(\frac{3R}{2} - dy\right) \cdot F_2 \cdot \cos(\phi) - \left(\frac{R}{2} - dy\right) \cdot F_1 \cdot \cos(\phi) + F_x \cdot \frac{R}{2} \tag{7}$$

The astute reader will quickly recognise that our assumption of F1 and F2 acting in opposite directions is going to have to be

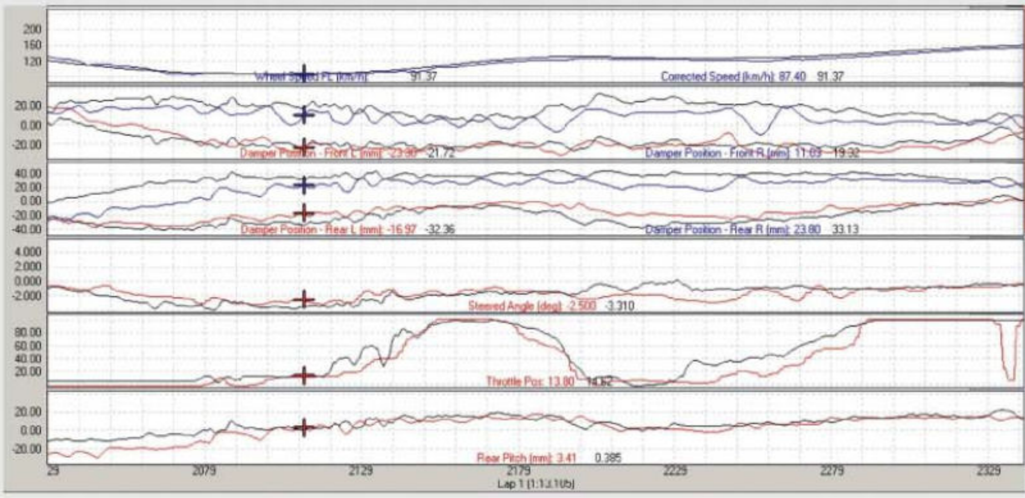


FIGURE 5
Comparison between actual and simulated V8 Supercar data

re-visited. Now F1 and F2 are acting in the opposite way to Fx, filling in the details it can be shown that,

$$F_1 = \frac{F_x}{\cos(\phi)} \cdot \left(\frac{1}{2} - \frac{dy}{R}\right)$$

$$F_2 = \frac{F_x}{\cos(\phi)} \cdot \left(\frac{1}{2} + \frac{dy}{R}\right) \tag{8}$$

Let's now take moments about the c of g. In this case, our moment equation becomes,

$$\sum M_{cg} = F_1 \cdot \cos(\phi) \cdot \left(h - \frac{R}{2}\right) + F_2 \cdot \cos(\phi) \cdot \left(h - \frac{3R}{2}\right) - F_1 \cdot \sin(\phi) \cdot dx - F_2 \cdot \sin(\phi) \cdot dx \tag{9}$$

Working through equation (9) it can be seen that,

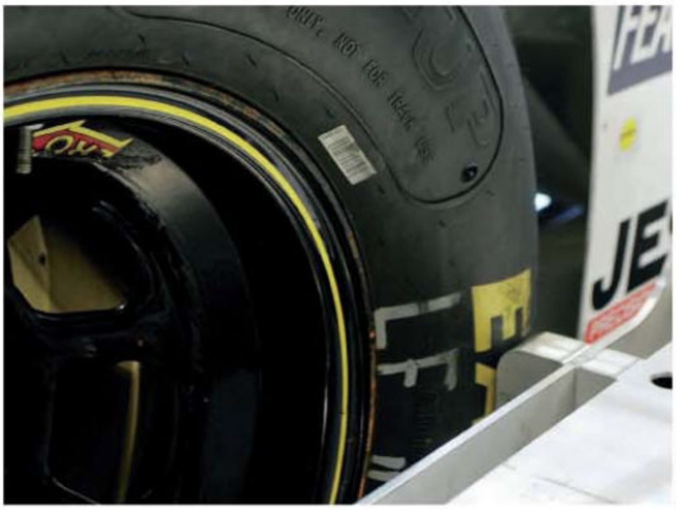
$$\sum M_{cg} = F_x \cdot \left((h - R) - wdf \cdot wb \cdot \tan(\phi)\right) \tag{10}$$

Equation (10) has some very interesting implications, particularly for our V8 Supercar example. As per the assumption of when the force application line is on the ground, the change in moment arm is exactly the same. However, the devil as always is in the detail, so let's consider our numbers. With the radius rods parallel and assuming the force application point through the axle centreline, and assuming a rolling tyre radius of 300mm, the moment arm is 0.15m. Assuming all the same numbers from before, the moment arm change is now 0.1m, or a change of approximately 33 per cent. This is much larger than our 10 per cent change on the ground.

Looking at this further, let's consider some actual V8 data vs simulated data from ChassisSim. For the simulated data the force application for the rear axle forces was placed on the ground, as shown in fig 5. This comparison between actual (coloured) and simulated (black) data shows speed and dampers at equivalent throttle displacements. While obviously not an exact match, you can still see that from a no-throttle application to a full-throttle application the dampers are compressing by a similar amount and that they converge to the same values after throttle application. The discrepancy with the outside rears is due to the fact the ChassisSim damper displacements are logged at the track location, whereas on this car the dampers are mounted slightly inboard, and this is where the movement is logged. However, the real data trace to look at is rear pitch as this is the average of both rear dampers. We can see very clearly from this that the data traces are within 1mm of each other. And given the similarities of the steering and throttle traces, this shows very clearly that under power the force application is on the ground.

If the force application line was really on the axle centreline there would be no way this data would be even close. This also brings into sharp relief the fact that if we consider the force application line on the axle centreline then this becomes a huge adjustment, as opposed to a fine adjustment. That is, it's the sort of adjustment you would do looking for 0.5-second increments, as opposed to fine tuning the car.

In conclusion, what we have discussed here has been a fascinating case of what can happen when a colleague or peer asks you a question. Armed with a few basic principles, we are able to confirm that it is indeed the anti-dive and anti-squat effect that is the primary driver of what happens when we drop the radius rods at the axle. Furthermore, we can also see that there are some significant problems when we view the force application line at the axle centreline, as opposed to viewing it on the ground. More importantly, I hope this article reinforces how the application of a few basic principles can really light our way in what is going on with the racecar.



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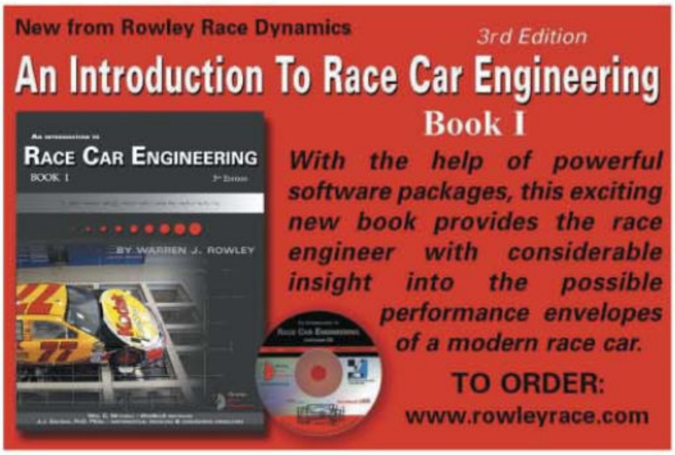

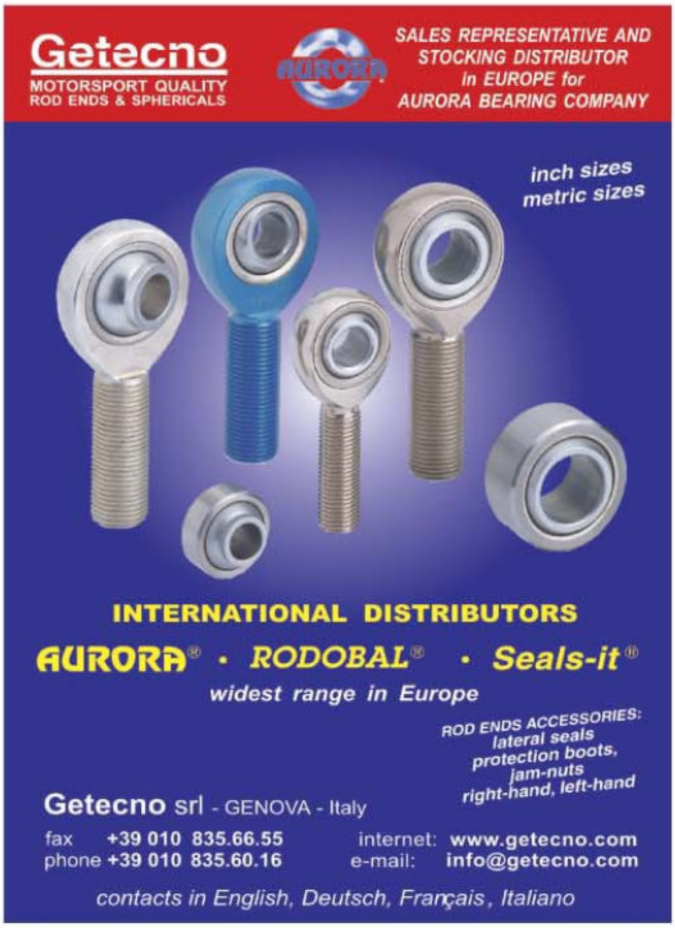

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T: +44 (0) 1582 488040
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USA T: +1 704 793 4319
USA - 4005 Dearborn Place, NW, Concord, NC 28027
www.bmrs.net

FAE MACHINE
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FUEL SAFE
T: UK +44 (0) 1799 541 955
GOODRIDGE CA
T: USA (+1) 310 533 1924
GOODRIDGE INDY
T: USA (+1) 317 244 1000
GOODRIDGE EAST
T: USA (+1) 704 662 9095
GOODRIDGE UK
T: +44 (0) 1392 369090
HENRY'S ENG
T: USA (+1) 410 535 3142

KRONTEC MASCHINENBAU GmbH
T: (+49) 9401 5253-0
Pommernstraße 33, 93073, Neutraubling, Germany
www.krontec.de

RACETECH
T: +44 (0) 1327 359 912

THINK AUTOMOTIVE
T: +44 (0)208 568 1172
292 Worton Road, Isleworth, Middlesex, TW7 6EL, England
www.thinkauto.com
matt@thinkauto.com

WELDON RACING PUMPS
T: USA (+1) 216 232 2282
XRP INC
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HYDRAULICS

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rsteele@moog.com
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www.moog.co.uk/industrial/ motorsport

LEE PRODUCTS
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PERFORMANCE SPRINGS
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www.performance-springs.com
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CHEVRON RACING CARS LIMITED
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43040 - Varano Melegari
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http://www.dallara.it/

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DOME CO,LTD
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ELAN
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JADE
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JEDI
T: +44 (0) 1933 440774

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F: +44 (0) 1480 482970
lola@lolacars.com
www.lolacars.com

MYGALE
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PILBEAM
T: +44 (0)1778 424838

RML GROUP
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6-10 Whittle Close, Park Farm Industrial Estate, Wellingborough, Northamptonshire NN8 6TY, England
www.rmlmallock.co.uk info@ rmlmallock.co.uk
F: + 44 (0)1933 676519

SHELBY AUTOMOBILES, INC
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RACING RADIOS
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andy.bloyce@oerlikon.com
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MK43 0AL, England
www.cranfield.ac.uk
motorsport@cranfield.ac.uk

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AEROCOM METALS LIMITED
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motorsport@atieurope.eu

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SMITHS HIGH PERFORMANCE
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www.superalloys.co.uk
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T: +44 (0) 1952 292401

NMB MINIBEA
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HERBERT TERRY
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WOODHEAD
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Unit 6H Thorn Business Park,
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HR2 6JT, England
www.ahfabrications.co.uk
alexahfabs@fairadsl.co.uk.
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Stafford Park 17, Telford,
Shropshire, TF3 3DG, England
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MOTON
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PENSKE RACING SHOCKS
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ROEHRIG
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T: UK +44 (0) 115 9869211
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METALORE
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www.superalloys.co.uk
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F: +44 (0) 845 8380444

TEX RACING
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T: +44 (0) 1952 292401

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TREVOR MORRIS ENG
T: +44 (0) 1547 530289

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RACE-TEC NAK
T: +44 (0) 2380 246986
Rolwey House, School Close,
Chandlers Ford, SO53 4BY, England
www.race-tec.com
Email: gary.williams@rolwey.com

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F: +44 (0) 1952 292403
T: +44 (0) 1952 292401

STEERING SYSTEMS
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1010 Cambourne Business Park,
Cambourne,
Cambridgeshire, CB23 6DP, England
www.nevodevelopments.com
info@
developments.com

WOODWARD MACHINE CORP
T: USA (+1) 307 472 0550
PO Box 4479, 3592 Burd Road,
Casper, WY82604, USA
F: USA (+1) 307 235 1551
www.woodwardsteering.com

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AH FABRICATIONS
T: +44 (0) 1432 354704
Unit 6H Thorn Business Park,
Rotherwas, Hereford,
HR2 6JT, England
www.ahfabrications.co.uk
alexahfabs@fairadsl.co.uk.
F: +44 (0) 1432 359762

SUSPENSION
DYNAMIC SUSPENSIONS
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GROUND CONTROL
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ROD MILLEN MOTORSPORT
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Ernst-Sachs, Strasse 62, 97424,
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www.sachs-race-engineering.de

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FSUSPENSION TECHNOLOGY
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www.cranfield.ac.uk
motorsport@cranfield.ac.uk

TRANSMISSION

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www.alcon.co.uk
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www.sachs-race-engineering.de

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GOODYEAR
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WILFRIED AND RALPH EIBACH
THE INTERVIEW

Where is Eibach based and how many people does it employ?
RE: The two main places where we actually manufacture our parts are in Finnentrop in Germany and in the US. There are between 260 and 270 people in Germany and about 90 in the US. We need good people and we need experience. I try to know everyone in the factories by name. We also have a high percentage of people who get educated within the company, in apprenticeships, and that's about 10 per cent of the people in the company. We put a lot of weight on this issue, because that's our future.

When did Eibach first become involved in motorsport, and what's its involvement today?
RE: It seems like we've been involved forever! In the old days, when we stepped into the aftermarket with performance kits, that was with AMG, and that may have been the first steps into motorsport. That was in the 1970s.

These days we are involved in anything that's out there, from grass roots racing to Formula 1 and NASCAR, we're everywhere. For instance, in NASCAR, on the super-speedways, our springs are mandatory.
WE: Eibach has been involved in just about every form of motorsports with our hi-tech suspension springs – from grass roots racing to Touring Cars and from circle track to the big leagues of Formula 1 and NASCAR. Not to forget our leading role in motocross bikes.

[But] for me the so-called small guys, the less famous race series, are just as important for us and receive our attention and sympathies. They *also* have 'The Will to Win' [Eibach's motto] and we share their pride.

Wilfried Eibach (CEO)
Ralph Eibach (MD)
1951: Eibach was set up in 1951 and is that rare thing – a truly global family concern, Ralph taking over at the head of the company from his father Wilfried six years ago. Wilfried remains heavily involved and marks his 50th year with the company in 2009. Eibach makes all sorts of springs – from those used in air rifles through to those found in ski lifts – but it's automotive springs that the company is most famous for. The company also makes other suspension components and kits

What is the most demanding motorsport environment your springs are used in?
RE: The most demanding motorsport out there is certainly Baja off road racing, but then we are proud of all the motorsport we are involved in, and all are demanding in their own ways. But Baja is a really big test, as is rallying. Sometimes I think our products are almost too good though. Many years ago we used to make yellow springs - it must have been at least 10 years ago, or maybe even 15 years ago - and you still find them out there because people know they last forever. In a way it's one of our biggest problems, because they last forever and we don't have extra sales!

What is Eibach's involvement in Formula 1 and how challenging is it to produce springs for this level of motorsport?
RE: We are not allowed to say who we supply in Formula 1, but I could *almost* claim that all the teams that run coil springs run Eibach. We can be very proud of that because we know their requirements and we know it reflects on our other products as well. Also, you are always looking at new materials and this then transfers to our other product lines.

If you look at the Formula 1 spring, it is challenging, because you have very tight tolerances and the design is maxed out. But they change their springs after each race, just as a precaution. They say that if the design is that maxed out, because they want to save weight, then it may happen that the spring takes a set, so they exchange the springs. But they don't need to, in our eyes.

Has your motorsport work helped with the development of your products for the road?
RE: I would say so, yes, because the mind of your engineer gets used to the maximum of performance that a material can reach, and by knowing these limits you can apply them to the street performance - you know where you can go and you know where you can't go. It doesn't transfer directly, but you can apply your knowledge.
WE: We regard Motorsport as the ideal proving ground. The experience we gain at the highest levels of racing is directly converted into the development of the highest grade chassis components on the planet. And in terms of PR, how does that saying go? 'Win on Sunday, sell on Monday'?

What sort of equipment is used when it comes to designing your racecar springs?
WE: Based on the extensive knowledge and experience we have gained over the decades we have been in business engineering a race spring is usually not so complicated. We know the potential and the limits of all the extreme high tensile materials that we use in all our springs. Principally, all our springs are engineered and manufactured to be block-resistant, so they basically will last forever.

How are your motorsport springs made?
WE: We use the best state-of-the-art CNC manufacturing equipment. Our most important machines are co-engineered with the Eibach engineers to new technology levels. [But] using the best materials, machines and technology is only part of the recipe to make our suspension springs. I am most proud of our people or, as I call them, the Eibach *Springmeisters*. Each one is a talented, expert craftsman, committed to creating the finest race springs possible.

Q How are your springs tested?
WE: Each design goes through extensive testing, including cycle testing. We want to make sure that the performance in our springs will not deteriorate over time. After production, all motorsport springs are tested and rated to the designs for guaranteed linearity and rate consistency.

Q What new technology is in the offing in the coil spring world?
RE: We have tubular springs under development. It is quite a difficult process to develop a tubular spring though. The idea is that the area that does the most work is the outside area. The inside doesn't get distorted that much, so it makes sense to use tubular bars. And this may come into motorsport in the future.

> **"I could *almost* claim that all the [F1] teams that use coil springs use Eibach"**

We are also looking at carbon fibre springs, too. We have made these already, but it is too early in the development process for them to be used yet. We need to get the consistency and obviously it's a different production process than making a normal spring. We have a partner working on this with us, and this is a project that is going on in the US right now.

Q Can you tell us more about Eibach's valve springs for race engines?
WE: For over a decade we have been making ultra-high performance valve springs for motorsport applications. This includes the IRL, Touring Car, drag racing, SCORE off road and circle track. By using our proprietary, ultra-pure, high tensile strength steel we can yield a higher natural frequency for the same spring pressures. This helps eliminate the need for damper springs, and the problems they can cause, such as cutting into the spring retainers. Our double and triple-spring set ups also have less friction pressure between the inner and outer springs, reducing friction-generated heat and ultimately reducing overall engine oil temperatures. Our continuous investment in state-of-the-art manufacturing techniques includes automated chamfering, shot peening and a very special proprietary pre-setting process to yield better consistency, giving added spring stability and even longer life.

RACE MOVES

Ferrari team manager **Luca Baldisserri** has been transferred to a factory-based role within the team, while his role on the pit wall has been taken by chief track engineer **Chris Dyer**. The move came after tactical errors ruined the team's race in Malaysia.

The **Brawn GP** team, which rose from the ashes of the Honda Formula 1 operation, has announced that it is to make 270 members of its staff redundant.


Dave Ryan
LAT

Dave Ryan has parted company with McLaren in the wake of the Australian Grand Prix controversy, where the FIA says the McLaren sporting director was instrumental in misleading the stewards as to the circumstances of a change of position under the safety car. Ryan had been at the team for 35 years.

Toro Rosso is to recruit 70 more staff as it gears up


Luca Baldisserri
LAT

to designing and building its own car for the 2010 Formula 1 season. Ironically, the Faenza, Italy-based team recently had to make some members of its test team redundant due to the new F1 testing limitations.

Former Motor Sports Association chief executive **Peter Cooper** has died at the age of 86. Cooper spent more than 50 years in motorsport, during which time he became a well known international steward, finished in second place as a competitor on the 1954 RAC Rally, and served as a member of the FIA World Council.

Gary Bechtel has joined **Tommy Baldwin** as co-owner of the Tommy Baldwin Racing Sprint Cup NASCAR team. Bechtel was previously a team owner in Cup and Nationwide with his Diamond Ridge Motorsports outfit, before selling his operation to **Joe Gibbs** in 1999.

GR-Asia boss **Paul Ridgeway** is to be the race engineer for **Liam McMillan** in the BTCC this season, while ex-Triple 8 man **Paul Colman** is to be chief mechanic on the teenager's SEAT Toledo. The new team is to be run by McMillan's father, Paul.

Former Honda test driver **Alex Wurz**, a respected development driver who has also fulfilled the role at McLaren and Williams, has stayed on to become test driver with the Brawn GP team.


Alex Wurz
LAT

Walter Giles is the new head engineer at NASCAR Sprint Cup team Tommy Baldwin Racing. Giles, who was formerly a race engineer at Dale Earnhardt Inc, started his racing career in Australia, before moving to the States in 1997 to take up a position at Richard Jackson Motorsports.


Fairuz Fauzy
LAT

Malaysian racer **Fairuz Fauzy** has taken over the Fortec Formula Renault 3.5 team in a move that some say might help to develop Asian racing talent in Europe.

Nicolas Hennel has joined Toyota F1 as 'manager future car development, aerodynamic'. He was principal aerodynamicist at McLaren before.

Stephen Hemmels moves from senior project engineer for wings and crash structures at Toyota, to senior engineer for front wings and nosebox.

Moving to a great new job in motorsport and want the world to know about it? Or has your motorsport company recently taken on an exciting new prospect? Then send an email with all the relevant information to Mike Breslin at bresmedia@hotmail.com

OPINION

Failed State

Whatever happened to the great American motor racing industry? Did the accountants finally get the better of the engineers?

MIKE FULLER

I'm reading the January issue of *RE*, reflecting on the fascinating UK-originated Bloodhound Land Speed Record project and thinking to myself, 'We could do that.' That's specifically a collective American 'We.' But then I think – could we? In the past, yes, absolutely. But, at some point between then and now, the will to think big disappeared.

In school, my inspirations came from NASA, which was just up the road, and Sportscar racing – Sebring and the Daytona 24. While becoming a Sportscar anorak during those formative years – the late '80s and very early '90s – I was also drawn to the Indy 500. As much of an influence as the UK racing industry had on Indy Car racing even then, there were still American builders present as well: All American Racing (AAR), Galmer, Penske and Truesport.

During the same time, in IMSA GTP, American racecar design and engineering prowess was the only way to go. You had the Toyota, built by AAR in Santa Ana, California. The Intrepid GTP was designed and built just outside of Detroit, Michigan. And then of course the Nissan effort, run by Nissan Performance Technology Inc (NPTI), was a neighbour of AAR down in Vista, California. All of this advanced racecar design, situated right here in the USA, certainly made a huge impression on me. A big enough one that I pursued racing as a career for a decade. Then it all dried up. But where on earth did it all go?

At some point, between the last big recession during the early '90s and our current downturn, the dross and the vultures started calling the shots. The accountants took over and, as a result, the Galmers, NPTIs and Truesports began disappearing. In some cases they were lost legitimately. In others, the accountants saw past their value, scattering them to the wind. A vile new directive emerged that many of the remaining organisations readily embraced. Not only were the racers and ex-mechanic team owners pushed aside, but profitability at all costs became the focus.

Racecar operations got bogged down with the financials. For one reason – it was easier than actual engineering. No longer was it about creating a strong engineering base and selling that capability, that was too difficult. Instead, it became about re-packaging whatever was sitting around and calling it something else – parts-bin manufacturing. And then, irony of ironies, engineering was seen as being the contributing factor to high overheads and became the sacrificial lamb. It wasn't cherished as a service to sell because that's too hard. Instead, it was reduced and then effectively eliminated, leaving a simple manufacturing service provider in its wake.

The free-market people will babble along about the industry's survival, that the trend was implemented to ensure sustainability, but that's spirit-crushing business speak and I don't agree at all. What really matters is the long-term effects this illness has had on the US racing industry. The current racing economy is so reliant on this misguided mentality that it doesn't have a fall back point. The American racing community has eschewed its own heritage and principles – it's about engineering, stupid – and now doesn't have the agility or diversification to survive. Such shortsightedness. Instead of being engineering-driven and able to better control its own destiny, the US racing industry is now dependent on the easy money that comes through symbiotic associations with sanctioning bodies and marketing dollars, with all the limitations associated with both. These operations are now propped up by spec series and have lost their direction and motivation.

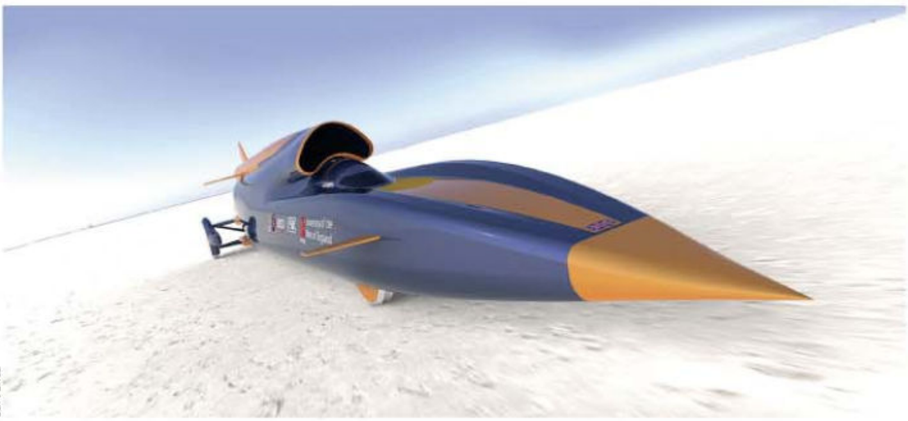
"The American racing community has eschewed its own heritage and principles"

Yet all one has to do is to look at either Porsche or Dallara for examples of racing operations that take an engineering-centric approach, which in turn leads to profitability. Look at Dallara's extensive involvement with Audi and its various Le Mans Prototypes, for example. And you can be sure it has its fingers in many more pies, and why not? Dallara takes the one unique resource at its fingertips and puts it to good use to bring customers in the door. And the Porsche racing paradigm has always been geared towards profitability, so it can be done.

Sadly, Sergio Rinland's September 2008 commentary describes similar conditions in the UK, and that the spec series trend has severely affected the motor racing industry there, too. In the end, I see the UK industry as being infinitely in better shape. Yes, the grass is always greener, but at least their mindset hasn't been completely sullied.

But back to my opening scene. We, meaning America, could have thrown our collective efforts behind a project like Bloodhound, but the reality is there simply isn't the desire these days. Accountants take one look at something like Bloodhound and sneer 'Why bother?' It's a lot of effort for no return, and remember, ROI (return on investment) is everything...

Mike Fuller is an aerodynamics specialist and runs the mulsannescorner.com website



Curventa

Are projects like the Bloodhound LSR car the last bastion of true engineering excellence these days?

Email the Editor: racecar@ipcmedia.com **or write to:** The Editor, Racecar Engineering, IPC Media, Leon House, 233 High Street, Croydon, CR9 1HZ, England. **Visit** www.racecar-engineering.com


LAT

For an example of a non-spec series that really works, look at Formula Ford – cheap, affordable, open technology and plenty of room for innovation

A BETTER WAY?

The world economy is dictating abrupt changes to the motorsport industry. "Cost cutting measures" introduced by several of the sanctioning bodies, from F1 to NASCAR, are just an attempt to prevent major sponsors and established teams from jumping ship. It seems that many of the racing series have decided that converting to a spec series will curtail cost and stop the bleeding. Down the road this might be a more economical way to race, but it certainly won't be initially, and race teams and sponsors need relief now.

The cost of new designs, re-tooling, R&D and the testing required to be in compliance with these new rules is not going to produce the expected results. On top of this, the cost to replace previous designs and test data from the tunnel and track would be astronomical.

The logic behind spec series racing must be that mass production results in a reduction in the overall cost of materials and manufacturing. Seems like a great idea on the surface, right? But if you subscribe to this type of thinking then you would probably see no problem in curing dandruff by decapitation.

Motorsports are not just comprised of cars and drivers. Without the multitude of gifted and talented people behind the scenes (which, thank God, are not forgotten by this publication) this industry would not exist. When people go to the theatre to see a show, they may love the costumes but think little about the costume designers who created them. They may love the dialogue but give no thought to those who put the words in the mouths of the actors. Sorry for taking the fork in the road but here is where I'm going with all this. Running spec classes may be cheaper in the long run but, at the same time, destroys the creative, intellectual and motivational drive that has in the past rewarded teams that excel in these areas. Significant advances in the mainstream automobile industry would come to a standstill under the restrictive environment that a spec series operates under and, as a result, the gifted and talented engineers and designers would leave motorsports rather than give up what attracted them to it in the first place – creative thinking. There has got to be a better way!

> **"prevent unauthorised acquisition of goods and services through the back door"**

I hate people who criticise and then offer up no alternative solutions, so here is mine: sanctioning bodies should immediately give up the idea of producing racecars like they were cookies for all of the reasons stated. The powers that be should meet with the team owners and establish a total Dollar, Pound or Euro limit that would not favour one team over another. The amount of money agreed upon would be the same for all teams and each would have the freedom to decide the best way to utilise it. There needs to be a way to verify spending and one way to do this is to have all materials, rentals and contract work orders go through the sanctioning body. This would prevent unauthorised acquisition of goods and services through the back door.

Naturally, each team would have its own ideas about the best way to budget their money and by the end of the season they would know if they made the right choices. It would be like bringing 25 chefs to a grocery store and giving each the same amount of money to create their best meal, except in this case the store would offer aerodynamics, CAD, wind tunnel testing, composite materials, R&D and track test days. I do not have a problem with limiting horsepower, but I do when you dictate how it is to be made. There will need to be limits on chassis dimensions and wheel size, but materials and compounds should be left to the teams.

By setting up a series that allows teams to creatively think again will spark the engineers behind the scenes to think inside or outside the box, but with a budget. Racecar designers will have to decide if the benefit of carbon fibre is worth the cost or could the money be spent more effectively elsewhere. When cost restraints are placed on a race team, rather than just spec design, the creative juices again will flow and innovative thinkers will rise to the occasion and the teams that employ them will become well acquainted with the podium.

James Donovitz
via Email

Racecar engineering
The International Journal of Motorsport Technology

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LATE APEX

The spice of life

It seems the comments in last month's Late Apex column (V19N5) regarding diversity in motor racing struck a chord with readers, several of you having emailed us, agreeing with the sentiments expressed. My view was that it was futile to try turning the clock back in motorsport to a simpler, less regulated era as technical progress made in the last 30 years cannot be expunged, nor the concerns of the modern world ignored. Progress is one thing, but diversity quite another and, with a couple of notable exceptions, one attribute of the sport that seems to have been largely sidelined in recent years is variety.

It may be the preference of manufacturers' marketing departments to stage one-make championships, as the products of their employers are guaranteed to win, while regulatory bodies may espouse spec series on the grounds of promoting close racing and containing costs. These arguments undoubtedly have validity, but it seems a number of you much prefer to see different cars, with different strengths and weaknesses, powered by different engines, racing on track at the same time.

> "one of the most refreshing aspects… is the attitude of the organising body"

As an aside, it is interesting to postulate that the apparent upsurge of interest in this year's Formula 1 World Championship may be due, in part, to the imposition of wide-ranging new technical regulations, resulting in teams developing different solutions to the mechanical and aero challenges facing them. In the process, they have produced cars that actually appear quite different from one another, even to the relatively casual observer. One assumes that, come the 2010 season, many of those individual traits will start to disappear, as teams abandon less successful solutions and work on developing their own versions of the winning Red Bull and Brawn chassis. This season, however, that diversity is clear for all to see and undoubtedly a contributory factor in what appears to be a classic championship year in the making.

But I digress. The matter of diversity in motor racing came to mind most recently while interviewing Kirt Wightman, boss of Georgia-based Hyper Sport Engineering – the company responsible for the Lotus Exige S featured in the Lotus files feature (see p32). The car is competing in the GT class of the Sports Car Club of America's Speed World Challenge for the first time this year, and it seems to me that one of the most refreshing aspects of the whole story is the attitude of the organising body to the arrival of a new competitor in one of its Pro Racing series.

'The SCCA just loves the idea of the car being there,' observes Wightman. 'It's different. They know the [Lotus] club guys are going to show up at the races to support us and it's a great manufacturer name, so they're working with us rule-wise. They came to us and said, "Within our format, our power-to-weight ratios and so on, what do you need to be competitive?" We said, "We don't know yet, but we may need latitude in these areas." Their response was, "Okay, just let us know and we'll talk about it."

'So if I had to stretch the wheelbase, they would let me – things like that – and we put all that on the table. I also said, "We could run this much horsepower, but we don't really want to. We'd rather run at this level, know the motor is reliable, and just match [the performance] to the formula.'

For one who cut his motorsport teeth as a weekend warrior on the North American racing scene, and has even taken part in a few Pro Racing events, Wightman's comments brought back some great memories of hugely varied grids and close racing, courtesy of well-conceived regulations aimed at promoting performance parity and on-track diversity.

A few other series' organisers might just like to take note.

EDITOR
Graham Jones

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MAKING IT BETTER

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NEXTEL CUP CAR SHOWS THE WAY FORWARD

ZYTEK'S BUILT-IN FLEXIBILITY

How to cope when producing 65 race engines a year instead of 10

CLEANING UP COMPOSITES

Using a new wet-blast system to improve surface preparation

MACHINING FOR GLORY AT LE MANS

One man's plan to use a CNC machine to make a racecar

Some years ago, while visiting Ilmor Engineering's Northamptonshire factory, I had occasion to interview company co-founder, Mario Illien. After exhausting the inevitable questions about the company's engines, the discussion turned to the subject of manufacturing, and how computer-controlled milling machines had revolutionised the business of making engines. 'I tell you, the new machines are amazing,' he said. 'I mean, with our latest one, you programme it for the piece you want to make, set up a long, solid bar of aluminium to feed into it overnight, switch it on, and come back in the morning to find the aluminium bar gone and the hopper at the end full of the most intricately machined pump internals you could imagine.

'As a result, we are able to be more efficient, while producing the highest quality components with absolute consistency. It's very exciting.'

That fascination with the capabilities of automated machines, along with a readiness to embrace the new ways of working they made possible, was part of what helped to make Ilmor Engineering so successful as an engine design and manufacturing specialist.

In short, it may be the often unseen side of motor racing, but component manufacture and the machinery used to make it provide the bedrock upon which the sport is built. In this supplement, we look at how several leading companies have used the latest technology and manufacturing techniques to address particular issues. We also look at some of the most recent equipment to reach the market.

It may not be overtly glamorous, but those in the know in the motorsport industry understand just how important it is.

EDITOR
Graham Jones

The International Journal of Motorsport Technology
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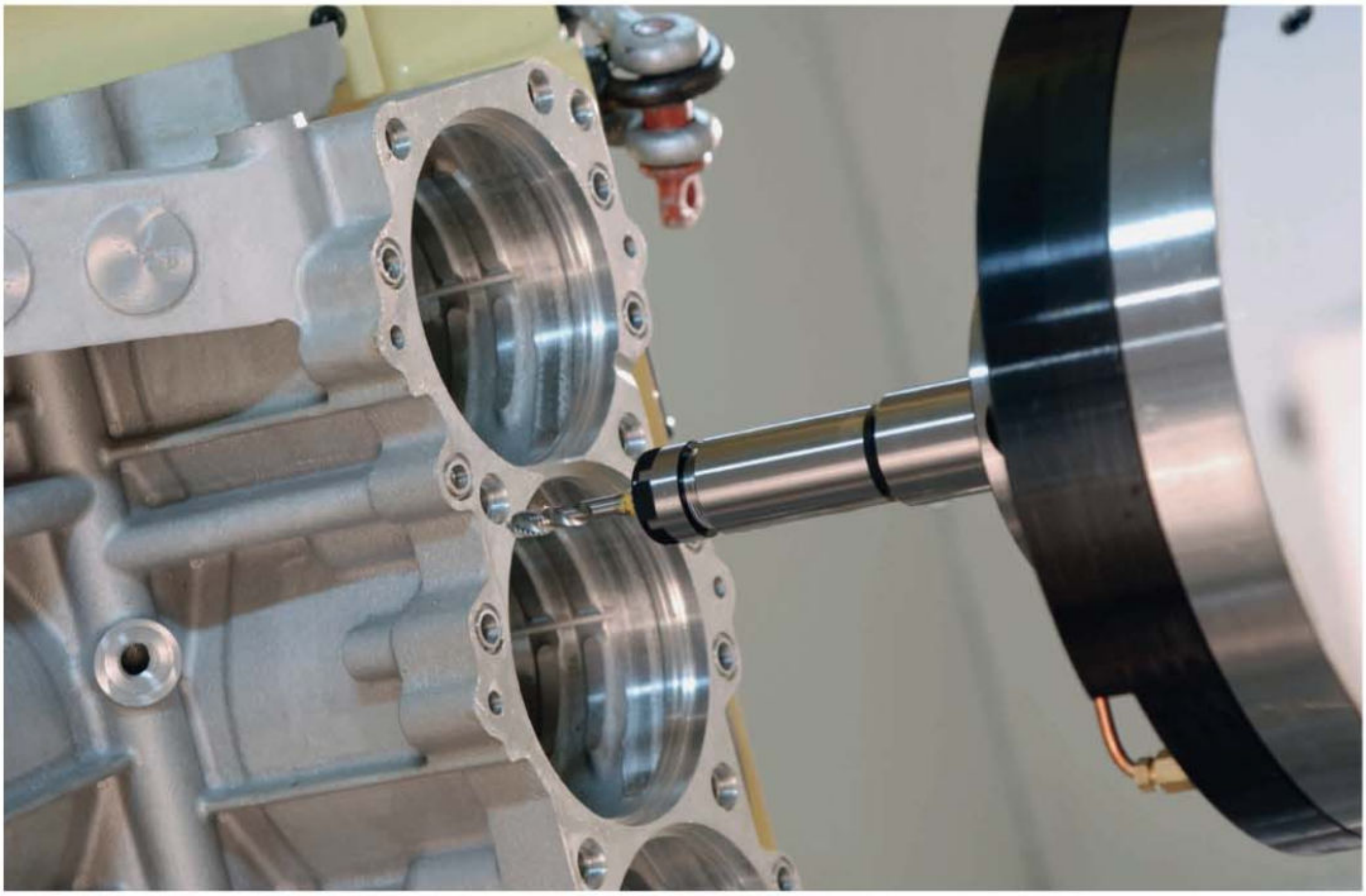
COMPANIES LISTED

Cover photo of a Matsuura H-Plus 630 horizontal machining centre in action courtesy of Matsuura Machinery Corporation, Fukui City, Japan

WHERE PRECISION MATTERS
Formula 1 teams, like any other firm in the performance engineering sector, rely on the latest manufacturing technology to get a competitive advantage. Toyota F1 is no exception, here one of its chassis is being checked using its in-house CMM facility, something every team now has



HIGH DEMAND

When Zytek Engineering won the contract to supply A1GP's engines, it had to increase its production rate tenfold overnight. Here's how they did it

IAN WAGSTAFF

The dominance of single-specification formulae has placed demands on the motorsport industry, often creating, to use a topical phrase, a 'boom or bust' situation. To the long-accepted pressures of a seasonal sport has been added the fact that 'spec' racing means a company's fortunes can vary between enjoying an overfull order book one season to having nothing to build the next.

As both an engine and a chassis manufacturer – a rare identity in 21st century motorsport – Zytek Engineering can cushion itself to a certain extent from the vagaries of the industry. However, the company's Repton, UK-based manufacturing facility has seen widely varying demands upon its services, pressures that have caused its production manager Ian Edmonds to think laterally in order to maintain a uniformly efficient operation.

Zytek had been the sole engine supplier for Formula 3000 for nine years, since 1996, during which time a total of 80 famously reliable engines were in use. When F3000 was replaced by GP2, Zytek lost out to Mecachrome, which then became the sole supplier for the new F1 feeder series. However, Sheik Maktoum Hasher Al Maktoum was soon to introduce his idea of an international single-seater series based on nations, rather than teams – what we now know as A1GP.

It was a radical idea that was to get off the ground partially due to the initial choice of experienced suppliers – Lola for the chassis and Zytek for the engine. For three seasons this paring supplied the cars for A1GP until, seduced by the charisma of the Ferrari brand, the current operators of the series decided to build their own chassis, which was to be powered by an engine based on a road-going unit from the Italian manufacturer.

The problem for those first major A1GP suppliers was that the equipment was not phased in over those three years. It all had to be available from the beginning. The fact that the first round of the initial championship featured a full grid perhaps contrasts with the halting start of the initial 'Powered by Ferrari' season. For Zytek, it meant having to manufacture 65 engines in one year. It was a major undertaking, given that only 80 had been needed for the whole of the nine years of the single spec F3000.

Prior to winning the A1GP contract in 2004, Zytek Engineering was producing approximately 10 engines per year, and each was slightly different as each had a slightly new design specification. Understandably, Edmonds found that they could not be produced as quickly as if they all had to be the same. But that's exactly what the A1GP contract meant. Suddenly, the company had to produce around 65 identical engines in one year – a massive tenfold leap in production.

'We had a year to produce

the engines from receipt of order,' he recalled. The obvious way forward would have been to purchase more machines and otherwise carry on as before, but that would have meant a surplus of machinery and personnel at the end of the production run. 'So we looked at methods of improving the way in which we were manufacturing.

'I looked at what was required and decided what we needed to spend, which included a second Mitutoyo co-ordinate measuring machine. I had to convince the directors that we would achieve what we were setting out to do by spending that.'

Mori Seiki had helped with the initial set up of the engines. However, Zytek wanted to avoid having to buy any more machine tools to cope with the extra demand. In order to do this the company approached 'partners' MAPAL, Delcam, Mori Seiki and Nikken Kosakusho with various ideas. 'We knew what we wanted, but we needed to know the best companies to do it with,' explains Edmonds. Fortunately, Zytek had a long history with each of its technical suppliers, all of whom understood the ways in which the company worked.

As a result, MAPAL supplied specialised tooling for making more than one feature at once, or for automatically machining a feature that, in the past, had been very labour intensive to produce. This was achieved using tools with monoblock PCD (polycrystalline diamond) technology, and guide-padded tooling. Cylinder head production, for example, was brought down from 30 manned hours and 40 unmanned hours to 10 and 15 hours respectively per cylinder head, solely on the strength of the MAPAL tooling and Delcam software. MAPAL equipment is, Edmonds pointed out, used in producing engines of all types, from road going to F1.

In the past, each tight limit bore, each dowel location had been produced with an adjustable, single point boring bar. As such, a trial cut had to be made, measured, adjusted and cut again, perhaps more than once, with a person in attendance at all times. MAPAL produced guide pad reamers that cut the hole quicker and more accurately without the need for any manual intervention.

Similarly, cylinder liner locations had required five tools, each with a trial cut, measure, final cut, second measure and possibly another cut after that. 'With MAPAL's help we got that down to two tools,' recalled Edmonds, 'one to rough it and one to finish.' This reduced production time of the cylinder blocks 'massively' and gave 'excellent' repeatability. Edmonds has calculated the various time savings made at 24.5 per cent for cylinder blocks, 33 per cent for cylinder heads and 12.5 per cent for lower crankcases.

> “we have combined and simplified operations”

Mapal's subsidiary at Rugby has been supplying Zytek virtually since it opened its Repton facility. 'We have developed a partnership with Zytek based on our ability to bring the latest cutting tool technology to them,' said UK sales manager Dick Arnold. 'As Zytek has expanded and made more products we have helped streamline its tooling methods. We have combined and simplified operations, particularly on cylinder boring, valve seat machining and dowel hole locations, which has given it a much quicker and better process in terms of quality and performance.'

This was backed up by on-site installation and support from Mapal's dedicated service team.

The one piece of machinery that was purchased because of the A1GP order was a second Mitutoyo co-ordinate measuring machine. 'We decided that having just the one would cause a bottle neck as all components are fully inspected, whether manufactured at Zytek or outsourced. The extra load on inspection facilities was at times greater than manufacturing (520 pistons, 520 rods, 260 camshafts, 65 cranks etc).

If we had stayed as we were with regard to engine production, this bottle neck situation would have happened for the major engine castings on the Mori Seiki MH633 machining centre. To make 65 engines we had to produce 130 cylinder heads. 'There just weren't enough weeks to do that.' The only alternative would have been to buy another MH633 'at something like half a million pounds. It would not have been an option anyway as it would possibly have meant an eight month delivery time.

'We know how long the cylinder heads take, we know how long the cylinder blocks take. Everything else we could have shuffled around on other machines but they had to go through the MH633. If we had continued as we were it would have taken us longer than a year to produce all the major engine components, let alone anything else. The heads and blocks were the critical paths and we needed to produce those quicker.'

Zytek also spoke to Nikken about the way in which tooling is set up and purchased a tooling pre-setter. This downloads the tooling

New automated tooling increased productivity and allowed significant time savings on component manufacture

ZYTEK'S TOOL SHOP

Zytek Engineering's current 8000sq.ft machine shop in Repton, UK was set up in 2001 and currently employs 11 people on manufacturing and inspection. The total is only one less than the year in which the A1GP engines were made, a drop merely caused by natural wastage.

The main engine castings at Zytek are produced on a Mori Seiki MH633 horizontal machining centre with five-axis capability. To this can be added Mori Seiki SV500, SV400 and Duracenter vertical machining centres (some with four-axis capability), a MT2000S five-axis mill turn with a sub spindle, SL2500Y four-axis mill turn and SL200 three-axis mill turn. MAPAL supplies the tooling for all these machines and every spindle-nosed tool is either from MAPAL or Nikken.

The use of new cutting tools helped improve accuracy and repeatability

geometry data direct to the machine tools, improving accuracy and removing manual errors in data transfer. In addition, Zytek changed its CAD partner to Delcam. 'We felt that we had outgrown our previous partner and, having spoken to Delcam, realised they did not just provide an add on to a CAD system. They were excited to help us produce programmes for doing the inlet and exhaust ports. With our help they produced specific strategies for the machining of the ports.' This has now grown on to reverse engineering where Zytek has, this year, started measuring hand-finished ports and converting them back into models. There is only so much that can be done on a computer when assessing airflow on an engine, it eventually needs to be physically tested. The engineer can then hand finish and improve on the calculated figures. But in doing so, all traceability of the port shape can be lost. However, this can now be measured and a model generated from the hand-finished port.

> "removing manual errors in data transfer"

Zytek Engineering is now easily able to produce the power units required for the LMP1 and LMP2 Le Mans racers and, when it starts production, the Ginetta-Zytek G50Z. In addition to this, it can also produce the majority of the chassis components for the cars, too. 'The legacy has been that we have gained useful extra capacity,' concluded Edmonds.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THE TAO OF DRAG

The biggest challenge in drag racing is getting the power down. To achieve this, the Leander Brothers in Sweden decided to machine their own clutches from titanium...

MATT BAILEY

Zaventem, Belgium, March 2008. Here's an interesting business objective, one that in many ways seems perversely out of kilter with the rest of mankind, increasingly pre-occupied with the possibility of its own self-annihilation: build the meanest, most single-purpose vehicle you can conceive to travel the quarter mile as quickly as humanly and mechanically possible. Repeat, indefinitely.

As business objectives go, it doesn't appear to make much commercial sense. Firstly, it consumes money marginally less efficiently than if you put a match to a pile of bank notes and, if you believe the old adage that if you want to accrue a small fortune in motorsport, start with a large one, it's particularly true of drag racing.

Secondly, it risks human life to achieve what, exactly? Surely, as our moment of environmental reckoning looms, we have more important things to be doing with our time and engineering creativity? Is it possible to justify drag racing – or any motorsport, for that matter – given the environmental challenges we face as a species? Well, yes, it is.

Arguably, humans learn most about themselves from the games they play. Businesses of all sizes, shapes and purposes look to many sports for the inspiration they need to achieve their particular goals – some prosaic, others profound (as I write, in Amsterdam airport, I'm overlooked by the image of a well-known golfer under contract to a consulting firm imploring me to find my inner Tiger…). Drag racing provides a model for focus, determination and guts – exactly the same qualities business owners and managers need to succeed in their own endeavours, whatever their goals may be.

And here's another reason why as engineers and technologists we can draw inspiration from drag racing: fire breathing, 3000bhp Funny Cars, of the type built and developed by Haas-sponsored Leanders Brothers Racing, Sweden's 2006 FIA European champions, run on methanol, an alcohol made from wood pulp, which is renewable and can be sourced from sustainable forests. Take that, Toyota Prius drivers.

Granted, the Leanders' car is hardly fuel efficient: it typically uses 20 litres to produce a run lasting less than six seconds, and that does include the burnout, where the driver warms the tyres by spinning the rear wheels until they all but ignite. Still, methanol burns cleaner than petrol, which at least helps offset some of the noxious gases produced by the gratuitous incineration of tyre rubber.

Methanol is also a close relative of ethanol, both of which have octane numbers more than 30 or so points greater than regular petrol. What makes methanol the fuel of choice for the likes of the Leanders Brothers is its suitability for high-compression ratio engines, meaning it's ideal for 10,000rpm, V8 monsters. That, and the fact that you can use water to extinguish the fire when it ignites.

But how did two brothers, working alone in a farm barn in north-central Sweden, become FIA European champions? 'All competition vehicles are built from NHRA or FIA-approved parts,' explains Ulf Leanders, younger brother and the team's designated driver, 'so the equipment [all competitors use] is similar. That way, well-financed individuals can't just enter the sport and clean up by throwing money around.'

Rich newcomers quickly learn that it's not a sport that permits overnight success. 'They get bored and leave,' says Ulf. 'It's a very even playing field.'

So that's the wealthy competitors taken care of. That leaves the sane ones.

VELVET SLIPPERS

Unless you're a space shuttle pilot (or a fellow drag racer) you probably can't imagine accelerating from 0-60mph in less than one second or, for that matter, to 250mph in less than six seconds, but that's what the leading drivers have to contend with.

'It takes a year or two to get used to the violence of the first couple of seconds,' explains Ulf. 'During that time, you're not really driving, you're just holding on and trying to keep the throttle pressed to the floor.' Something that is made easier by the fact that there's a metal stirrup over the pedal. 'My foot slipped' is not an excuse made by European Top Fuel champions.

'At the start, we're pulling approximately 4*g*,' says Ulf. Note: if you have an average-sized brain it would, at this point, weigh around 1600g (60oz) and, presumably, coat the back of your inner skull like wallpaper. I'm not sure whether drag racers' brains are bigger or smaller than

The Haas EC400 machining centre where the team produces its own titanium-based clutches for its Funny Cars

average, but these kinds of forces can't do much long term good for your cognitive functions, which is probably why it's non-driver Jörgen Leanders who is responsible for all the clever engineering on the car, including the all-important clutch.

THE BIGGEST CHALLENGE

It doesn't matter how skilled the driver is, the biggest challenge is getting the power down. Since electronic launch controls are banned, it's down to a slipper clutch – similar in concept to those used to reduce engine braking on motorcycles – to transfer power quickly and smoothly. 'A slipper clutch partially disengages to regulate the amount of engine power delivered to the wheels,' explains Jörgen. 'However, because the clutch uses friction to do its job, the pads are prone to serious wear, so we need to be able to quickly strip and re-assemble the clutch between runs.'

In most racing situations, clutches are made in aluminium to be as small and light as possible. In an F1 car, for example, they're designed to last just long enough to get the car to the end of the race, which is why drivers often have to nurse the clutch if the race is re-started or if the car is stationary longer than usual. Bolted steel segments help dissipate the heat, but they flex and bend and can quickly fail. In drag racing, the clutch has to be built to transfer a huge and violent surge of power, so the aluminium is replaced with titanium, which is both tougher and heavier.

One of the Leander Brothers' assembled floating plate clutches

The Leanders clutch uses a floating-plate system in place of bolted segments, which improves heat dissipation and makes it easier to take apart and rebuild after a run.

> **"drag racing could be considered a Zen discipline"**

In the corner of the Leanders' workshop, surrounded by glass fibre vehicle body parts and semi-used slick tyres, sits a brand new Haas EC400 horizontal machining centre, on loan to Leanders Brothers Racing as part of the sponsorship deal. Bolted to the table block is the aluminium base of a half-finished clutch.

'We mill just about everything on the clutch except the bolts and some small axles that hold the fingers and the adjusting screws,' Jörgen tells us. 'The aluminium is Alumec,' he adds, a relatively hard wearing tool-making aluminium with good machining characteristics and low weight. 'We also machine quite a lot of coated titanium, as well as tool steel for the fingers, while the facings and floaters are made from regular carbon steel.'

The Leanders' clutch is a new project, one the team hopes will give them the split-second advantage they need. The typically sanguine Jörgen is un-phased by the engineering challenge of designing and making parts, or of learning to operate a CNC machine tool. 'The Haas is very easy to use,' he says. 'It was making parts the day after it was installed.

'We currently only operate the Haas for around 100 hours a month but, if the regulating body in San Diego approves the clutch, we'll be using it a lot more and maybe, ultimately, will even sell our product to other teams.'

Aside from the Haas machine, the Leander Brothers' workshop is basic, yet their work is almost unbeatable in Europe

ENGINEERING RELEVANCE

Some businesses look pointless to some people, but make a great deal of sense to others – their customers, for example. At a typical drag race meet, hundreds of enthusiasts line the quarter-mile stretch of asphalt and many of them are engineers. Not necessarily the high-forehead types who work for NASA or IBM, but the gritty, often self-taught types who run machine shops doing clever things with metal and machine tools, which is one reason why Haas Automation became involved with Leanders Brothers Racing in the first place.

Besides offering ear-splitting entertainment, what can drag racing teach businesses beyond clever engineering? In his book, *Mastery*, author George Leonard uses Zen philosophy and the sport of Aikido to illustrate how long-term success and fulfilment only comes with long-term dedication to what you do. He accuses western business and industry of short-termism, a trait he considers to be the enemy of mastery. Leonard urges readers to forever practice what they do and even to 'love the plateaus', embracing them as learning opportunities, instead of always seeking instant gratification. The only way to win in drag racing is to keep doing the same thing over and over again, obsessing the detail until you make progress. Strange as it seems, drag racing could be considered a Zen discipline, albeit a very loud one.

Philosophers like Leonard tell us that whatever it is you do, keep doing it until you do it incredibly well. Focus, don't get sidetracked and persevere where your strength lies. Keep doing that and, the Zen masters say, success will most likely follow. You may only be a small, two-man team based in a shed in Scandinavia but, with the right tools, the right mindset and, we can only assume, very poor national TV, anything is possible.

BE PREPARED

How racecar composite specialist Global Technologies Racing successfully moved from traditional sand blasting to Vapormatt's latest wet-blast machines

IAN WAGSTAFF

In 2003, the founders of Global Technologies Racing (GTR) – John Biddlecombe and Simon Kingdom-Butcher – having sold their G-Force racecar manufacturing operation to Don Panoz, planned to set up a small composite company using part of their old Fontwell, West Sussex premises. At least, that was the idea.

G-Force had already won two Indianapolis 500s (and was under the Panoz G-Force banner to win two more) and been involved in a number of other successful projects, but now the pair wanted to downsize and look after just one or two customers in their newly refurbished workshop. To begin with, a small staff was recruited from former G-Force personnel but, as Biddlecombe reports, 'we just kept growing.' Jamie Keogh was recruited as manager from the world of Formula 1 where he had worked for Honda and Sauber and the staff quickly grew to 30 and then to 40 people. Instead of occupying just one half of the former G-Force premises, the company soon took over both units and customers now include Formula 1 and Indy Car teams, GTR having also been responsible for assisting Panoz with its short-lived Champ Car, the DP01.

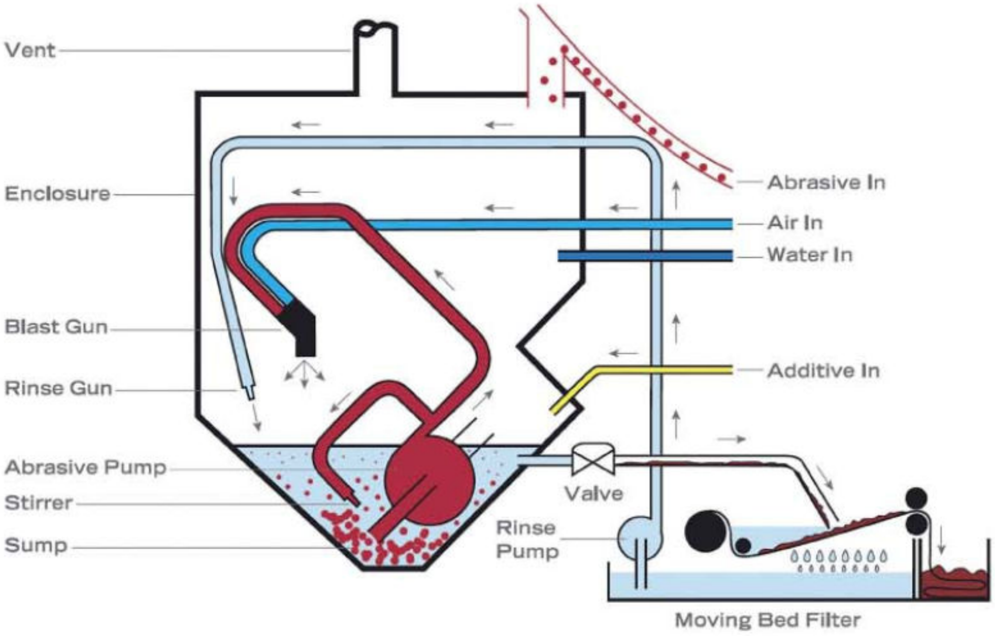
Keogh's knowledge of Formula 1 brought more but increasingly demanding business from that sector. Up until this point, GTR had been content to use a traditional sand blasting technique in its preparation procedure. However, as Biddlecombe puts it, 'the F1 teams call up what processes are to be used and we naturally comply with their wishes.' It was in this way that GTR was introduced to its first Vapormatt wet blast machine. The company quickly discovered the benefits of such a machine and, last year, ordered a second model – a Vapormate 3 with a 995mm x 700mm x 700mm processing enclosure. Although the two GTR premises are a mere 20m apart, this means a separate wet blast machine can now be used in the clean area that is used for laminating and also in the carbon assembly area. It is now what Biddlecombe describes as 'a more practical arrangement.' One Vapormate is now used for preparing parts before they are glued, the other for parts that have been cured in the autoclave.

> "eliminates the need for further cleaning"

The new Vapormate 3 is used for the surface preparation of post-cured parts prior to painting or coating, while for the surface conditioning of carbon fibre surfaces prior to laying-up and bonding an older Vapormate 1 with 700mm x 700mm x 700mm enclosure is used.

The Vapormatt wet blast process uses water and fine abrasives in suspension, delivered by a slurry

THE WET-BLAST PROCESS



By comparison with sand blasting the Vapormatt wet-blast system uses a slurry pump and compressed air to deliver a variable stream of fine abrasive suspended in water to scour the surface of the composite components, causing less damage to their microscopic structure than traditional blasting

pump and accelerated by compressed air to the process nozzle, which is normally manually operated. The action of the slurry scours the surface to create a totally clean and lightly abraded result. The water can be heated and a mild detergent added to ensure effective removal of grease and the ratio between the water pressure and air pressure in the process nozzle is variable. This enables a 'water buffer' to be maintained between the abrasive media and the surface being processed. This buffer effect is said to have a number of major benefits: it lubricates the action of the media, eliminates static build-up and washes the surface continuously during processing. It also prevents the impregnation of hard abrasive particles into the soft resin surface and prevents fibre damage.

The wet blast process has now superseded the use of hand abrading in many composite surface preparation applications, mainly because it overcomes the latter's inconsistencies, but also because it eliminates the need for further cleaning. The process uses no solvents or potentially hazardous chemicals, so is not subject to EU solvent emission, VOC or dust emission legislation and is said to be particularly effective for the preparation of complex automotive components, such as those manufactured by GTR.

GRP and carbon fibre are notoriously difficult to bond due to the presence of resinous material on the normally smooth, non-retentive surface, while the presence of any grease or dust will further compromise effective adhesion. The traditional method used by most manufacturers involves a combination of peel ply and hand flatting using wet and dry abrasive papers, but this tended to leave an uneven surface finish with the part still needing to be chemically cleaned to remove any contamination left on the surface. Dry sand blasting has also been tried but, as Vapormatt claims, when the carbon fibre is then examined using scanning electron microscopy (SEM) more damage of uni-directional carbon fibre (UD-CFRP) is visible compared to when using its own process.

Unsurprisingly, Vapormatt believes its technology is 'state of the art', and given the critical nature of composite bonding in racecar construction, it is important that the best processing techniques available are used. GTR's Formula 1 customers obviously believe the Vapormate machines meet their requirements and the fact that GTR has now purchased a second machine would indicate that it agrees.

> "this wet-blast process has now superseded... the use of hand abrading"

In their days as G-Force, Biddlecombe and Kingdom-Butcher could proclaim their successes. The former points, in particular, to 1997 as being a memorable year. 'It is incredible to win the Indianapolis 500, particularly at your first attempt,' he says. After two days of rain delay, Arie Luyendyk led home an all G-Force podium.

There was more to come though. In October, at the Las Vegas 500, G-Force wrapped up the Indy Racing League championship with Team Menard and now NASCAR star Tony Stewart. Then, within a few weeks, another high-profile customer, Richard Noble, had led driver Andy Green and the Thrust SSC team to a supersonic World Land Speed Record.

These days, the confidential nature of its business is such that GTR cannot broadcast its successes. However, it can be told that its customers number Formula 1 teams at the very front of the grid. And, at this level, suppliers have to ensure their equipment is the most effective available if they are to retain the business.

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Mastercam's multi-axis machining technology offers increased speed and improved finish

Multi-axis machining can dramatically increase a race shop's competitiveness, and Mastercam's multi-axis machining offers a wide range of machining strategies, from basic to advanced. Some enhancements to Mastercam's multi-axis machining include features in the Port5ax and Flow5ax toolpaths, TrueSolids five-axis verify improvements and much more.

PORT5AX AND FLOW5AX

These tool paths now include a new feature that allows an overlap or blend to be added at the beginning and end of a tool path – a feature that is very useful for creating better finishes where tool paths may need to meet from opposite directions. Several options are available for controlling the start and end of a port or flowline multi-axis tool path, including skipping the first pass, last pass or both passes, and blending the entry, exit or both.

TRUESOLIDS 5-AXIS VERIFY

TrueSolids 5-axis Verify is now included in Mastercam's multi-axis machining. Using this solid modelling technology for tool path simulation, after verifying a part in TrueSolid mode, you can rotate and magnify the part to more closely check features, surface finish or scallops created.

SMART INTERFACE

Mastercam's advanced multi-axis machining lets you choose what type of project you are doing, and adjusts the interface to show exactly what you need to complete your job. Other multi-axis features include:

- **General speed improvements**
- **Advanced gouge checking and a 5-axis safe zone around parts to help ensure safe cuts in even the most complex operations**
- **The ability to machine 5-axis curves with independent definitions of tool side angle and lead / lag angle**
- **Special options for machining cylinder heads and converting probe data to machinable geometries**

Focus RS success highlights Quaife Engineering's OEM capabilities

Ford's new version of the Focus RS comes equipped with Quaife's traction-enhancing automatic torque biasing (ATB) differential as standard equipment, marking a significant OEM success for the Kent-based transmission specialist.

The contract for 8000 ATB differential units is the result of two year's close liaison between Quaife, Getrag and Team RS in Germany, although the production unit has required remarkably little re-design for the Focus RS road car application.

Indeed, the main changes required were adding an extra planetary pinion into the ATB unit, allowing for larger, stronger driveshafts to be fitted to the latest in Ford's long line of RS models.

Commenting on the project Quaife Engineering director, Michael Quaife, said 'We've enjoyed an ongoing dialogue with Ford and we're very pleased with the end results as they were a particularly good team to work with. Quaife has long been associated with the Ford brand and we're delighted that this is set to continue into the future.

'Naturally, we're pleased that the initial press reviews of the car seem to be overwhelming positive. Even with 300bhp and 320lb. ft of torque being pushed through the front wheels the combination of the Quaife ATB differential and Ford's patented Revoknuckle front suspension is highly effective,' Quaife remarks.

The Focus RS ATB differential project marks the culmination of Quaife's investment in a state-of-the-art robotic CNC machining facility in Gillingham – a huge asset for a company that enjoys ISO9001 and TS16496 Compliance.

The Focus RS project represents 18 months work for the company, which employs 65 staff and exports 55 per cent of its product.

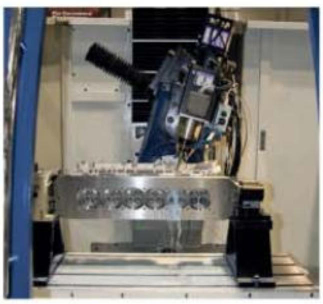
Renishaw's 'revolutionary' measuring head and probe

The new REVOTM measuring head and probe system is the first in what maker Renishaw claims is a range of revolutionary products offering five-axis measurement capability and designed to maximise CMM throughput, while maintaining high system accuracy. REVOTM uses synchronised motion and Renscan5TM measurement technology to minimise the dynamic effects of CMM motion at ultra-high measurement speeds.

Using Renscan5TM, measurements are taken while moving the REVOTM head synchronously with the CMM. The unwanted effects of CMM dynamics at high scanning speeds are removed. The use of a flexible tip sensing probe system, RSP2, say Renishaw, 'further adds to the system's accuracy and flexibility. This removable probe system, used in conjunction with a low-cost changer, provides system flexibility and the potential of accessing new probe technologies in the future.'

see: www.renscan5.com

The latest Renishaw REVOTM measuring system provides five-axis capability



The flexible probe system can easily be upgraded as new probe technologies become available

Rottler set the standard for valve seat machining

The versatility of Rottler's SG7 and SG8 machines makes them equally well suited for working on the older type classic cylinder heads and the modern multi-valve cylinder heads found in today's engines.

Both machines can be used for a wide variety of machining operations. For example, cylinder heads with integral valve seats and / or valve guides can be machined to accept removable valve seats and guides or bronze valve guide liners. They can also be used for the machining of valve spring seat platforms and valve guides to accept non-standard valve stem seals.

As an example, a leading UK manufacturer has produced three high volume car cylinder heads where the inlet and exhaust valves are 23° 30' and 25° 30' from the vertical respectively when viewed from the end plane and 8° 45' and 13° 30' from the vertical respectively when viewed from the side plane. For correct machining of the seats or guides, it is essential to position the valve guides accurately on the machine quill centreline.

The latest Rottler SG7 and SG8 models can be used for a wide variety of maching operations on both older style cylinder heads and modern multi-valve units

Using the Rottler SG machines, with their air-float head systems with 15-degree tilting quill and cylinder head rollover fixtures, you can be confident that you will be able to position the quill centreline in exact alignment with each valve guide.

Twin-bladed milling heads for the machining of valve seat insert counter bores are available in increments of 1/16in and the milling heads are equipped with four-point, index-able and replaceable carbide tips.

Rottler has also patented a unique, spring-free, spherical, self-aligning seat cutting system for its SG series machines, and their carbide tip holders for three-angle seat cutting accept the industry standard carbide tips, which are available to cut the throat, top-narrowing angle and seat angle all at the same time.

Rottler says its new SG machines can be proven to cut valve seats more accurately than any other valve seat and guide machine in its price range. This is partly due to their solid, slow tapered carbide pilots, which do not rotate in the guide.

The variable speed and reversible motor provides additional versatility, such as the replacement of press-fit rocker studs by drilling, tapping and replacing with threaded studs.

Centroid A560 simplifies cylinder head porting process

The new Centroid A560 5-axis articulating head high-speed CNC cylinder head porting machine is a complete turn-key system, including comprehensive one-on-one CNC porting training and support. The A560 can port cylinder heads from a wide range of engine configurations, including V12, V10, V8, V6, in-line 6, 5 and 4 cylinders, motorcycle, petrol and diesel engines.

The cast iron articulating head of the Centroid A560 prioivides 60 degrees of lift in each direction for cutting better ports with seamless transitions

The Centroid porting system overcomes the limitations of other CNC porting machines through its unique and patented technology, which provides better ports with seamless transitions. Centroid has also simplified the porting process, so now you can digitise a head in the morning and be cutting perfect copies of it in the afternoon.

Centroid's ballscrew drive articulating head was designed specifically for CNC cylinder head porting.Made in the USA of rigid cast iron, the articulating head provides 60 degrees of tilt in each direction (120 degrees total) so the tool can cut even the most radical ports.

The design of the A560 minimises tool motion for a fast, smooth cutting action and the unique ballscrew drive of the articulating head is said by the company to produce the smoothest 5-axis action on the market.

With its ingenious, robust design, the A560 has also overcome some of the backlash and maintenance problems found with some other machines, enabling users to produce fantastic results every time. The combination of accuracy, repeatability, training and support allows customers to produce race-winning heads time after time.

SOLID STATE

Jean-Michel Vallet dreams of producing a car to compete at Le Mans using six blocks of aluminium and a single Haas CNC machine

The small town of Rugles is approximately 130km north of Le Mans, venue of the world's greatest 24-hour motor race. Like many of his contemporaries, Jean-Michel Vallet was smitten by the sights and sounds of Le Mans and decided at an early age that one day he'd own and race his own Sportscar.

In the intervening 40 years or so, Vallet has built up his eponymous engineering company by making precision components for local companies, but always with one eye on his long-held dream of building a race car and one day, perhaps, driving it at Le Mans.

In that time, Vallet has honed his knowledge and skills as a manufacturing engineer. In the early 1970s he was quick to realise the potential of CNC, investing in the first of many numerically-controlled machines. Within 20 years, his collection of machine tools was, he says, eclectic. But when, in the late '90s, the time came to move to new premises, it offered the ideal opportunity to streamline the workshop.

'When we built this new factory, we had something like seven different makes of CNC machine tools,' he says. 'Running the factory was complicated and inefficient so, for the sake of productivity, we had to standardise.'

In 1998, Vallet took a trip to the Paris Machine Tool Show where, for the first time, he came across Haas CNC machine tools. 'We found the best machines for our growing company,' he says. 'For a start, all Haas machines have the same control, which means if you can program one, you can program them all. Plus, they're powerful with lots of torque, which is ideal because we often use large diameter end mills on stainless steel.'

He was also impressed with the Haas' fourth-axis capabilities and the fact that all machines can quickly and easily be fitted with a Haas rotary table. 'It's as simple as plug and play,' says Vallet.

Consequently, the company now boasts an armoury of Haas machines, including a VF-9 vertical machining centre.

CURRENT WORK

Vallet began by making machines for bottling plants but today the company's bread-and-butter work mainly comprises making parts for food packaging and processing machines, plus some special and secretive aerospace projects, which he's reluctant to discuss, except to say that customers include EADS and Dassault.

'We make scale models of new and prototype aircraft, which are used for wind tunnel testing. We also make five-axis parts for our aerospace customers, which are actually comparatively straight forward to machine. The trickiest parts we make are for the food processing industry, which are machined from special stainless steels. These parts often have very tight tolerances, which is a challenge because we have to find ways of making them at the price the customer wants to pay. It's demanding work, but we're able to do it because we use accurate but relatively low-cost tools.'

In Vallet's busy workshop is a line of Haas machines, including eight CNC vertical machining centres and five CNC turning centres. One, a Haas VF-1, runs 24 hours a day using a Kuka robot arm to change parts. An adjacent PC, using software designed personally by Vallet, controls the robot separately. PCs interconnect all the machining stations, allowing managers tight control of planning and scheduling and the factory runs 24 hours a day, with 10 Haas machines running through the night with just five operators on duty.

Daily chores for Haas machines at the Vallet factory include producing parts for food packaging equipment, plus wind tunnel models for aerospace

SEEING THE FUTURE

Whatever your art, part of the genius in creativity is vision. And though there are more than 75,000 Haas CNC machine tools installed around the world, few people could stand in front of a Haas VF-9 and see a racecar.

'My aim,' says Vallet, with a flickering smile, 'is to create an entire racecar from just six blocks of aluminium, in 70 hours, using only four tools.' From these he intends to machine all of the major and supporting structural components. There are to be no castings, no extrusions, just solid parts.

'We'll buy in brakes, glass, wheels, that sort of thing,' he says. 'We'll make the body from glass fibre and use an Alfa Romeo V6 engine, giving 340bhp. But otherwise, we'll make it here, on one Haas machine, in less than a week of running two shifts a day.'

Expected cost? Vallet reckons $100,000 (£68,650) for a road-going version, though considerably more for something capable of putting up a fight at the famous 24 Heures du Mans. If he achieves his goal, we'll let you know.