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SPEED INFLUENCE ON TIRE/ROAD NOISE INSIDE A PASSENGER CAR

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ABSTRACT
The paper contains detailed analysis of the speed influence on the level and frequency spectra of the tire/road noise inside a passenger car. Special experiment performed to estimate the influence was described and its results were discussed. Different noise-speed characteristics were obtained for interior and exterior tire/road noise. As it was expected, the sound levels of exterior noise are proportional to the logarithm of the speed. Tire/road noise inside a cabin of passenger car is not governed by the same rules. The speed influence on A-weighted sound pressure level is linear. The noise level increases on the average 1.2 dB(A) per 10 km/h. In the frequency domain speed-dependent and speed-independent tire/road noise generation mechanisms were observed and discussed in the paper.

1 - INTRODUCTION
Tires are one of the most important sources of noise in moving modern cars. Because of this tire/road noise has become one of the most important driving comfort and safety problems related to vehicles affecting the driver and passengers travelling in the car.
The speed of a vehicle influences tire/road noise very much. Within the speed range form about 50 up to about 120 km/h, when the tire/road noise dominates over other noise sources in vehicle, changes in the noise level inside a passenger car cabin can reach 20 dB(A). The spectra of interior noise have speed-dependent and speed-independent frequency components.

2 - SPEED INFLUENCE ON NOISE LEVEL
Special laboratory experiment was designed and performed at the Technical University of Gdansk to estimate the speed influence on both interior and exterior tire/road noise. Three tires were selected to be utilized the test: one with smooth tread (Slick tire), one with typical summer tread (Michelin MXT) and one tire with constant pitch tread pattern specially manufactured for the purpose of this test (named S60).
The test car − Ford Sierra was situated on the roadwheel facility for the measurements of tire/road noise in such a way that the right front wheel of the car with the test tire was rolling on a drum equipped with a replica of smooth asphaltic concrete road surface (fig. 1). The interior tire/road noise was recorded by a microphone situated on the front right seat of the test car in the passenger head position. At the same time the exterior noise was recorded by a microphone situated close to the examined tire. The microphone positions were fixed according to the corresponding international standards [1, 2]. Both A-weighted sound pressure levels and frequency spectra were measured for rolling speeds from 30 to 130 km/h with the step of 1 km/h.
The results of the experiment (interior and exterior tire/road noise levels versus speed) are presented in fig. 2.
The speed influence on exterior noise is rather uniform for the Slick and Michelin MXT tires. Some irregularities in noise-speed relation can be observed for the special tire with constant pitch tread pattern. Local maxima occur for certain speeds when measuring noise of this tire. The experiment confirmed the conclusions published by other researchers (collected in [3]) that sound levels of exterior tire/road noise are proportional to the logarithm of speed.

Figure 1: Test car on the roadwheel facility at the Technical University of Gdansk.

The increase of tire/road noise measured inside vehicle cabin due to the increase of speed is lower than corresponding increase of exterior noise. The interior noise-speed characteristics are not so uniform and this is irrespective of the test tire. Partly it is an effect of the influence of acoustic properties of the car body, partly it depends on the tire construction. Also much smaller differences between tested tires in absolute noise levels inside the car, in comparison to outside ones, are the consequence of dumping properties of the car body.

But the most interesting in the results of this experiment is an observation that noise-speed characteristics obtained for interior tire/road noise are different type than in the case of exterior noise. The relations seem to be close to linear. Thus more detailed analysis was performed. It was based on the results of this experiment and of the other 239 previously made interior tire/road noise tests (6 passenger cars and 96 different tires were utilized in the tests).

Two types of noise-speed characteristics were considered: logarithmic $L_A = A + B\log(v)$ (like in the case of exterior noise) and linear $L_A = C + Dv$. For each measurement the coefficients A, B, C and D were calculated using the least square method. Then differences between measured and calculated noise levels were determined for each test speed. Finally, standard deviations and mean deviations for both logarithmic and linear relations were calculated. Results are presented in fig. 3. As it can be seen, smaller errors one are obtained when using the linear noise-speed characteristic in the case of the interior tire/road noise.

3 - SPEED INFLUENCE ON NOISE SPECTRA

The speed influence on spectra of the tire/road noise measured inside passenger car cabin was also investigated during the previously described experiment. Third-octave band spectra were recorded for the selected tires. The most interesting seems to be a spectral analysis of the tire with constant pitch tread pattern (fig. 4). The dashed line in the chart corresponds to calculated harmonic frequencies of the tread pitch as a function of speed.

For all tested tires for the frequencies below 300 Hz no speed influence on noise spectra can be observed. The highest levels in this range occur for the frequency of approximately 250 Hz, which correspond to the tire cavity resonance frequency. This noise generation mechanism is speed independent. Also another mechanism namely tread block vibrations (speed dependent) can be easily observed for the frequencies above 300 Hz. The frequencies with high noise levels of measured spectra correspond to the calculated harmonic frequencies of the tread pitch of the tested tires. Local maxima can be also observed for the frequency of about 1250 Hz. Because this phenomenon is visible for all tested tires (including Slick tire), the vibration of the air inside tread grooves mechanism must be excluded. Probably the tire belt and carcass vibration − speed independent mechanism is responsible for high noise levels for this frequency.

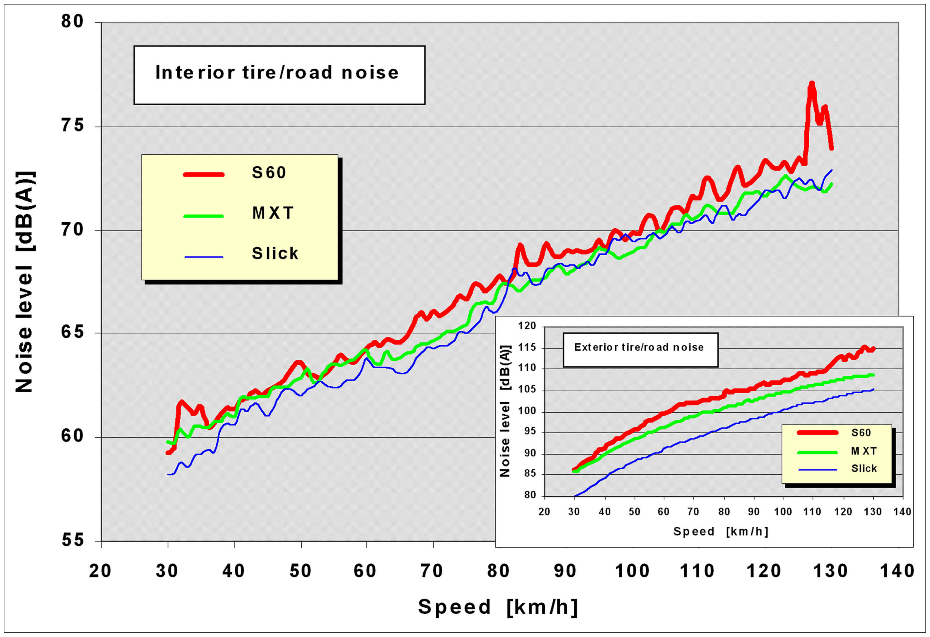

Figure 2: Speed influence on interior and exterior tire/road noise levels.

4 - CONCLUSIONS

It was proved that the sound levels of exterior tire/road noise are proportional to the logarithm of the speed. During road and laboratory experiments of the speed influence on interior tire/road noise it was noticed however, that the noise inside a cabin of passenger car is not govern by the same rules – the characteristic is close to linear. The noise level inside a passenger car increases on the average 1.2 dB(A) per 10 km/h.

In the frequency domain speed-dependent and speed-independent tire/road noise generation mechanisms can be observed. The knowledge about the speed influence on frequency spectra of interior tire/road noise can be helpful in the acoustic modeling of the car body as well as in the process of tire construction.

REFERENCES

1. **International Organization for Standardization**, *Acoustics - Measurement of noise inside motor vehicles*, ISO 5128-1980 (E), 1980

2. **International Organization for Standardization** , *Method for measuring the influence of road surface on traffic noise - Part 2: The Close Proximity Method*, ISO/CD 11819-2, 1998

3. **P.M. Nelson**, *Transportation Noise Reference Book*, Butterworth & Co. (Publishers) Ltd. Great Britain, 1987

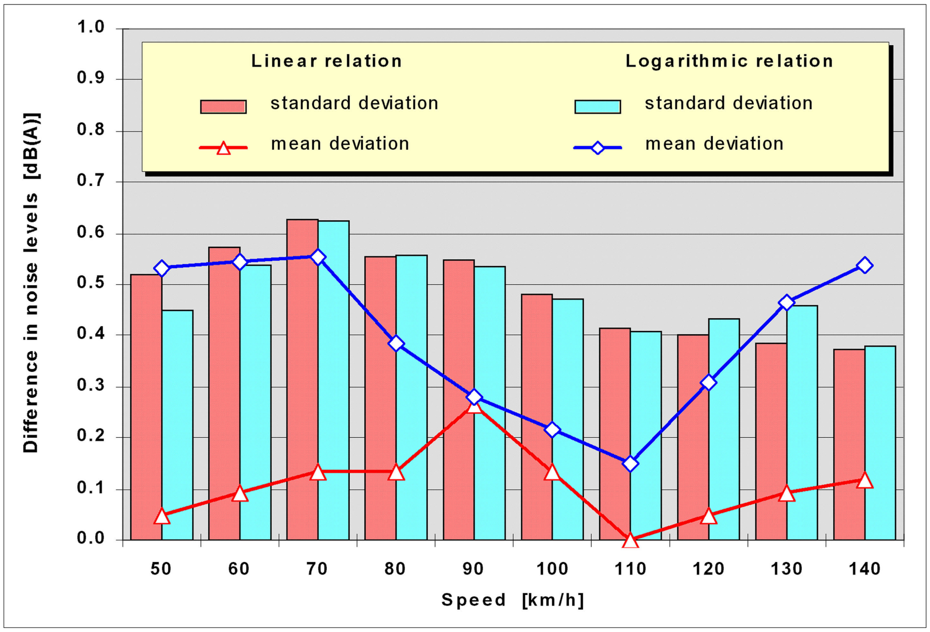

Figure 3: Differences in measured and calculated interior tire/road noise levels.

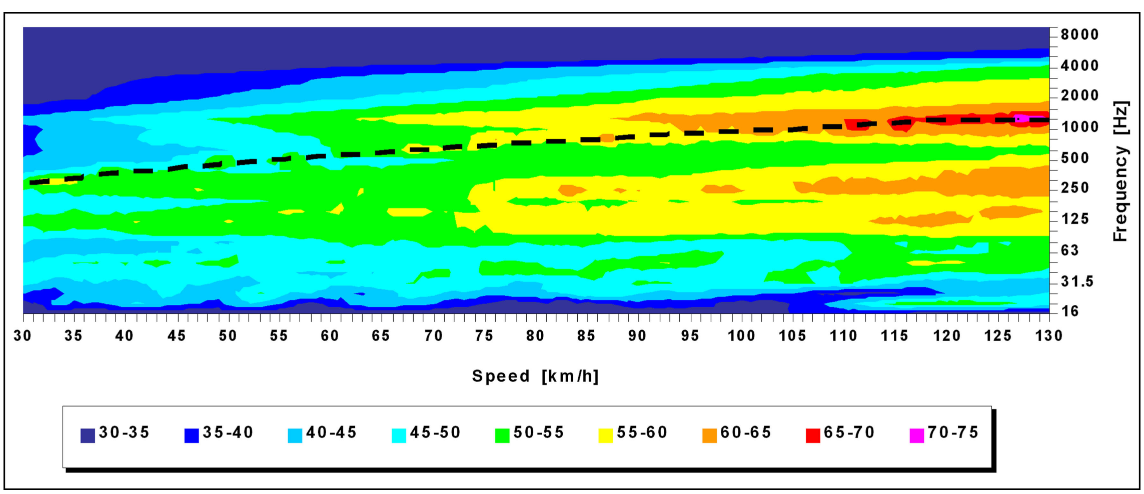

Figure 4: Speed influence on tire/road noise spectra inside car cabin (tire S60).