CASE STUDY

Pirelli Reifenwerke
Noise and Vibration Analysis of Tyres

Germany

Automotive

PULSE, Transducers

Over one hundred years' experience of tyre technology has enabled Pirelli to combine maximum levels of security, durability and comfort in its products. With today's enhanced technology, and an enthusiasm for driving, Pirelli engineers have been able to make vast steps forward. Each Pirelli tyre provides not only performance but also a "feel for the road" and communication with the driver, allowing a better understanding of the vehicle's performance.

Pirelli Reifenwerke uses an 8-channel PULSE multi-analyzer to record and analyse tyre noise from controlled coast-down tests made in a semi-anechoic test cell. The test data is extensively used in the development of new, quieter tyres.

A World Market Leader

Within the automotive industry, the name Pirelli is synonymous with the manufacture of high-performance, safe, durable, high-quality tyres for cars, trucks and motorcycles. Its a world market leader and supplies tyres as OEM equipment to such companies as Mercedes, BMW, Audi and Porsche. The Pirelli Reifenwerke factory at Höchst, 70 km south-east of Frankfurt, Germany has some 3000 employees and manufactures about 20 000 tyres every day, seven days per week – more than seven million tyres each year.

Pirelli's headquarters and main development centre is in Milan, Italy. Car tyres are produced at Höchst and at other sites, including Turin, Italy. Truck tyres are mainly manufactured in Turkey. About ten years ago, Pirelli acquired Metzeler – renowned for the manufacture of motorcycle tyres.

About 30% of Pirelli's tyres are sold directly to automotive manufactures. This high percentage is very important to Pirelli. The balance of 70% is distributed as replacements through tyre distributors throughout the world.

In Search of Quieter Tyres

Fig. 1
Bernd Sattler is an acoustics expert. He has worked at Pirelli for over 18 years

Bernd Sattler heads Pirelli's noise and vibration test department. He has a degree in mechanical engineering and has worked with acoustics at Pirelli for more than 18 years.

Mr. Sattler says, "Tyre noise is an ever increasingly important issue. Our aim is to produce quieter tyres, but without sacrificing durability or safety. For instance, wet tyres are generally more noisy than dry tyres so we aim to achieve the best possible roadholding while reducing noise to a level that does not compromise safety – and safety is always our first concern. We test both car and motorcycle tyres, and the noise testing of motorcycle tyres is greatly increasing".

He continues, "The noise test data is mainly used in the development of new, quieter tyre designs but we also benchmark test the tyres of our competitors".

State-of-the-art Test Facility

Fig. 2
The semi-anechoic test cell at Pirelli's Höchst facility

In the late 1980s, Mr. Sattler was closely involved with the design and construction of the test lab building, the anechoic room, test instrumentation and methodology – it was the subject of his degree thesis.

Mr. Sattler explains, "We use an 8-channel PULSE multi-analyzer to record data from controlled coast-down tests made in a 10 × 7 metre semi-anechoic room. The room has a cut-off frequency of 170 Hz and the floor has reflecting characteristics similar to road surfaces".

Fig. 3
The acoustic test cell control room

He continues, "By means of heating built into the floor and good thermal insulation, a temperature of 23° C is maintained within the anechoic room. We aim for a temperature of 20° C on the "safety walk" surface of the dynamometer drum. Our research shows that the noise varies by 0.3 dB for each 10°C above 20°C, and by 0.6 dB for each 10°C below 20°C. Therefore, before each test, we allow the tyre to warm up by running it at 80 kilometres per hour for ten minutes".

The electrically driven drum of the dynamometer has a diameter of two metres and is 40 cm wide. The motor is located remotely and sound insulated to ensure that it has no effect on the accuracy of the test data.

Testing

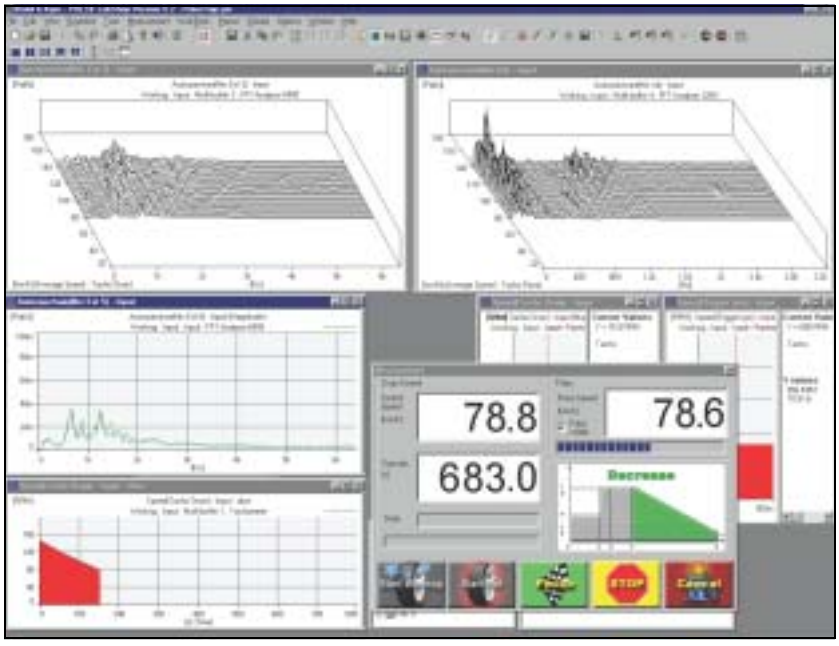

Fig. 4
Typical display during a measurement on a tyre. The waterfall plots are scaled in Pascal instead of dB – this makes them easier to read

In the acoustic test cell, the noise from a tyre is recorded in relation to speed. Coast-down tests are made over an accurately controlled speed range from 180 to 20 km/hour over a twelve minute period. A-weighted overall level, FFT spectra and order analyses are made on each channel.

During a test, one microphone is placed inside the vehicle, two microphones outside the vehicle in the far-field (Brüel & Kjær Type 4190). A Triaxial Accelerometer Type 4321 is mounted on the vehicle, as close as possible to the tyre being tested

The following parameters can be measured in a single measurement:

- Overall level versus speed
- Overall level calculated from a specific frequency range versus speed
- Order versus speed
- FFT versus speed

and the following analyses made:

- FFT analysis as waterfall diagram
- Order analysis as waterfall diagram
- FFT analysis as contour plot
- Order analysis as contour plot

Two tachometer signals are available. One provides the rpm of the tyre when order analysis is carried out. The other gives the speed in km/hour of the dynamometer road surface drum.

In Germany, the internal microphone is placed on the driver's seat so that the tyre noise is measured at this location. In Italy, the microphone is placed centrally within the vehicle and the measured noise is representative of the whole passenger cabin.

Fig. 5
A specially designed fixture is used to test motorcycle tyres

Testing is always carried out on the non-driven axle (e.g., the front axle of a BMW, the rear axle of an Audi). To test the tyre on the other axle, the propshaft/differential are disconnected.

A specially designed fixture is used to test motorcycle tyres.

With external tyre noise, the main frequencies of interest are around 1 kHz; for tyre noise measured in the car, lower frequencies are more relevant.

Mr. Sattler continues, "During a typical test, overall levels, FFT spectra and order analysis will be carried out for each channel in relation to tyre speed. We measure the SPL every one kilometre per hour and therefore take 160 measurements. We make FFT and order analysis measurements every two kilometres per hour and therefore have 80 values. On the external and internal microphones, we measure over a frequency range from 0 – 6.4 kHz."

Three different FFT frequency ranges are set up with the internal microphone:

- 0 – 800 Hz
- 0 – 3.2 kHz
- 0 – 6.4 kHz

Fig. 4 is an example of a typical display during a noise test. From top left to bottom right it shows:

- waterfall from external microphone
- waterfall from internal microphone
- external frequency spectra
- speed of drum (km/hour)
- speed of tyre (rpm)
- speed vs. time

Typical tests on one car, including setup time, normally take about a day. A standard test involves between five and eight sets of tyres. One set of tyres is from a competitor and one is an existing Pirelli model which is used as the base specification for a new tyre design.

PULSE

Mr. Sattler says, "We have used Brüel & Kjær analyzers, sound level meters, sensors and calibrators for over fifteen years. They have a reputation as the world market leader in the field of sound and vibration measurement".

He continues, "PULSE is known to be an easy-to-use and accurate measurement platform. It was an advantage to be able to see PULSE in use, together with a user interface developed by Akustec, and to obtain everything from one source as this ensures that all the component parts fit together and function correctly. These are the reasons that we chose to buy PULSE".

Akustec – ARTI Software

Fig. 6
The ARTI software was developed by Akustec, based in Munster, Germany

Three years ago, Bernd Sattler, in cooperation with his colleague Massimo Mortarino in Milan, worked with the German company Akustec, based near Munster, to develop a user interface for use with their PULSE multi-analyzers.

Mr. Sattler explains, "The PULSE software automatically runs in the background and is controlled by Akustecs ARTI (Anechoic Room Tyre test International) software. This also controls the drum speed, makes the measurements, displays the results, and stores and retrieves the data to and from an Oracle database. After the system is started, all aspects of the test are controlled completely automatically. A new test template can easily be defined inside the ARTI program."

The overall specification for the complete noise measurement system includes:

- calibration of acoustic channels
- management of setup parameters and data headers
- configuration of channels and analysis
- configuration of start and update trigger conditions
- output set speed points to the test stand to perform the assumed speed profile
- visualisation of data during the coast-down travel
- data transfer from PULSE
- storage and management of data in a database
- management of the use of time data recording tracks of the PULSE system
- display of the test data in graphical form for viewing, editing and comparison of measurements
- report generation using a selectable range of data
- export data as ASCII files

Mr. Sattler continues, "It is very important for us to be able to instantly compare the noise from different tyre designs. The facilities in the Akustec software allow us easily and quickly to store, retrieve and compare test data. The total noise acquisition system is reliable, stable and easy to use, and we get good back up and technical support from both Brüel & Kjær and Akustec. I am very happy with it".

Subjective Testing

Pirelli has a small, highly experienced team that carries out subjective testing on the local roads around Höchst. This gives Mr. Sattler and his colleagues a good overview and helps to achieve a good correlation between road noise under real conditions, and the noise measured in the test lab.

Pass-by Testing

For pass-by testing, Pirelli uses an ISO track at a small airfield about 20 km from Höchst. The test surface is paved with ISO asphalt and it is 600 metres long and 15 metres wide.

A Brüel & Kjær Pass-by Noise Measurement System Type 3558 with a 2-channel Order Tracking Analyzer Type 2145 is installed in van that has been converted for use as a mobile noise laboratory. A Radar Unit ZZ 0231 provides speed signal.

The tests are made using two special, acoustically insulated, “silent” cars (a Toyota and a BMW) The noise data is acquired during a coast-down in the speed range from 90 to 40 kilometres/hour. The speed is more or less constant in the test area. Regression analysis techniques are used to calculate the noise values.

The ISO test track is also used in the certification of pass-by noise with new vehicles. The ISO standard in Europe specifies a maximum noise level of 74 dB(A) and this figure is determined by using the maximum value of the noise data measured at full acceleration in second and third gear after approaching the test area with a constant speed of 50 kilometres per hour.

Test Data and Reports

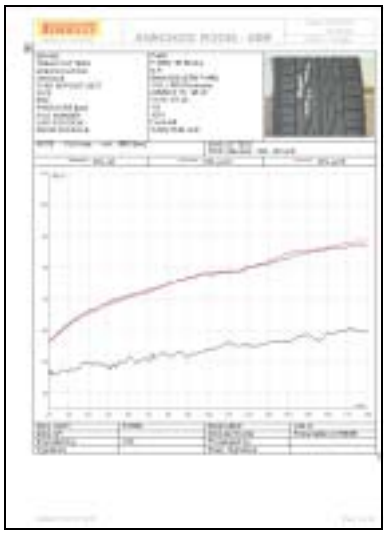

Fig. 7
Example of a test report made using Microsoft® Word

Pirelli’s main R&D centre in Milan has an identical PULSE system that is used for the acquisition of test data. This also uses the operator interface developed by Akustec.

Mr. Sattler explains, “We have a permanently leased line that links us with our colleagues in Milan. As the data acquisition systems are the same, we can easily and quickly exchange data with each other. We also send copies of our final reports to Milan. The test systems runs under Windows NT®. The data are saved in an Oracle database. The test results are exported as ASCII data and printed reports are automatically generated using Microsoft® Word. There is also a facility to archive and retrieve the data using a tape streamer, if required. The reports are sent to the development departments in Milan and Höchst.

The next step is to put the software and test data on the PCs used by the development department and to make it “interactive” and a test version is now being evaluated. The aim is to be able to predict the noise of a new tyre design before it is actually produced. This will shorten the development time and reduce costs.

Key Facts

- The Pirelli name is synonymous with high-performance, safe, durable, quality tyres
- Pirelli supplies tyres as OEM equipment to major automotive manufacturers
- Pirelli’s Reifenwerke factory manufactures more than seven million tyres each year
- Tyre/road noise is an ever increasingly important issue
- Pirelli’s aim is to produce quieter tyres without sacrificing durability or safety
- An 8-channel PULSE multi-analyzer is used to record and analyse tyre noise
- In the acoustic test cell, the noise from a tyre is recorded in relation to speed
- The test data is extensively used in the development of new tyres
- Pirelli has used Brüel & Kjær products for more than fifteen years
- “Brüel & Kjær has a reputation as the world market leader in sound and vibration”
- Akustec developed the special ARTI user interface – after the system is started, all aspects of the test are controlled completely automatically
- “The total noise acquisition system is reliable, stable and easy-to-use, and we get good back up and technical support from both Brüel & Kjær and Akustec”

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