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A source path contribution analysis on tire noise using particle velocity sensors

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Introduction

Road tire noise is an important topic of research where acoustic particle velocity based testing techniques can be expected to bring new insights. Modal analysis can be carried out using non contact particle velocity sensors, and PU sound probes can be used to measure the radiated sound without a need to use anechoic testing conditions. A further breakdown of the overall sound pressure levels measured in to its various sources can be made by applying a source path contribution analysis, using the PU probes to measure velocity, sound intensity and, for determining the reciprocal transfer path, the sound pressure. The concept of using this type of transfer path analysis will be outlined and illustrated by a tire noise case.

Method

For a pass by noise test the sound pressure has to be measured at a height of 1.2m and at 7.5m distance from a passing car on a ISO 10844-surface.

In the present method the sound pressure at the measurement location of the pas by is calculated with a breakdown of a source measurement and multiple path measurements. In this method [1], [2], [3], [4], [5], [6], the source can be measured in a completely separated environment from the path measurement. The latter measurement must be done in the realistic environment.

The source is in this case the rotating tire, is measured on a drum. The path must be measured at the test track. In this case the path measurement is split in two measurements. 1) a set of relative paths as explained in [1] and one complete path.

The sound pressure at the measurement location is calculated by the relative paths multiplied with the complete path p_r / Q_r, and the source strength $v_n \Delta S$:

$$p(\vec{x}) = \sum \frac{p_r}{Q_r} v_n \Delta S$$

The path is measured in a reciprocal way with a monopole source Qr [8] and a sound pressure microphone p_r at the different tire locations.

The source strength is defined as $v_n \Delta S$ with v_n the local particle velocity and ΔS a measurement section of the tire. In this case the intensity is measured and converted as explained in [4].

The path measurements are repeated for all angles so that a full pass by test can be synthesized.

Sensors, sources and challenges

The measurements are done with a half inch PU probe capable of measuring particle velocity and sound pressure simultaneously, see Figure 1.

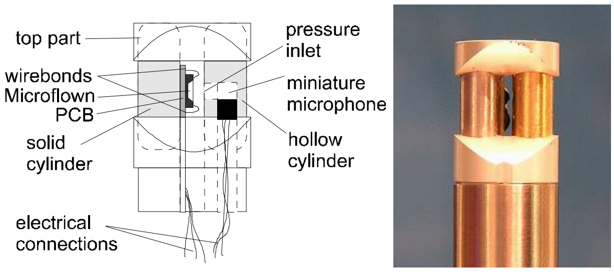

Figure 1: PU probe a sound probe measuring particle velocity and sound pressure

The particle velocity that is measured with the PU probe is very sensitive for wind that is produced by the rotating tire since wind and particle velocity have the same physical quantity.

From the measurements it showed that a standard polyurethane open foam wind shield was sufficient to block the wind, without effecting the measured particle velocity very much.

In this investigation the intensity was measured. And as long as the velocity probe is not overloaded by the wind (i.e. it stays in its linear range, 125dB) the wind induced noise is not seen in the intensity values. This is because the wind induced noise that is measured by the sound pressure microphone is not correlated with the wind induced noise of the velocity probe. (the wind causes no propagating sound waves and that is what is measured with intensity).

For the measurement of the path, a monopole (omni directional) sound source with a known volume is required. This source is described in [8].

Figure 2: Tire -drum measurement set-up.

In this R&D it became clear that the source was loud enough to reach a large signal to noise ratio over the required 7.5 meters. A sine sweep type of measurement was used to increase sound levels.

Measurements

Source measurements are done at Vredestein on 235/45R17 tires mounted on a drum covered with a 'Safety Walk' surface under typical car loading conditions and a speed of 80 km/u. Below the measurement set-up is shown while performing some Scan and Listen procedures with the PU-probe. [9]

A measurement grid is applied at several cm's from the rotating tire at two rectangular surfaces on the two sides of the tire (12 x 11 measurement points) and one curved surface following the tread contour of the tire (6 x 47 measurement points). As the sound pressure and particle velocity are measured simultaneously the sound intensity can directly be calculated. The sound intensity plots from a tire in the most relevant frequency range are shown below.

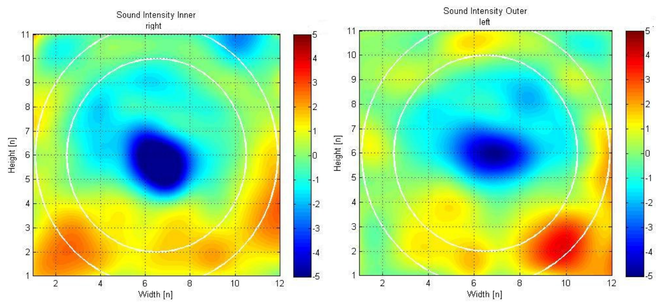

Figure 3: Relative sound intensity distribution of the tire at 80km/h. Left: inner part; right: outer part.

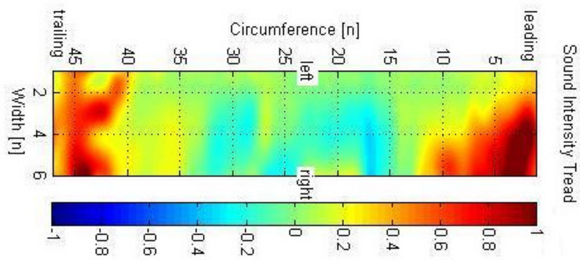

Figure 4: Relative sound intensity distribution of the tread at 80km/h.

Even with these relative coarse grids the most relevant sources of tire-road noise can easily be identified as the leading and trailing edge of the contact surface. Also the vibrating and radiating side wall of tire construction can identified as a source .

As the tire under real operating conditions the shielding of the car body has to be taken into account a relative transfer path analysis has been performed.

The relative transfer path reveals how much sources have to be weighed relative to a certain reference point and in this case this was the axis of the wheel. The resolution of this measurement is not as dense as the source measurement because the path is not varying much over the surface. Because the intensity is measured only the amplitude information is used [4].

As can be seen in Figure 5, the lower outer part of the tire is most dominant. The inner part is damped 4dB to 7dB. So sources that are shown in Figure 3 (left) have a (4dB to 7dB) reduced importance.

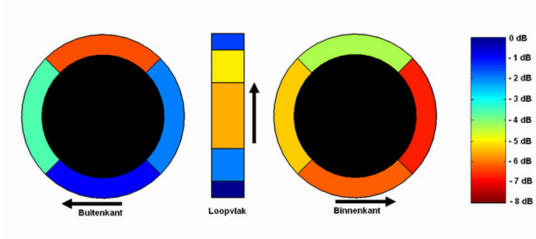

Figure 5: Amplitude of the transfer path at 1kHz.

Conclusion

It shows that it is possible to measure an high resolution intensity distribution of a tire on a drum at 80km/h. The induced wind problems are solved with a standard open foam windcap. The measurements with a pu intensity probe are relative straightforward because the probe is small and has no p/I index related problems. Due to this no special acoustic environment has to be created.

The intensity measurements can be related to a sound pressure at a certain position. This is done with a source path contribution measurement. The applied omni directional sources proved to be useful regarding emitted sound power.

The path measurement provides also an insight of the relative weighing of the measured sources. In this case it showed e.g. that sources at the inner part of the tire are weighed -4dB to -6dB.

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