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TECHNICAL BULLETIN No. 1

BRAKE JUDDER AND "WARPED" DISCS

Introduction

Brake judder is experienced by the car driver as a regular pulsing of the brake pedal and / or side to side vibration of the steering wheel and / or car body vibration. Not surprisingly, these symptoms frequently result in complaints about "warped" brake discs.

In the vast majority of cases the fault being described is a condition call **Disc Thickness Variation (DTV),** and the assumption is that the discs have either been manufactured incorrectly or have developed a fault because of a quality problem. However, in the vast majority of cases, the *actual* underlying causes of DTV have nothing to do with disc manufacture or quality and are one of the most frequently misunderstood aspects of automotive braking.

What is DTV and why does it cause vibration?

DTV is the result of a brake disc **developing** a lack of parallelism between its inboard and outboard braking surfaces, after a short period in service. The word "developing" is important here because it means that the disc was within tolerance when it was first fitted.

When the brakes are applied on a car with a disc that has developed a DTV problem the pads will encounter thicker and thinner areas on the braking surface in rapid succession. This will cause the pads to move rapidly backwards and forwards, transmitting pulses through the caliper pistons, via the brake fluid to the brake pedal. This may also cause the steering wheel and / or car body vibration depending on whether the affected disc(s) are at the front or the rear.

Causes of DTV

In order of their frequency of occurrence - the causes of DTV are:-

- Disc fitment errors.
- Driver error or abuse.
- Manufacturing fault.

If the causes of DTV are understood it becomes a simple matter to eliminate brake judder problems by following a few simple rules.

DTV – Cause No. 1:- Failure to ensure that the mounting surface of the brake disc and the hub are perfectly clean prior to disc fitment.

By far the most common cause of DTV is the failure to properly clean the mounting surface of the disc and the vehicle's hub. The axial run out caused by the smallest fragment of dirt or rust scale, caught between the mating surface of the disc and hub, is magnified as you move towards the outside of the disc. To put this in perspective, a single spec of rust scale measuring only 0.05mm in thickness (diameter of a human hair) trapped between the mounting surface of the disc and the hub can easily cause the axial run out to exceed 0.1mm when measured at the centre of the braking surface. Even this degree of run out can be enough to start a process that will lead to brake judder and irreversible brake disc damage over time.

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To understand why brake judder and disc damage occurs, it is necessary to understand the two principle mechanisms that operate between the brake pad material and the brake disc when the brakes are applied. All brake pads rely on a combination of **abrasion** and **adhesion** in order to generate friction (Semi-metallic formulations commonly used for standard road pads rely more heavily on abrasion whereas fast road and race formulations generally rely more heavily on adhesion).

Abrasion - In simple terms friction is generated by the mechanical gripping and breaking off of opposing pad and disc materials at a molecular level, the materials slowly wearing each other away in the process.

Adhesion – In this process some of the pad material is transferred to the braking surface of the disc, where it forms a thin, uniform layer of friction material. This means you now have the friction material of the pad coming in contact with identical friction material that has been deposited on the disc surface. Under braking the molecular bonds between the two are constantly breaking and reforming with friction material crossing the pad/disc interface in both directions, generating friction in the process.

If the above case is considered where a new brake disc has been fitted carelessly and leaves the workshop with a small degree of run out (say 0.1mm). On many vehicles this amount of run out will not cause brake judder and will not be noticed by the vehicle driver. However, after a period of between 500 and 5,000 miles of driving the disc starts to develop a DTV problem and the brakes begin to judder. This becomes progressively worse, leading to the impression that the disc has "warped". However, all brake discs, regardless of quality, would have developed the same DTV - for the following reasons.

When the brakes are applied the pads will first come into contact with the disc at the point of maximum run out. The **abrasive** properties of the pads will cause the disc to wear fastest at this point causing DTV and brake judder to develop. The **adhesive** properties cause the pads to deposit more friction material onto the surface of the disc at the point of maximum run out. This unequal distribution of friction material on the brake surface creates a difference in friction coefficient at this point, causing further brake judder and accelerating the formation of DTV.

Once DTV has developed the brake disc will start to heat unevenly, with the high spots becoming very hot compared to the rest of the disc. If the temperature at these high spots exceeds 650 deg. C. , the cast iron changes structurally and transforms into an immensely hard substance called Cementite. The disc is now composed of materials of different hardness, causing the disc to wear unevenly, resulting in the DTV becoming progressively worse. This whole process will take between 500 and 5000 miles to develop, which is why the vehicle driver will often return to the garage complaining of brake judder after several months.

It should be noted that skimming the discs may not solve the problem. If Cementite has formed and penetrated deep into the disc surface, skimming the disc will not remove it and the brake judder will return after a period of time as the disc continues to wear unevenly. The only solution is to replace both discs and pads.

DTV Cause No. 2: - Improper bedding in of new discs and pads.

After fitting a new set of pads (or pads and discs) it is important to bed in both the pads and discs by driving and braking in a moderate fashion for the first 500 miles or so, to ensure that the brake temperatures do not rise to excessive levels. This will encourage an even and consistent layer of friction material to be transferred to the disc surface resulting in a constant coefficient of friction around the whole circumference of the disc and even heating of the disc surface. Failure to do this carries the risk of uneven or spot transfer of material from the pad to the disc, leading to uneven heating of the discs. This may cause distortion of the disc which will lead to the formation of DTV and brake judder.

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DTV Cause No. 3: - Severe overheating of brake discs.

A brake disc typically undergoes about 100,000 heating and cooling cycles during its lifetime. A medium sized car stopping from 50mph will generate enough heat within the braking system to boil 2 litres of water in 3 seconds! The discs and pads are easily able to cope with this provided the driver knows how to use the brakes correctly, to avoid severe overheating of the discs.

Typical scenarios that cause overheated brake discs are an over reliance on the brakes (as opposed to utilising engine braking) on long steep descents and, more commonly, making several emergency brake applications in quick succession without allowing time for the discs to cool between stops. Apart from the possibility of inducing dangerous brake fade, disc temperature may increase to over 600 deg. C. at which point the cast iron will start changing into Cementite (see above). This leads to DTV formation and brake judder.

The message is simple – the brakes can be used as hard as you like when necessary BUT enough time must be left between brake applications to allow the discs to cool.

DTV Cause No. 4: - Manufacturing faults.

With modern CNC manufacturing techniques and quality control procedures, it is extremely rare for discs to leave the factory with either DTV or Run Out (which will cause a DTV to develop) outside the specified tolerances. For this reason, the number of brake vibration problems caused by manufacturing errors is very low.

Rules for avoiding DTV

Development of DTV can be almost completely avoided by following the simple rules:-

- Ensure that both the mounting surface of the disc (usually the inside of the top hat) and the vehicle's hub are perfectly clean and free from rust scale or any other form of dirt or grease. The disc should be cleaned using a cloth and suitable solvent. The hub should be cleaned using a soft wire brush or emery paper, followed by wiping with a cloth and solvent until no trace of rust or other contamination remains.

- Once fitted the disc run out should be measured with a dial gauge before re-assembly of the caliper etc. If the run out exceeds 0.08mm the disc must be removed and the hub cleaned again. If the problem persists then the hub should be measured for run out using the dial gauge. Hub run out in excess of 0.04mm is likely to cause a problem and should be investigated.

- Always bed in new brake pads and discs according to the manufacturer's instructions.

- Avoid overheating the discs by inappropriate use of the brakes. Allowing disc temperatures to exceed 600 deg. C. risks destroying the discs and pads. Avoid continuous, consecutive heavy braking from high speed and utilise engine braking when making long steep descents.

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