Wind Noise - A Dominant Source for In-Cabin Noise in Comparison to Other Noise Sources of a Vehicle

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Introduction

Previous examinations of the vehicle interior noise only take into account a single sound source such as engine noise or rolling noise, but don't care about their contribution to overall noise [1-2].

By measurements in an aeroacoustic wind tunnel and in a vehicle acoustics test stand the in-cabin contribution of wind, rolling and drive train noise are determined separately. Measurements were carried out at different car speeds, in different gears, on two different street pavements to determine the overall noise and the appropriate engine speeds and loads.

Already at medium speeds wind noise is the most important sound source for interior noise at frequencies above 2 kHz, independent of road surface and engine speed. Even in the low frequency range wind noise can be louder than engine and drive train noise. At low vehicle speed and high engine speed the engine noise is rather high. If the engine speed goes down the rolling noise becomes dominant. On concrete pavement the rolling noise is dominant even at high driving speeds.

Test Procedure

Determination of Operating Data on Road

Basic requirement of the test bench measurements is the determination of the relevant operating data for several parameters such as driving speed, the road pavement, engine speed and load, and finally the class of the vehicle. While driving stationary at different speeds, the engine speed and interior noise were recorded (see Figure 1). Atmospheric wind speed should be as low as possible and the road has to be dry to achieve reliable results.

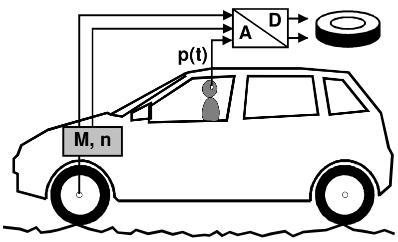

Figure 1: Determination of operating data of the engine and interior noise of the car driving on road.

Measurements in the Aeroacoustic Wind-Tunnel

As a standard in the automotive industry, the in-cabin wind noise induced by the air flow of the vehicle can be determinated under repeatable conditions in an aeroacoustic wind tunnel. Although the turbulence intensity of the air flow in the wind tunnel is less than found in road measurements, the results of the averaged spectra are comparable [3].

Measurements on the Vehicle Acoustic Test Stand

To measure the engine and drive train noise the car is positioned on mounting boxes while none of the wheels are rotating. The engine power is transmitted to a dynamometer placed outside the test stand. In order to achieve this the rim has to be cut out and the differential gear has to be locked (see Ref. [4]).

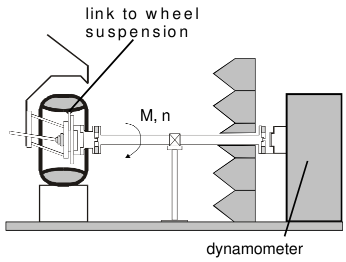

Figure 2: Scheme of the drive train noise test bench.

Determination of Rolling Noise and Tyre-Road Noise

The remaining part of the combined rolling noise and tyre-road noise is calculated by the energy difference between total noise measured on road and the contribution of wind noise and engine noise measured on test bench.

Results

To know about the contribution of noise sources in frequency domain is helpful for automotive engineering in an early stage of development. Evaluation of measurement results can be done by looking at the frequency spectra. The following charts show the A-weighted third-octave spectrum for the right ear of an artificial head in front passenger position for an upper middle class car. Driving speeds are 50 km/h, 90 km/h and 160 km/h on asphalt pavement.

As shown in Figure 3 the wind noise contributes little to the total interior noise at the slow driving speed of 50 km/h. The engine noise is lower than the calculated rolling and tyre-road noise because of the low engine speed (1800 1/min), but in the upper frequency (2 kHz) range the engine noise dominates.

Figure 4 shows the spectra for 90 km/h. The characteristic of the wind noise spectra does not change much in comparison to the engine spectra rises due to the increase of engine speed. The aeroacoustic noise at 90 km/h driving speed is both in low frequency and high frequency ranges as loud as the other sound sources. Only around 100 Hz the engine noise is the loudest source due to the 2nd engine order. Over 2000 Hz wind noise is 5 dB higher than engine noise which can be heard by passengers as a high frequency static noise.

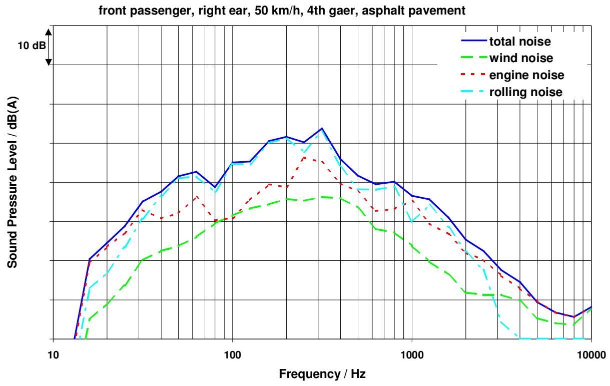

Figure 3: Third octave-band spectra of noise sources at 50 km/h (upper middle class car).

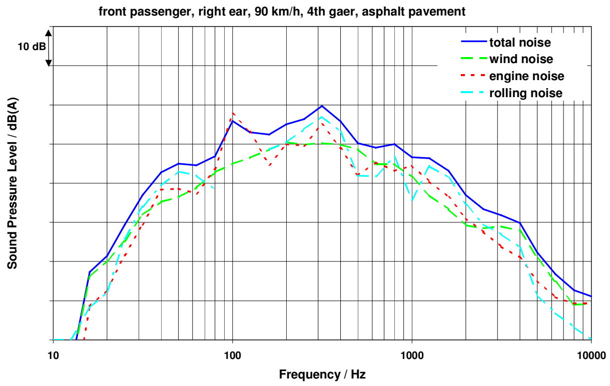

Figure 4: Third octave-band spectra of noise sources at 90 km/h (upper middle class car).

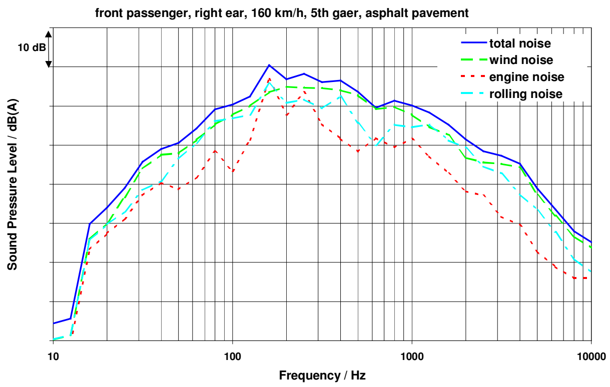

Figure 5: Third octave-band spectra of noise sources at 160 km/h (upper middle class car).

With further increase of driving speed the wind noise becomes the loudest noise source over the whole frequency range. The reasons are the decreasing tightness of the door and window seals as well as the long life high pressure fluctuations due to the separation of air flow [5]. Only at the 160 Hz third octave band the engine noise contribution is higher (see Figure 5).

Psychoacoustic Evaluation of Wind Noise

The subjective evaluation of wind noise shows an annoying impression because of the high frequency balance. The sharpness is a good psychoacoustic parameter which shows a quite good correlation with the subjective evaluation. Figure 6 shows the large contribution of the wind noise sharpness to the sharpness of the total noise.

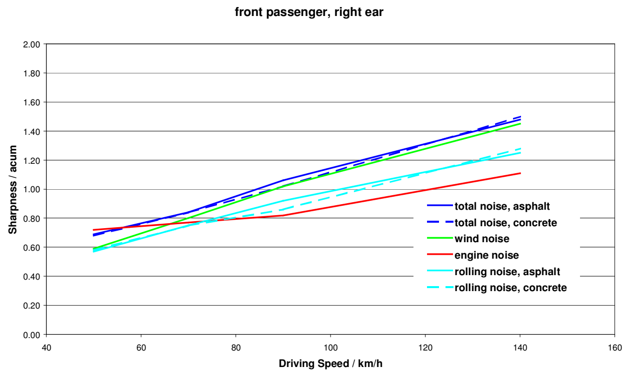

Figure 6: Sharpness of noise sources for an upper middle class car, front passenger, right ear.

Summary and Further Investigations

The experimental separation of noise sources in-cabin could be helpful for automotive engineers developing cars. With the knowledge of the interior noise characteristic in dependence of the driving speed and the engine load it is possible to improve in detail the wind noise in relation to the other noise sources. The experimental determination of the remaining parts (rolling noise and tyre-road noise) are still in progress.

Acknowledgements

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