The Development of Air-actuated Disc Brake Friction Materials for Heavy Commercial Vehicles

a report by

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Introduction

Commercial vehicles have been a crucial part of our industrial landscape for hundreds of years. From the first horse-drawn wagons to today's modern diesel-powered trucks, the movement of freight across the world remains key to our global economy.

While the drivetrains of heavy commercial vehicles have become ever more powerful and fuel-efficient, it is only in recent years that truck manufacturers have changed from using drum brakes on both front and rear axles to the use of modern disc brakes.

The development of friction brakes in motor vehicles began with the use of wood and leather as friction material. It was quickly recognised that these were no longer sufficient to meet the requirements of a modern truck or bus, and the development went from woven and rolled brake-band over pressed drum brake linings (blocks) finally to disc brake pads.

The use of disc brakes in commercial vehicles started (apart from a very few special application vehicles) in 1973. From this date, front axles of some coaches and travel buses could be equipped with hydraulic disc brakes by special request of the customer. The rear axles stayed with drum brakes.

With time, increasing numbers of trucks equipped with pneumatic (air) disc brakes came onto the market. The first real breakthrough occurred in 1996 when Mercedes-Benz announced that, on its ACTROS model, all axles were to be mounted with air disc brakes. Since then, a fast growing number of truck and trailer manufacturers have been offering their vehicles with air disc brakes.

Requirements concerning safety and economy lead to several challenges for the engineers developing disc brake pads for commercial vehicles including the safe attachment of the friction material to the shoe plate and a constant friction level from the first stop to under the most severe conditions of temperature, pressure and speed.

Solutions

Attachment

Friction pads consist of a highly-filled organic material moulded onto a steel plate. Besides high-shear forces, they are exposed to severe environmental conditions from low temperatures and corrosive environments, to temperatures in excess of 900°C. Therefore, a safe bonding between the two parts is of extreme importance to the safe operation of the brake system under all of these conditions. Pure adhesive bonding systems are often not sufficient and therefore the friction industry has found ways of using mechanical solutions to support the chemical bonding.

Using experience gained in sinter powder-metallurgy, a pure mechanical bonding system was developed that protects the brake shoe from interface corrosion and assures a safe connection between the plate and the friction pad even under the highest temperatures and stresses.

Green Friction

It is essential to have a high friction level, especially for trailer applications, when the pad is new, to guarantee the minimum deceleration required by law from the very first braking application. This problem was solved with a patent pending coating, which raises the green unbedded friction co-efficient to the required level, and assures a smooth and proportionate transition to the desired operating friction level.

Performance/Friction Stability

Over the years, dramatic changes in the parameters affecting braking performance have occurred. Vehicle speeds and acceleration have increased, as have vehicle loads and demands on handling. Friction stability under extremely high temperatures in case of misuse is essential. On the other hand, increasing numbers of commercial vehicles are fitted with an additional exhaust gas brake or retarder. As a consequence, low brake temperatures in cross-country traffic can lead to glazing of the pad surface, resulting in low friction level and low output from the brakes. Both demands must be met with one friction material.

The development of such custom-tailored engineered materials is the result of close co-operation between the friction material supplier and the brake-system and vehicle-system manufacturer, and especially between friction material compounders and test engineers. To select, combine and test the right material combination that fulfils today's demands is a sophisticated engineering process using the knowledge of the engineers assisted by carefully designed testing and computer modelling.

New raw materials, different combinations and improved manufacturing techniques, as well as the latest testing and measuring equipment to monitor the friction process, have contributed to a substantial improvement in the performance of brake pads over recent years.

Testing

During the development of a friction pad, most of the time and money is spent on testing new materials. This starts in the chemical and physical laboratories where, as well as other aspects, the compressibility of the pad is measured. This property correlates to the propensity for noise and disc cracking. The corresponding compressibility machine that has been developed has become the standard in the brake industry.

The next step is the testing on inertia dynamometers. Here, the friction properties such as friction co-efficient (μ) and its dependence on temperature, speed, and pressure and the wear of the pads are measured and optimised. By simulating vehicle speed and mass on a dynamometer it is possible to obtain test results without the disturbance of external influences. These tests are carried out with the original brakes and disc/hub. The current generation of truck dynamometers are able to simulate an axle weight of up to 16 tons, at a speed of 200km/h and 35.000nm torque. In addition, through the use of chambers connected to climate control systems, it is possible to vary the working environment in which the brake is running to simulate heat, cold and humidity as found under everyday driving conditions. This increases in importance as a tool to solve noise, vibration and harshness (NVH) issues that can occur as part of everyday use, especially when sophisticated electronics allow dynamometers to simulate both front and rear brakes in tandem.

The final confirmation for the selection of a friction pad is done in vehicle testing.

Testing of the new brake pads is carried out simultaneously by the friction, brake and vehicle manufacturer. In this way, the results can be cross-checked and compared, and the data analysed on a joint basis.

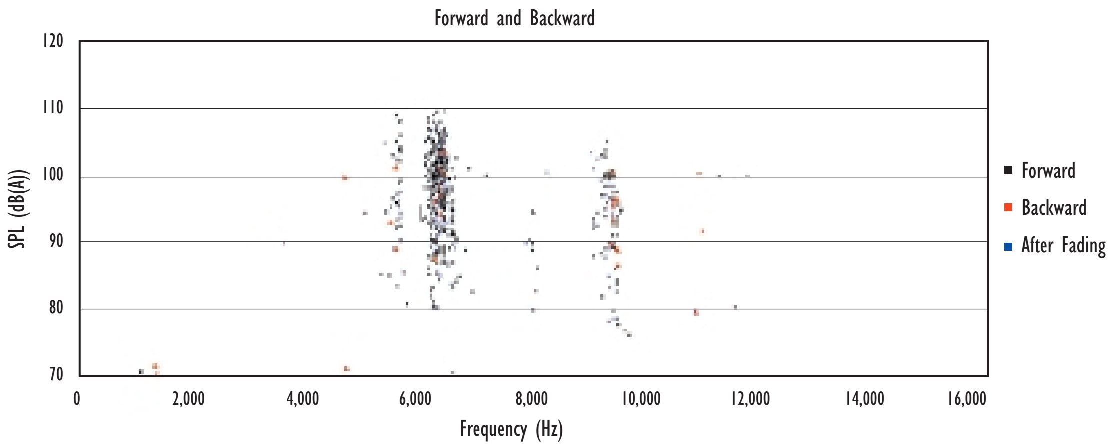
Test vehicles are fitted with electronic measuring devices to record all essential performance data. These are fed automatically into an on-board data acquisition system, which collates and analyses the figures and prints out the results. The newest versions combine data acquisition for performance and NVH testing.

Road tests are designed to monitor the performance of brake pads under all kinds of driving conditions – from endurance tests in cross country and city traffic to special tests on purpose-built test tracks or steep mountain passes. Prolonged braking under these conditions can generate temperatures of 900°C or more in the friction pad.

Noise, Vibration and Harshness Investigation

Significant attention in evaluating the brakes of today's cars is related to the improvement of noise behaviour. Very often, 50% of the engineering

Figure 1: Sound Pressure Level (SPL) Versus Squeal Frequency



budget is directly or indirectly dedicated to NVH investigation. Also, for commercial vehicle pads, this aspect of braking is becoming increasingly important.

Figure 2: Finite Element Analysis Squeal Model (Deformation at 3,500Hz)

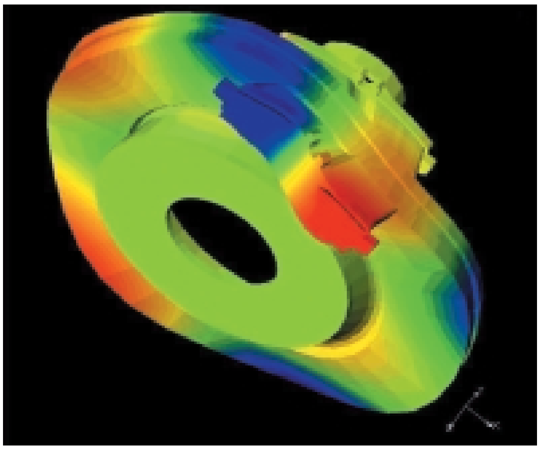


Figure 3: Uniform Temperature Distribution Simulated by Finite Element Analysis

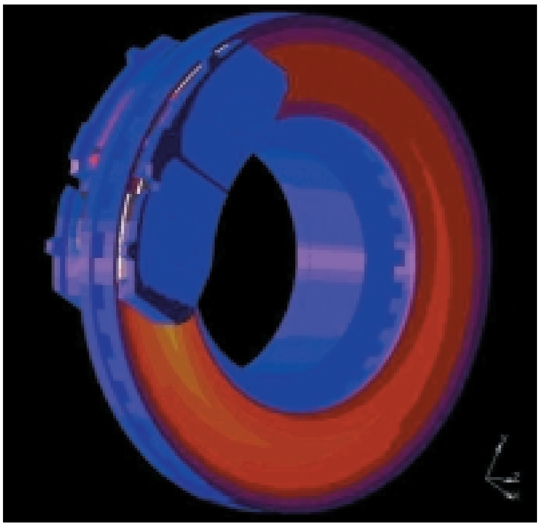
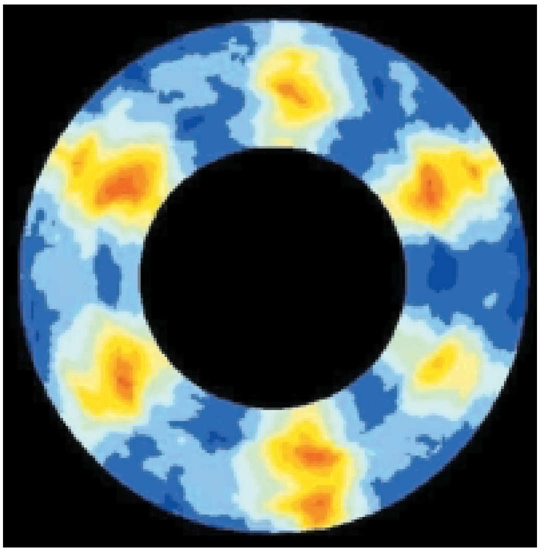


Figure 4: Non-uniform Temperature Distribution Measured by Thermal Imaging



Vehicle parts outside the brake strongly affect the NVH behaviour and, because of this, the related tests on a dynamometer have to include either the full axle or the brake corner in order to be representative. What has become the standard for passenger car and light truck noise testing, is now also available for heavy commercial vehicles, with the standard noise procedures being run on a dyno including the mounting of the full axle. Improvement actions can be tested in a 'clean' environment without the need for vehicle testing.

Standard tools for investigation of NVH problems, such as modal testing, laser vibrometer, etc., have been incorporated into test schedules, and also modelling of a brake system using finite element analysis is used in today's brake pad development. These models (see *Figures 2–4*) support the understanding of the NVH problems, especially the interaction of pad/disc and pad/brake, and the selection of the best friction material.

Disc Cracks

Disc brakes show significantly less fading than drum brakes and, as a result, there is the possibility that abuse leads to rotor cracking and therefore the design of the rotors is under permanent optimisation. However, the friction material also influences the tendency to cause rotor cracking. The knowledge about the relevant crack mechanism and the parameters of the friction material influencing this is the basis on which to analyse this phenomenon and to develop the best friction pads. A special procedure was developed, using finite element analysis and thermal imaging to predict the propensity of a pad for disc cracking without the otherwise usual long cracking test procedures.

This knowledge and these tools have made it possible to develop and improve new friction materials far quicker than in the past.

Outlook

Increasing legal restrictions concerning the use of raw materials requires a new generation of friction materials; the development of these 'green materials' has already led to the first pads being introduced into production for some applications.

Eventually, as new models are introduced, we should expect that our vehicles are braked by high performance, environmentally friendly friction materials. In this regard, commercial vehicle manufacturers no longer lag behind their colleagues in the passenger car industry. Indeed, in many ways, a modern commercial vehicle air disc brake system is at the cutting edge of vehicle braking technology. ■