Table of Contents

Road Force Balancing

Initial Print Date: 3/06 Revision Date:

Road Force Balancing

Model: All

Production: All

OBJECTIVES

After completion of this module you will be able to:

- Understand the Causes of Vibration
- Diagnose and Correct Wheel Balancing Concerns
- Operate the GSP9700BMW Road Force Wheel Balancer

Introduction

Today, there are ever increasing expectations by the driver regarding ride quality and smoothness. Every BMW vehicle is well known for it's superior handling and ride quality. So, when this ride quality is compromised by vibration, an accurate diagnosis and timely repair is the primary goal.

To improve fuel economy and reduce emissions, many of the vehicle components have been weight optimized. Some of these weight reduction techniques involve suspension components such as strut housings and control arms. These components are now made from aluminum rather than steel or cast iron. The aluminum components work well for reducing weight, but they do not have the same dampening properties as the iron or steel components.

Therefore, procedures such as wheel balancing have become much more important in recent years. The GSP97BMW wheel balancer features "Road Force Measurement" technology which allows the tire and wheel assembly to measured while "loaded". This allows "radial force" variations to be measured and corrected.

This training module is designed to help the technicians understand the potential causes of vehicle vibration as well as the best methods to correct these concerns.

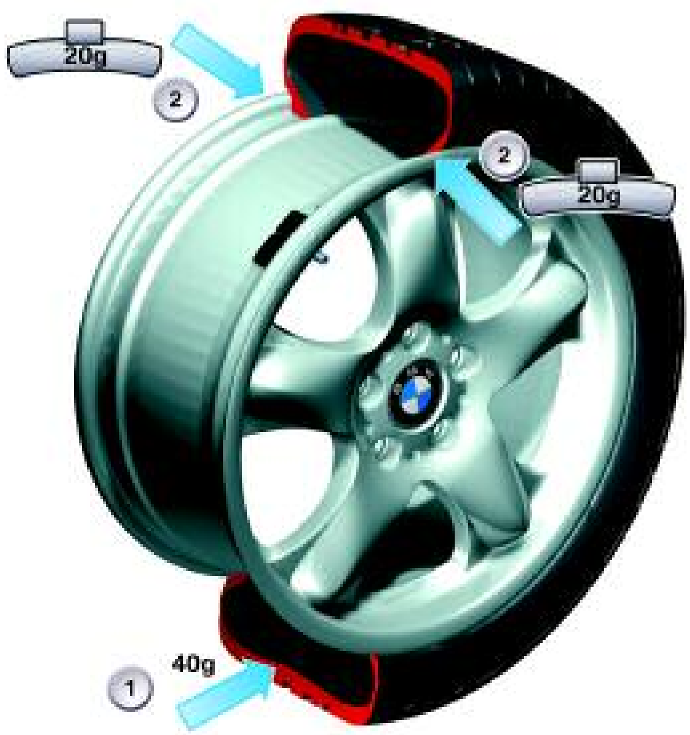
Basic Tire Balancing

Static Imbalance

"Static Imbalance", as the name implies , indicates that the tire and wheel assembly is in a state of imbalance when standing still. Therefore, there is a "heavy spot" which would cause the tire to come to rest in the same position. Many years ago, tires were balanced using a "bubble balancer" and weight was added to restore the tire to a "statically balanced" condition.

When a tire and wheel assembly is statically imbalanced, the tire and wheel assembly will tend to travel in an "up and down" motion. This causes the tire and wheel to "bounce" on the pavement when the vehicle is moving. In extreme cases the wheel assembly can leave the road surface. This causes a vibration which is transferred to the driver via the chassis and suspension components. Also, the tire will wear and create a "cupping" pattern on the tire tread surface.

As far as balancing is concerned, static balancing procedures are no longer the accepted method for balancing tire and wheel assemblies. Static balancing can only correct for imbalances on one plane. This is only effective if the imbalance were only near the centerline.



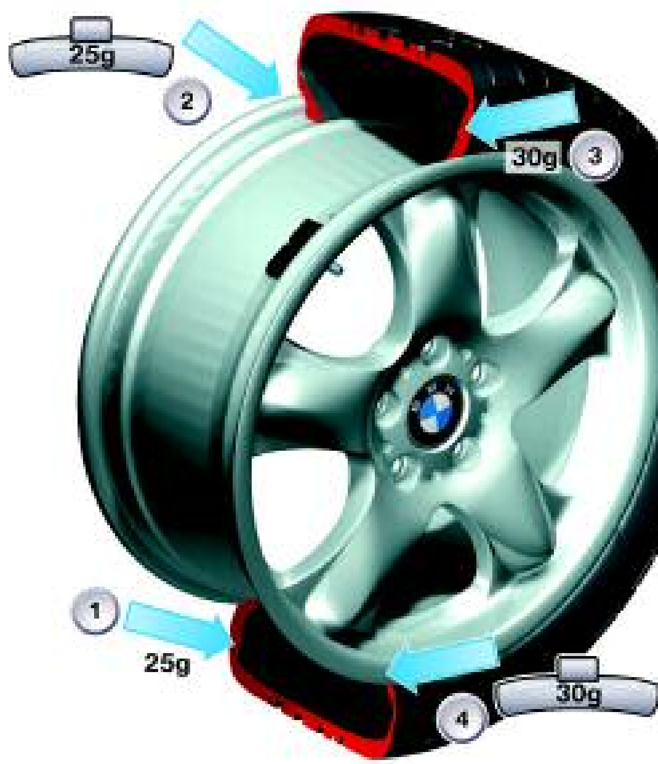
Index	Explanation	Index	Explanation
1	40 gram static imbalance	2	20gram (x2) balance weight for correction

Dynamic Imbalance

As compared to static imbalance, dynamic imbalances pertain to situations present during vehicle movement. Also, two planes of weight correction are considered. When mass (weight) is unevenly distributed across two planes, the resulting force tends to cause the tire and wheel assembly to "wobble". This motion is in a lateral direction which causes a steering wheel "shimmy".

Aside from the obvious potential customer complaint, the "shimmy" caused by a dynamic imbalance can cause wear and tear on the tires and suspension components including wheel bearings and steering linkage.

If a wheel and tire assembly with a dynamic imbalance is installed on the front of the vehicle, the effect is usually noticed right away. When installed on the rear of the vehicle, the vibration is somewhat dampened by the rigidity of the rear axle.



Index	Explanation	Index	Explanation
1	25 gram dynamic imbalance	3	30 gram dynamic imbalance
2	25 gram balance weight for correction	4	30 gram balance weight for correction

Residual Imbalance

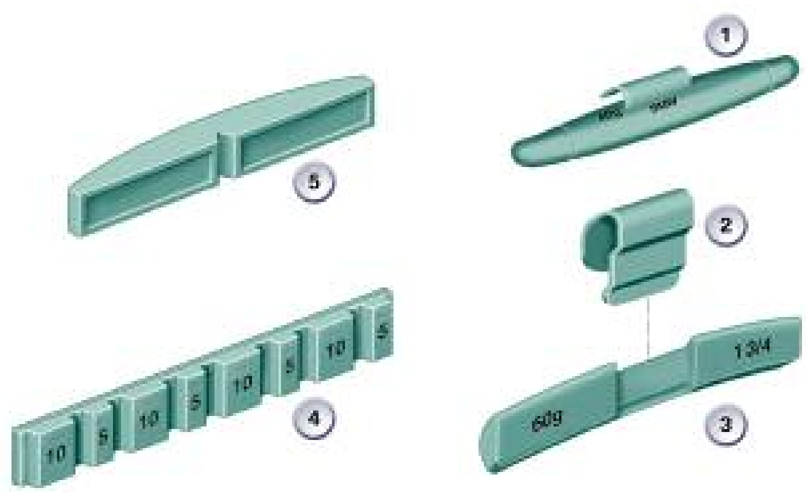
For technical reasons, a tire and wheel assembly cannot be “perfectly” balanced. Therefore, there is a maximum allowable residual imbalance which is acceptable for smooth running performance. The maximum values are as follows:

- Less than 15 grams (1/2 ounce) for residual static imbalance
- Less than 7.5 grams (1/4 ounce) per plane for residual dynamic imbalance

These values are usually the default values programmed into most wheel balancers. Depending upon the type of wheel balancing equipment used, these values can be altered (low or high). This is usually not recommended unless required due to a specific concern.

Balance Weights

In order to correct imbalances, balance weights must be used. Today there are many types of balance weights used doe to the different wheel rim styles in use. Most wheel weights are made from lead, but due to recent legislation regarding lead safety, many wheel weights available through the BMW parts system are be made from zinc.



Index	Explanation
1	One-piece clip-on (hammer-on) balance weight
2	Clip (clamp)
3	2-piece wheel weight for use with above clip (#2)
4	Adhesive Weight
5	Adhesive Weight

When installing wheel weights, be aware that there are various mounting procedures for different weights. Do not try to install incorrect wheel weights, cosmetic damage to the wheel may occur. Also, the weights may come loose and cause an unnecessary return visit.

For example, wheels which have a smooth rim flange should only use adhesive weights. Depending on the rim style and offset, the adhesive weights can be installed on the inner and/or outer area of the rim.

Clip on weights can only we used on steel wheels or aluminum wheels which have the necessary flange configuration. Two-pieces weight need to be installed with a special tool to prevent rim damage.

Weight Conversion

Wheel weights available from BMW are marked in grams and range in size from 5 to 60 grams. For the purposes of weight conversion, 1000 grams is equal to 2.2 pounds (or approximately 35 ounces). The chart below represents some conversion values.

Weight in Grams	Actual Weight Conversion (decimal ounces)	Comparable Wheel Weight Fractional Ounces (rounded off)
5 grams	0.176 ounces	1/4 ounce
7.5 grams	0.2645 ounces	1/4 ounce
10 grams	0.3527 ounces	1/4 ounce
12.5 grams	0.4409 ounces	1/2 ounce
15 grams	0.5291 ounces	1/2 ounce
17.5 grams	0.6172 ounces	1/2 ounce
20 grams	0.7054 ounces	3/4 ounce
22.5 grams	0.7936 ounces	3/4 ounce
25.0 grams	0.8818 ounces	3/4 ounce
27.5 grams	0.970 ounces	1 ounce
30 grams	1.058 ounces	1 ounce
32.5 grams	1.146 ounces	1 ounce
35 grams	1.234 ounces	1 1/4 ounce
40 grams	1.410 ounces	1 1/2 ounce
45 grams	1.587 ounces	1 1/2 ounce
50 grams	1.763 ounces	1 3/4 ounce
55 grams	1.940 ounces	2 ounces
60 grams	2.116 ounces	2 ounces

Runout

Another method for checking tire and wheel irregularities is by checking runout. Runout is an indication of an out-of-round condition or a variation in the projected movement of an object.

Runout can be checked using a dial indicator or the GSP97BMW Road Force Wheel Balancer. As far as wheel and tire assemblies are concerned, radial and lateral runout can be checked on the wheel and tire individually or as an assembly.

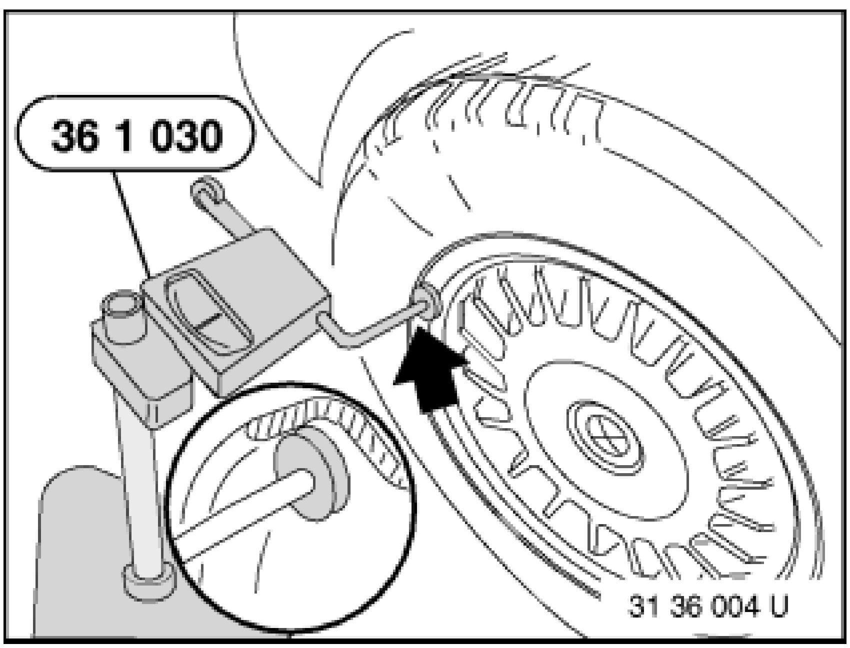
In order for the tire and wheel assembly to be optimized for smooth running, it is very important that the wheel (rim) is within specification. Once the tire is mounted to the rim, the tire will conform to the shape of the wheel. In other words, if the wheel is "egg-shaped", then the tire will be egg-shaped.

The wheel can be checked for lateral and radial runout using a dial-indicator.

Wheel Runout

When checking for radial runout on a wheel rim, the maximum specification is 1.1 mm for one-piece aluminum wheels. The radial runout should be checked on both bead seating areas. The most accurate method for checking radial runout on a wheel is to dismount the tire. However, if the wheel has a sufficient flange area, the radial runout can be measured as shown below.

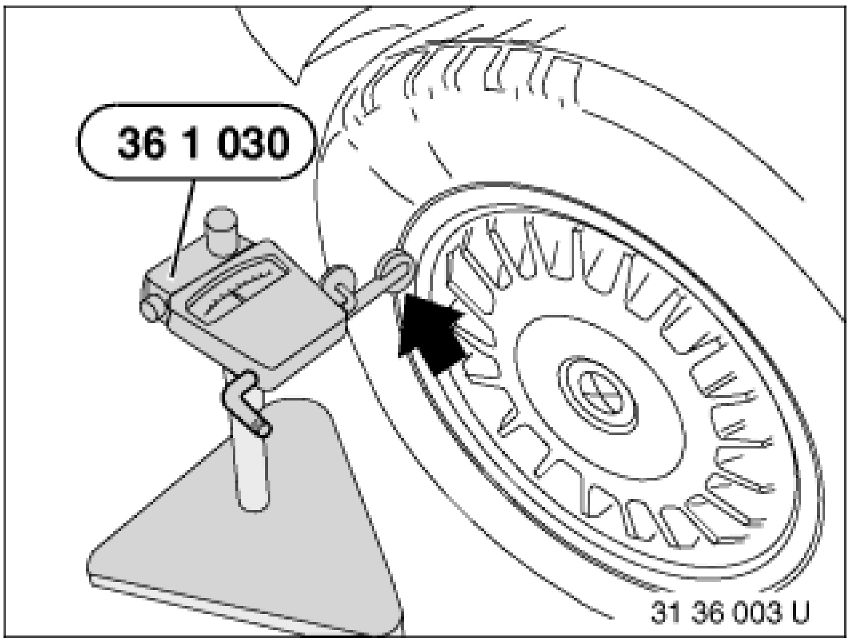
Note: Always check the runout specifications in Web TIS for the most accurate specification.



Excessive radial runout can caused conditions similar to a static imbalance. Radial force variations are also affected.

Lateral Runout (Rim)

The maximum lateral (axial) runout on a one-piece aluminum wheel is 1.3 mm. This can also be checked using a dial indicator as shown below. Refer to Technical Data and Repair Instructions in Group 36 for more information on checking wheel and tire runout.



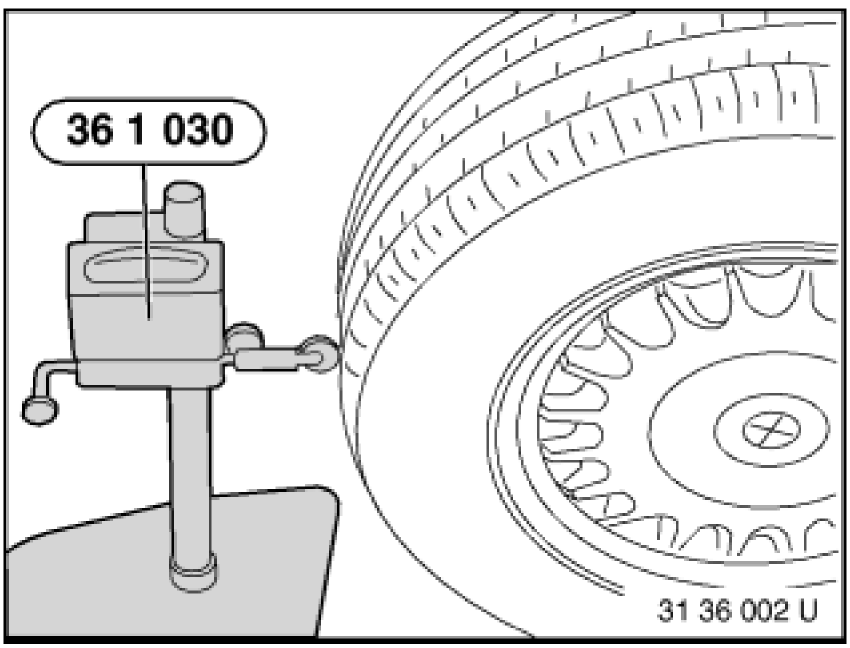
Tire Runout

Once the tire has been mounted to the wheel, tire runout can be checked radially and laterally (axially). This is an "unloaded" measurement which does not take into account radial force variation (or lateral force variation). Radial force variations can only be measured when the tire is loaded which is only possible using the GSP97BMW wheel balancer.

Radial Runout (Tire)

On a tire mounted on a one-piece aluminum wheel, the maximum radial runout is 1.1mm. The tire and wheel assembly should be mounted on a "spin-type" balancer or on the vehicle. Be aware that any wheel bearing or hub irregularities may affect this measurement. Be sure the check for wheel bearing play or hub runout.

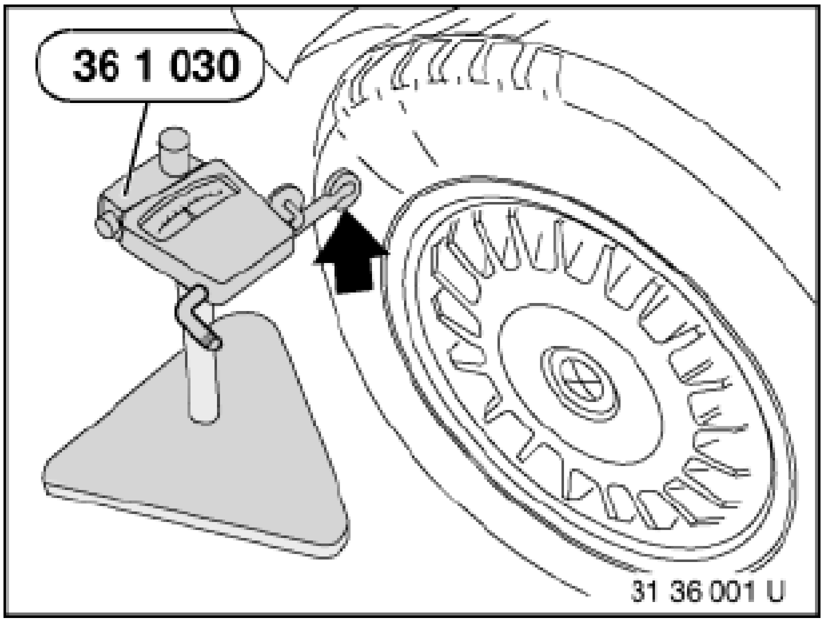
Note: Refer to Technical Data and Repair Instructions in Group 36 for more information on checking wheel and tire runout.



Lateral (Axial) Runout

Lateral runout measurements are an indication of possible broken belts in the tire. Aside from possible vibration issues, excessive lateral runout can cause a pull to one side. The maximum allowable lateral (axial) runout is 1.3 mm.

Note: Refer to Technical Data and Repair Instructions in Group 36 for more information on checking wheel and tire runout.



Component Runout

In addition to tires and wheels, there are other components which can contribute to vibration issues. Wheel bearings, hub assemblies and rotors should be checked for excessive play and runout.

Radial Force Variation

Radial force variations are caused by non-uniform stiffness in the tire sidewall. This variation can be best illustrated by imagining a series of springs around the circumference of the tire sidewall. If these “springs” were of equal force, the tire would roll evenly across the road surface when under load. However, if one or more of these springs were “stiffer” than the rest, the tire would not roll evenly. This would cause a noticeable vibration.

Index	Explanation	Index	Explanation
1	“Soft spots” in the tire sidewall	2	“Hard spots” in the tire sidewall

The causes of radial force fluctuation lie in the manufacturing and processing of the many different components in the tire. Components such as casing plies, belt plies and contact surfaces, etc. are combined in a tire press to make the tire blank.

Manufacturing and assembly differences arise during this process. If the differences are too large, harder and softer spots occur along the tire periphery. As a result, the tire does not flex evenly around the entire circumference.

When radial force fluctuations occur, this will have the same effect as a static imbalance. However, tire irregularities not only cause steering wheel wobble and vibrations, they also contribute to noises such as drumming, rumbling and jolting.

Radial force variations cannot be detected by standard wheel balancing equipment. This is due to the fact that standard wheel balancing equipment only measures the tire and wheel assembly in an “unloaded” state. When a tire and wheel assembly is dynamically balanced, this does not mean the the radial force variation is within specification.

Also, checking the radial runout of the tire (when unloaded) does not give and indication of radial force fluctuations. The only method to accurately check for radial force variations is to use the GSP97BMW wheel balancer.

The GSP97BMW wheel balancer uses a load roller assembly to apply pressure to the tire and wheel assembly to simulate “on the road” conditions. The radial force variation is calculated during this process.

Lateral as well as radial force fluctuations occur. These can be traced through the side-ways wobble of the wheel. Lateral means sideways. Lateral force fluctuations have less of an effect on harmonics than radial force fluctuations.

Tire which have excessive radial force variations must be replaced. However, tires which have small amounts of radial force fluctuations can be optimized by using the Hunter GSP97BMW Road Force Wheel Balancer. (This will be covered in more detail later in this training course).

Vibration Diagnosis

Vibration, by definition is a recurring motion which is referenced to a central position. In the case of a tire and wheel assembly, a wheel with excessive radial runout rotates around a fixed central point (wheel bearing). If the wheel is somewhat “egg-shaped”, the tire will conform to this shape. When traveling on the road, the tire assembly will cause a vibration at a frequency proportional to road speed. For example, the vibration frequency will increase with road speed.

In automotive applications, vibrations can be classified into two basic categories:

- Forced Vibrations - A forced vibration is caused by an object which is rotating. An example of forced vibration is any engine driven component, the wheel and tire assemblies or any electric motors.
- Free Vibration - This is usually caused by an irregularity in the road surface. A pothole, crack or expansion joint in the roadway can cause a momentary jolt which stimulates an oscillation. This oscillation can affect suspension components, sheet metal in the body, exhaust system components or the steering wheel. The notable characteristic of this type of vibration is that the vibration (or noise) dissipates quickly. This type of vibration is not a common as a forced vibration.

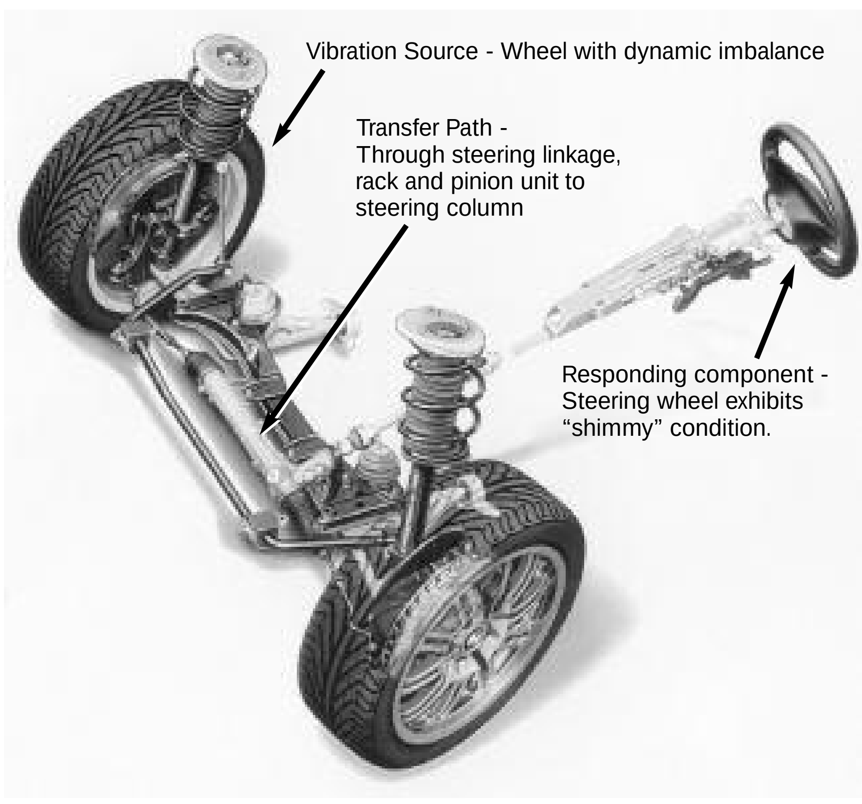
When diagnosing forced vibrations, there are some helpful terms which pertain to how to classify the frequency or intensity of the vibration. These terms include:

- Cycle - A cycle is an event or disturbance. Using an example of a static imbalance, every time the imbalance creates a vibration, this is considered one cycle.
- Frequency - The common unit of measurement for frequency is Hertz (Hz). Hertz indicates how many cycles per second an event occurs. Therefore, an event that occurs at a rate of 50 cycles per second is otherwise known as 50 Hertz.
- Amplitude - The intensity or harshness level of a vibration.
- Natural Frequency - This is the frequency at which a given object will vibrate most easily. For example, a tuning fork will vibrate when struck at a certain frequency. This will be very consistent. A vehicle chassis can vibrate at a rate of 10 to 50 Hz. Some of the factors that contribute to the natural frequency are the type of suspension, the tires and the weight of the vehicle.

When diagnosing vibration complaints, there are three basic components of a vibration which should be considered. Not all vibrations are caused by imbalanced wheel and tire assemblies. Some of these vibrations could originate from engine, flywheel or driveline irregularities.

The three components of a vibration are as follows:

- Source - The vibration source, usually pertains to the rotating component. This includes tire and wheel assemblies, engines or engine driven accessories. Sometimes, the source is not the root cause of the complaint. For example, some engine have characteristic vibrations which should be dampened by the engine mounts. Therefore, a defective engine mount can be the root cause, not the engine itself.
- Transfer Path - Transfer path is the pathway between the source and the responding component. For example, the engine mount can be considered, the transfer path. As given in the example above, the transfer path must be considered during the diagnosis of a “rough” running engine.   Other examples of transfer paths include; the center support bearing on the driveshaft, the strut assemblies, transmission mount or the steering column.
- Responding Component - The responding component is the item that the driver notices. For example, a dynamic imbalance on one of the front wheels would cause a steering wheel vibration. So, in this case, the steering wheel is the responding component.

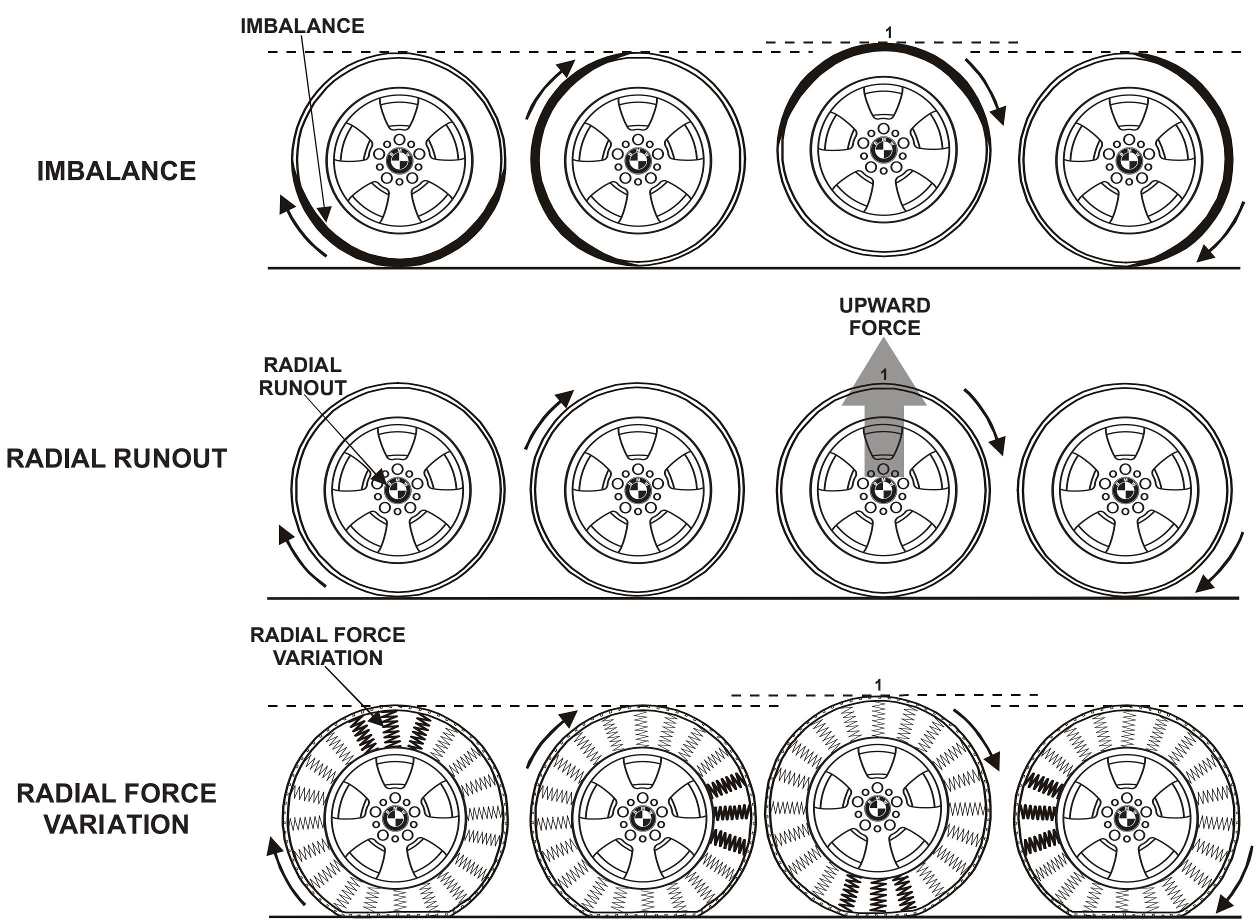


Harmonics

Harmonics refers to the number of occurrences per revolution. They are classified as First Order(R1H), Second Order (R2H) and Third Order (R3H) harmonics. The complete spectrum of harmonics can be measured from R1H through R15H, however this requires special equipment. For the purposes of vibration diagnosis in a workshop environment, the GSP97BMW Road Force Wheel balancer is only capable of R1H through R4H. The major source of concerns regarding vibration occur in R1H through R3H range.

First Order Harmonics

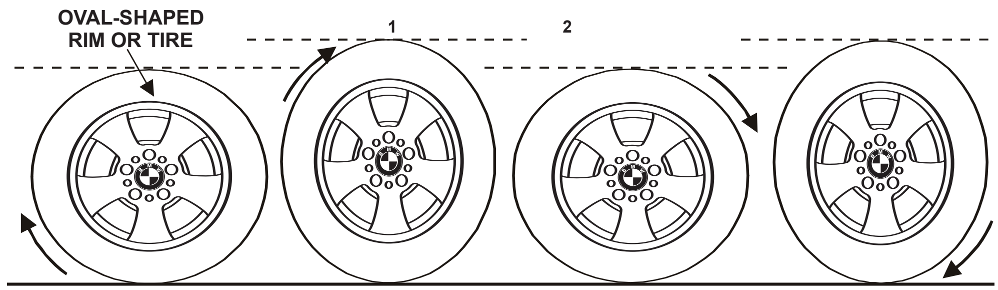
Harmonics in the first order occur once per revolution. An example of this would be a wheel with a static imbalance or excessive radial force variation. Imagine a tire with a "hard spot" rotating on a vehicle. The hard spot would have an effect only once per revolution. A tire or wheel with an excessive "unloaded" radial runout can also influence first order harmonics.



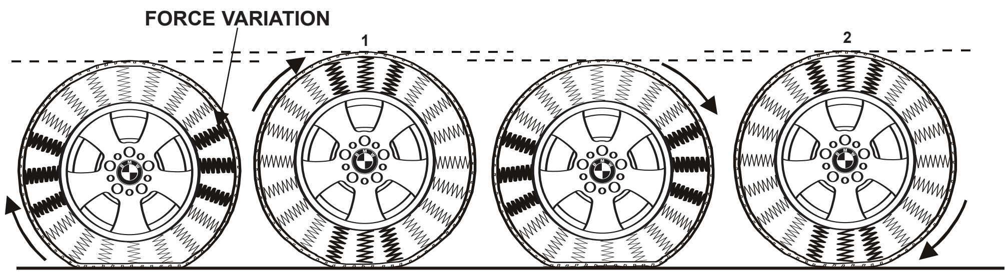
Second Order Harmonics

Second Order vibrations occur twice per revolution. For example, a tire which is “egg-shaped” would have two occurrences per revolution. This can be caused by tire and/or wheels which excessive radial runout. Also, loaded tires with excessive radial force variation (RFV) can cause 2nd order harmonics.

RADIAL RUNOUT



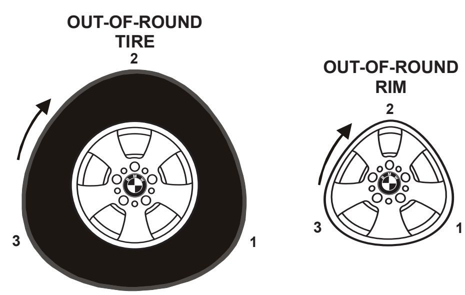
RADIAL FORCE VARIATION



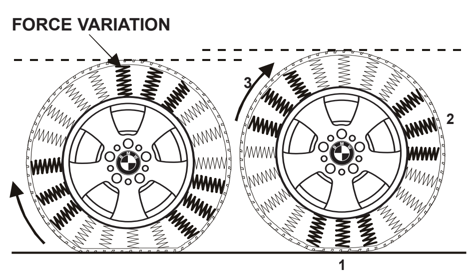
Third Order Harmonics

Harmonics in the third order occurs 3 times per revolution. Damaged wheels with excessive radial runout (triangular shaped) can cause this condition. Tires which are “flat-spotted” in multiple locations can show up during the Road Force balancing procedures. Usually, 3rd order harmonics are caused by damaged wheel assemblies.

RADIAL RUNOUT



RADIAL FORCE VARIATION



Tips on using the GSP9700 Wheel Balancer

The GSP 9700 BMW Road Force Wheel Balancer is capable of solving many vibration issues related to tire and wheel assemblies. However, certain concerns must be observed to get the most out of this equipment.

The following is a list of hints and tips to ensure accurate results:

- Tires should be warmed up to remove temporary flat spots prior to balancing. For example, of a vehicle is left overnight for testing, it is possible to have temporary flat spots on the tire. This would show up as excessive radial force variation. Always warm up the tires by road testing for a least 5-10 minutes at highway speed.
- Verify that the wheel is mounted on the wheel balancer properly. The balancer has a “centering check” feature if needed.
- Use the proper mounting hardware for the balancer. Use only the specified cones and adapters provided by the manufacturer.
- BMW wheels are “hub-centric”. This means that the primary reference for the wheel centering is the hub. Use of the improper wheel with excessive hub tolerance can result in an vibration which is not correctable.
- Tire and wheel assembly must be free of debris. Mud and rocks should be removed from the tire tread before balancing.
- If it is not possible to measure the runout on the bead seating area of a wheel due to wheel design, then the tire should be removed from the rim.
- Do not replace a tire based on the radial force measurements alone. Use the Force Matching and Matchmaker features of the GSP97BMW Wheel balancer to optimize the tire and wheel assemblies and reduce vibration. There is no set specification for Road Force which will condemn the tire.
- Always be sure to check for correct tire mounting. If the bead of the tire in not seated correctly, the Road Force measurements may be affected. When mounting the tire to the wheel, be sure to use sufficient lubrication. Do not use silicone, this could cause the tire and wheel to slip on the rim during hard braking.
- Make sure that the tire is inflated to the correct specification as per manufacturers guidelines. Check the b-pillar inflation placard for exact tire pressure.
- Bure sure to keep the wheel balancer maintained in proper working order. Clean cones, adapters and balancer shaft according to maintenance schedule. Replace any damaged accessories with Hunter approved components.
- Periodically perform calibration checks on the wheel balancer to achieve the most accurate and consistent results.

NOTES PAGE

Workshop Exercise - Road Force Balancing

Go to the "calibration screen" and perform calibration.

Mount a designated tire and wheel assembly using proper procedures.

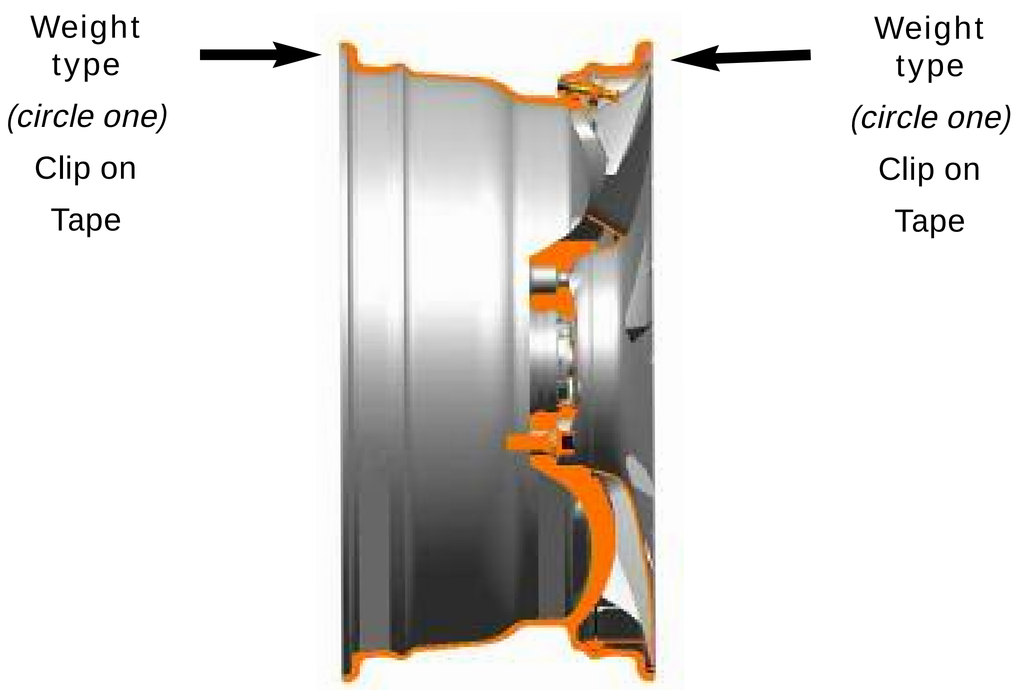
Which cone (adapter) should be used on BMW wheels? (and why?)

Perform "centering check" and adjust as necessary.

Once the "centering check" is complete access the "balance mode" using the soft keys.

Select tire configuration (P, SUV, LT etc.) using the control knob. Make sure the load roller is enabled.

Enter the wheel weight configuration and complete the chart below:



Workshop Exercise - Road Force Balancing

Continue by entering rim dimensions using the "dataset" arms.

Check and adjust tire pressure.

Where can the correct tire pressure specifications be found?

____

____

____

Why is it important to set the tire assembly to correct pressure?

____

____

____

Lower the hood and proceed with balancing procedure. Record results below:

Road Force ______ lbs

Weight needed

______gr

Weight needed

______gr

Workshop Exercise - Road Force Balancing

Install needed weight and re-check.

Remove weight and re-install using the "Split Spoke" feature. Also, use the servo-aided weight installation feature.

Re-check balance.

What does the "road force" number indicate?

Is there a specific specification for road force? NO

Continue with balancing procedure on additional tire assemblies (4) using the "StraightTrak®" feature.

After checking all 4 tires using the "StraightTrak®" feature, select the "vehicle Plan View" and note the recommended tire placement.

Select all of the possible placements, such as "Least Pull", "Least Vibration" and "Alternate Placements".

Which tire (tag number) has the most road force?

Is there anything that seems consistent regarding the tire with the most road force?

Workshop Exercise - Road Force Balancing

Install a bare rim assembly on the balancer and perform the runout measurement.

What is the maximum runout on the left and right tire bead?

Does this rim assembly have any excessive runout or harmonics? (if so, what are they)

Is this rim a candidate for “Force Matching”?

When would it be necessary to measure the runout on a bare rim?

Is it possible to measure rim runout with a tire installed?

Classroom Exercise - Review Questions

1. What is the difference between a static and a dynamic imbalance?

2. How are BMW wheels centered on the vehicle (hub or lug-centric)? Explain answer.

3. Why is the “loaded” radial runout measurement of a tire considered more conclusive than an “unloaded” radial runout measurement?

4. What is meant by residual imbalance? What are the maximum thresholds for residual imbalance?

5. What is “Force Matching”?

Classroom Exercise - Review Questions

6. What are the specifications for “maximum road force” on a BMW?

7. When balancing tires on a vehicle, should the vehicle be driven to warm up the tires or should the tires be balanced cold? Explain answer.

8. What is the purpose of the “Matchmaker” (feature on the GSP97BMW?

9. Where can the correct tire inflation pressures be found?

10. What is the purpose of the “StraightTrak® LFM” feature on the GSP97BMW?