You will find the figures mentioned in this article in the German issue of ATZ 9/2001 beginning on page 792.

Testen wie auf der Straße
Auswechselbare Laufrollenoberflächen
für NVH Rollenprüfstandsanlagen

Almost Like On-Road Testing

Changeable Roller Surfaces for NVH Chassis Dynamometer Systems

In addition to simulating free-field conditions, the factors that are becoming more and more important in NVH (Noise, Vibration, Harshness) chassis dynamometers for optimising vehicle acoustic properties are the surface of the dynamometer roller itself and therefore the ability to simulate real road surfaces. As a test system supplier, AVL Zöllner has developed new, changeable shell elements which are designed both for extreme axle loads and high speeds. This significantly extends the application range of an NVH chassis dynamometer system.

By Jörg Haeder and Bernd Haefke

1 Introduction

Apart from compliance with the existing statutory provisions on air pollution reduction, reducing traffic noise is now increasingly becoming a critical task in environmental protection in the transport sector.

The significant increase in passenger car and truck registrations over the next decades anticipated by the statistics and forecasts (the Shell Study [1] shows a 25 % increase from 1996 to 2020 for passenger car registrations in Germany) makes the reduction of noise emissions from all vehicles an absolute necessity.

Not only will there be more vehicles travelling more miles, but also improvements in drive power will continue to progress.

The reduction of interior and exterior noise is therefore an essential contribution to environmental protection as well as to increasing driving comfort.

It will become more and more imperative for manufacturers and the supplier industry to reduce both drive noise and especially also tyre-road noise – depending on road surface and speed. Tougher legal requirements will define the development investment needed for the future.

2 Requirements for Future Roller Surfaces

In order to be able to meet both legislation and customer demands, acoustic chassis dynamometer operators already demand considerably more of their roller surfaces. The conventional roller surface coating – usually a sprayed-on metal coating – with its very limited application options has long been inadequate to meet the needs of all applications.

What is called for is the simulation of roads – and in particular their surfaces – on the surface of dynamometer rollers. This would then mean greater comparability with road tests, and more accurate predictions could be made from test bed measurements on how vehicles will perform on the road in terms of noise.

Operators of acoustic chassis dynamometers now need several different surfaces for their test sequences, firstly to meet the different needs of customers and legislation, and secondly to reduce costs by transferring possibly the largest part of the test track runs to the dynamometer. This trend is generally known as “Road to rig”.

The following specific requirements profiles apply to present/future roller surfaces and their environment:

- changeability of roller surfaces so that several surfaces can be used on the same roller
- installability of two or more different structures next to each other on one roller surface for immediate and direct comparison tests
- simulation of any surface (customer-specific road surface, ISO asphalt, etc.) for direct comparison with test track tests
- heavy duty surfaces up to extreme axle loads (trucks)
- tests with roller surfaces even at high speeds (v_{Test} up to 150 km/h and higher) for measuring the velocity-dependent properties of tyres, chassis, etc.
- surfaces must not delaminate at high speeds to avoid causing undesirable oscillations and harmonics
- low weight to facilitate short set-up times and easy handling by a maximum of two people without hoisting gear
- operation of roller also without changeable surfaces for use in other applications.

3 Structure and Properties of Changeable Roller Surfaces

The roller surface design is generally based on circular shell elements made up of a fibre-reinforced backing – for mounting purposes and strength – and a resin-based surface coating.

The conventional structure of the backing is created by a homogeneous mixture of resin and chopped fibre.

The structure of the surface coating depends on customer specification and is often implemented by taking a negative impression of a reference test track.

Usually, 4, 5 or 6 shell elements – depending on the diameter – are laid around the circumference of a roller, and are fixed by screws around the outside edge. Two adjacent elements form a butt joint.

This common design meets the demands of easy handling and long service life in critical mounting areas. **Figure 1** shows shell elements mounted on a roller.

4 Main Problem of Conventional Designs

Due to the fact that the shell elements are not physically joined together or to the roller at the butt joint, conventional designs give rise to the adverse effect described below.

The shell elements start to lift from the roller above a certain velocity (approx. 30-50 km/h) depending on the angular velocity, rotating masses and resultant centrifugal forces. The tyres experience sudden loads when travelling over the butt edges of two shell elements. Constant speeds and therefore frequency can result in oscillations or harmonics in the tyres, vehicle or roller.

The effect increases super-proportionally as the velocity increases, and from about 80 km/h it has an extremely distorting effect on the acoustic measurement.

The distortions occur in particular along the butt joint between two elements depending on the fixing points of the shell elements, and increase towards the centre of the coating. **Figure 2** shows FEM analyses which illustrate this behaviour.

5 Sandwich Design for the Backing Material

When developing these shell elements, AVL paid particular attention to the effect of delamination and to minimising or eliminating distortion in changeable roller surfaces.

Various approaches to the solution made it apparent that completely altering the basic design would no longer meet the fundamental requirements, such as easy handling.

The objective was therefore to develop a backing material for roller surfaces which not only increased the rigidity of the shell element but also reduced the mass, so as to minimise the effect of centrifugal forces and to prevent the surfaces from lifting.

The resultant solution was a sandwich design. The sandwich consists of a combination of glass-reinforced plastic and carbon-fibre reinforced plastic around a core of resin-impregnated foam.

Compared with conventional designs, the newly developed sandwich design is substantially stronger (modus of elasticity = 36000 N/mm^2 compared with approx. 4500 N/mm^2 of existing shell designs) and less dense (1000kg/m^2 compared with 1250 kg/m^2).

Further FEM analyses and tests, especially in relation to shell distortion, show that these adverse effects are reduced over the complete speed range. **Figure 3** shows the distortion of the sandwich design (in calculation and in tests) compared with the conventional design (in calculation). As a result the distortions could be reduced to less than a quarter of the conventional design.

The delamination of the cover coating and core material that previously occurred can now be reliably prevented due to the choice of materials.

Dynamic pressure tests with several million load changes in maximum axle load simulation tests confirmed this behaviour.

Figure 4 shows the result of a microscopic examination of the test sample, which was subjected to a compressive stress test of 10 million cycles with a maximum compressive load per unit area of 270 N/cm^2. The dynamically loaded area shows no structural damage, no tears or delamination and no permanent distortion.

6 Other Features

The chosen manufacturing process, in which the backing is first made in a mould and countermould and then the surface coating pressed on to it using a vacuum process, means that worn surface structures can easily be renewed and structures are interchangeable.

In particular when different surface structures are placed next to one another on a shell, they can also be screwed on to the shells at the transition between the two structures, **Figure 5**. This then further reduces distortion by a factor of 4 to 5.

It is also possible to eliminate existing unevenness in an original road surface inside the negative mould required for the manufacture. The roller surface itself then runs true around its entire circumference and any undesirable harmonics caused by periodic irregularities are therefore avoided.

7 Summary

As a system supplier of test beds for vehicles and drive trains, AVL is in a perfect position to integrate this new type of roller surface as a turnkey project in acoustic test beds in all the important phases such as planning, design, assembly, commissioning and acceptance.

The demand for substantially increased versatility of chassis dynamometers is amply met by the new development.

Operators of acoustic chassis dynamometers can simulate many different types of road surface with these changeable surfaces.

Tests can also be run at high speeds while excitation of oscillation is suppressed. There is no longer any restriction on high axle loads such as occur in truck testing.

Furthermore, the new roller surfaces mean significantly lower renewal costs for new surface structures.

The changeable roller surfaces mean that test beds can provide much greater versatility and usefulness, thus significantly supporting the ROAD TO RIG trend.

Reference

[1] N.N.: Gipfel der Motorisierung: Szenarien des Pkw-Bestandes and der Neuzulassung in Deutschland bis zum Jahr 2020 (Motorisation Peak: Scenarios of Passenger Car Statistics and New Registrations in Germany to 2020). Deutsche Shell AG, Hamburg, Volume 26, September 1995