Feature Article

Brake Test Systems

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For quality assurance and technical refinement of brakes, which are of course highly important for vehicle safety, the brake R&D engineering community makes extensive use of a variety of dedicated brake test systems. For example, a friction tester can evaluate wear-behaviour and friction coefficient of materials and is utilized for managing the production quality of such materials. An inertia type brake dynamometer is the defacto test machine used for doing fundamental R&D work on friction material and brake assemblies. A brake NVH dynamometer is a helpful tool for testing the noise, vibration and harshness (NVH) generated by brakes. For the inertia type brake NVH dynamometer, complete brake assemblies along with relevant suspension system and complete axle structure are subject to NVH measurements. On the chassis type brake NVH dynamometer, the complete vehicle in its original condition is used as the test specimen.

Introduction

A reliable brake is the most fundamental safety system of all vehicles. Even 2000 years ago Roman soldiers' chariots had a block brake incorporated. In order to manage the complex challenge of quality assurance and further technical refinement of vehicle brakes, the worldwide brake R&D engineering community makes extensive use of a variety of dedicated brake test systems. The most common brake test machines, used for investigating the basic brake's performance, power, wear, durability and NVH-behaviour are listed in Table 1. In this article, we introduce the brake test systems provided by HORIBA.

Friction Tester

One of the most violently worn parts of a vehicle are the brake pads or friction lining. In order to make sure that the end of line total brake system performance check completes with a positive result, it is most important that all individual components are refined to a high level of

Table 1 Brakes & Brake Components Test Systems

No.	Type	Test Subject	Test Sample	Test Result
1	Roller type brake dynamometer	Wheel brakes basic function test Service garage & inspections	Complete brake system mounted on fully operational vehicle. Test at low speed	Brake function
2	Roller type brake- & ABS function tester	Wheel brakes & ABS basic function test End of assembly Line	Complete brake system mounted on fully operational vehicle. Test at high speed	Brake function, ABS controls
3	Friction tester	Quality control for brake pads & friction linings	Friction material sample piece	Friction value, Friction material condition
4	Inertia-type brake dynamometer	R&D function test of a complete brake unit (drum or disc brake)	Corner module of brake pads, disc & calliper; or drum linings, shoes & cylinder	Friction value, Function of all parts, Wear & tear of all parts
5	Inertia type NVH brake dynamometer	R&D investigation on brake NVH (noise / vibration / harshness) checking for disturbing squeals, judder, creep & groan, etc.	Complete axle with brake pads, disc & calliper; or drum linings, shoes & cylinder	Brake function, Resonance vibrations
6	Chassis type NVH brake dynamometer	R&D investigation on brake NVH (noise / vibration / harshness) checking for disturbing squeals, judder, creep & groan, etc.	Complete vehicle including all parts of the original brake system (disc- or drum Brake)	Brake function, Resonance vibrations

R&D and produced at a dependable and stable quality.

The most important and common example for brake component testing is the conventional friction tester. The friction pairs (disc vs. pads / drum vs. shoes & lining) are the most critical wear and tear parts on each brake assembly. Depending on load cycles and driver habits, the typical service life time for friction pads is approx. 50,000 km meanwhile the rotor disc may last for 100,000 km.

Even more important than its wear-behaviour, is the parts performance with regard to a stable friction coefficient "μ" irrespective of speed and brake temperature. Normal organic friction material guarantees a friction coefficient μ of 0.2 to 0.4. For easy and repeatable determination of the friction material μ-value and batch control during high volume pad- and lining production, the friction μ-tester is found to be an ideal machine.

Figure 1 shows a friction μ-tester. A friction material sample of cube-shaped (within 50 × 50 × 15 mm) is mounted on a typical disc & calliper or drum brake assembly. This test brake is adapted to a rotating dynamometer shaft. Other test conditions are as follows:

- Dynamometer speed: 15 to 1500 rpm (variable, driven with an AC motor of up to 50 kW)
- Brake control: with a servo-hydraulic actuator
- Friction measurement: with Prony-type torque-meter (T_{Brake})
- Test cycle: automatically controlled by a computer, digital data acquired during cycle
- Items to be recorded: test speed (rpm), braking pressure (bar) and temperature (°C)
- Calculation of friction coefficient:
  $\mu\ (-) = T_{Brake} / 2 \times R_{Friction\text{-}Radius} \times A_{Piston} \times P_{Hydraulic}$

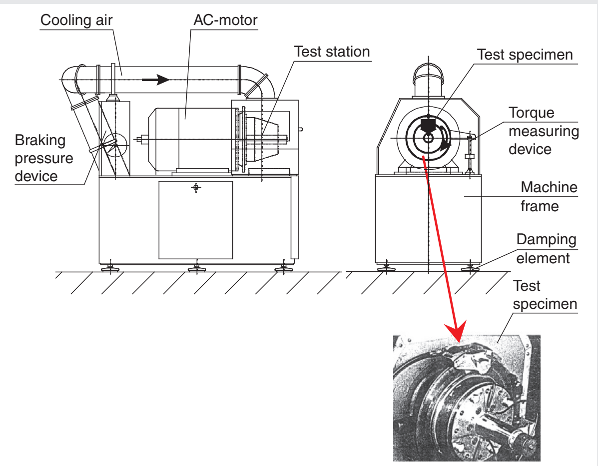

Figure 1 Friction Tester

- Data recording and result evaluation: performed automatically, e.g. by Excel-macro

The friction tester result shows the friction coefficient μ as a function of rubbing speed, brake pad temperature and nominal applied pressure per cm^2.

Inertia Type Brake Dynamometer

An inertia type brake dynamometer is the de facto test machine used for doing fundamental R&D-work on friction material and brake assemblies, by manufacturers of the friction material, brake systems and vehicle manufacturers. Figure 2 shows an example of inertia type brake dynamometer. A complete brake module, consisting of original disc, pads and calliper, or brake-drum, shoe and lining are mounted as a test-sample. For a conventional Inertia dynamometer test, the brake stator (all non rotating parts) will be adapted to the "prony-type" tail stock. Meanwhile the brake-rotor (disc or drum) are adapted to the rotating dynamometer main shaft.

With this machine a complete brake can be exposed to real life load cycles, and repeated as often as necessary. A typical test schedule comprises as many as 500 to 5000 times of stop and drag brake applications, which are performed by a dedicated control and automation system. A 200 kW main drive is used to accelerate the machine to initial speed, which lies within the range of 0 to 3000 rpm, before the test brake is applied. The kinetic energy for simulating the vehicle inertia mass is supplied by a set of flywheels. Accurate electrical inertia simulation is superimposed onto the flywheels inertia. Thus we are able to achieve a simulation accuracy of within +/-1 % of gross vehicle weight (GVW). Typical test conditions are as follows:

- Initial speed of dynamometer: 0 to 3000 rpm
- Items to be recorded: All important parameters, e.g. test speed (rpm), pressure ($P_{Hydraulic}$), braking torque (T_{Brake}) and Temperatures (°C)
- Calculation of friction coefficient:
  $\mu = T_{Brake} / 2 \times R_{Friction} \times P_{Hydraulic} \times A_{Piston}$
- Data recording and result evaluation: performed automatically, e.g. by Excel-macro

A full size inertia brake dynamometer allows accurate measuring of all physical parameters of the brake, while exposing it to dynamic real life load cycles.

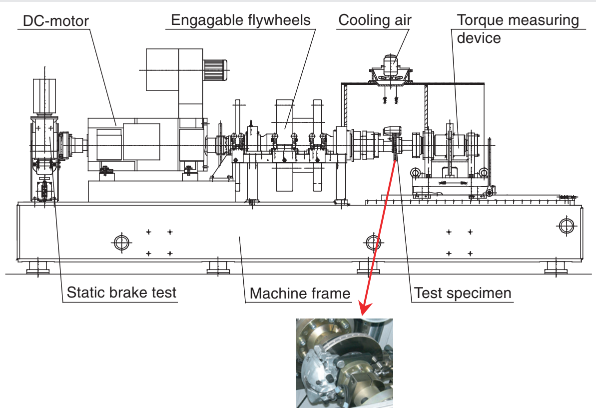

Figure 2 Inertia Type Brake Dynamometer

Brake-NVH Dynamometer

The extremely high power and speed potential of modern vehicles requires high energy braking systems to be installed inside rather small wheels and rims. At the same time the non-suspended axle mass should be reduced, or at least remain constant, for the sake of good suspension performance. Thus the specific technical requirements on the basic braking capability have increased drastically. The challenge is to deliver a light-weight, but high power brake. This trend has caused the brakes to become more susceptible to noise and vibration problems, including brake squeal (1 to 15 kHz) or brake judder (1 to 100 Hz).

Combined with the very competitive market and customer demands, especially on new car warranty periods exceeding 24 months, the cost for fixing brake related noise, vibration and harshness (NVH) problems has increased drastically. Quite often brake disc and pads are completely replaced, e.g. simply in order to cure the early morning squealing noise. The friction material and brake manufacturers have made great efforts in order to find dependable solutions for suppressing such brake NVH problems. A brake NVH dynamometer is a helpful tool for doing this challenging R&D work.

Inertia Type Brake-NVH Dynamometer System

The inertia type brake NVH dynamometer follows the basic idea of a conventional inertia brake tester as described above(Figure 3). To investigate the multiple vibrations which are generated by dry friction brakes, as a minimum the complete brake assembly along with relevant suspension system, or even better including the complete axle structure mounted to the testing station, shall be subject to NVH measurements. To accommodate such big test samples, an extra large noise insulated test chamber, along with an inline brake torque measuring device is required. A supplementary climatic air handling unit also allows measurements of the brakes NVH behaviour at variable temperature and humidity condition.

A multi channel, high speed PC based data acquisition and FFT analyzer enables the NVH engineers to pick up and characterize all audible brake noise, as well as lower frequency body noise which is generated by the dry friction pairs and conducted into the vehicles axle and body structures. Dedicated NVH test cycles target typical NVH problem zones regarding speed, braking pressure and temperature.

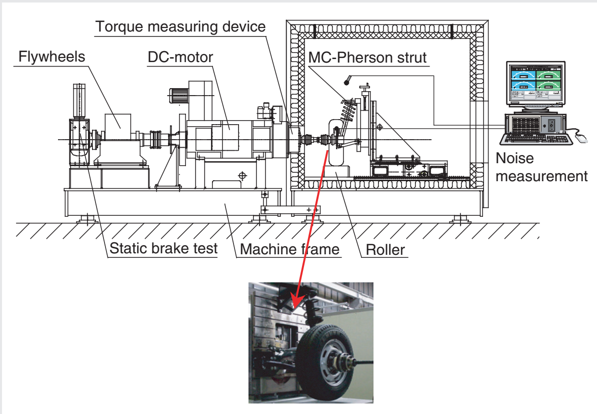

Figure 3 Inertia Type Brake NVH Dynamometer

Chassis Type Brake NVH Dynamometer

In general the target for R&D work by means of a dynamometer system is to get as close as possible to real life operating conditions, through simulation of all relevant engineering parameters. At the same time the disadvantages of on-road testing, especially the higher cost and limited repeatability due to changing traffic conditions can be overcome. The most efficient approach in order to reach this target is to use a chassis type brake NVH dynamometer.

Again, the basic idea is copied from the inertia type brake tester. But on the chassis type brake dynamometer, the complete vehicle in original condition is used as the test sample. The dynamometer is installed inside a large size chamber with heavy thermo-acoustic insulation and a corresponding climatic air conditioner unit. The dynamometer itself is typically a 48" single roller with approximately 300 kW main drive, for accurate control of variable speeds, torques and vehicle inertia (Figure 4).

Normally the vehicle engine is not running and the test brake is actuated either by a robot driver, or directly by servo hydraulic controls. A special, automated NVH test matrix along with dedicated NVH measuring system are prepared for screening all kind of operating conditions including the brake related noise and vibrations problem zones. Using this powerful machine, a 3 days automatic test cycle, run during the weekend, delivers a more useful NVH test result, compared to that a one week, stressful on road test can provide. All measured data are automatically processed for numeric and graphic presentation.

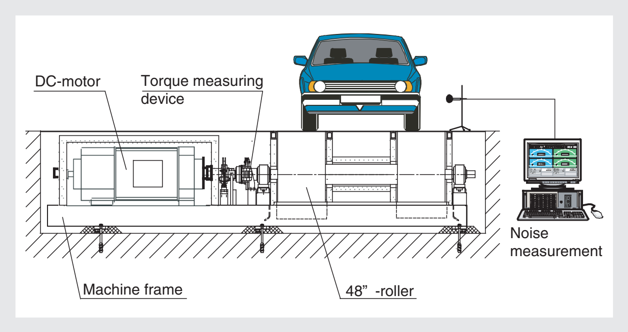

Figure 4 Chassis Type Brake NVH Dynamometer

Conclusion

Generally, conventional vehicles use the friction type brakes for which the wear of the related parts is inevitable. This type of brake transforms the kinetic energy into thermal energy when braking. Recently, regenerative brakes which are applied to hybrid electric vehicles is paid much attention as it can re-use the kinetic energy by converting the electric energy and contributes to improvement of fuel economy. Like this, the future trend of braking technologies can be drastically changed as well as other automotive technologies. For the brake test systems, advanced hardware and simulation tools for testing such new systems will be also developed.

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