PSYCHOACOUSTICS APPLIED TO TIRE NOISE

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ABSTRACT.

Tire noise is actually the most important noise source of vehicles. Other parts of vehicles like exhaust system or intake air, are silenced. The theoretical studies let us to design the sound emitted by cars. The overall level is not a problem from this point of view. But tire noise remains at the same values than many years ago. Newer tires offers best mechanical properties than older tires. The increase of safety, more grip, vibration comfort, etc. But noise is not considered as an important vector for design of tires. Only non uniformity design of pattern of footprint let to reduce the tonal components. New standard 2001/43/CE propose a new method for tire noise measurement, and maximum levels for each type of tire. Measurements seems not to agree with subjective impression of users.

TIRE NOISE STANDARD MEASUREMENT.

Tire noise is produced by the contact between tire and asphalt surface. For many years the design of tires was focused in achieve safety, economic, and durable tires. The emitted noise by tires was not considered because other parts of vehicle produce noise. The motor is the noisy source in any vehicle. But last years high efficient exhaust system reduces the exhaust's noise to low values. Is possible to design the sound from this exhaust system in order to reach a sportive sound for example. The engine increases his mechanical performances, and reduces noise also. In the 90's tire noise becomes the most important source in some conditions.

Standard 2001/43/CEE is recently created for tire noise measurements in test site. The test is made at 80 Km/h in an obstacle free zone, as old ISO R - 362 standard set-up. "Pass by" test is do many times in two directions left to right and right to left. For each trial test, maximum overall level (dBA) is measured. This kind of test measures only the noise produced without torque in wheels, any acceleration or breaking.

Some differences can be observed between tires. First is the pattern design. The distribution and number of ribs, transversal or longitudinal, produces different level of noise. But the measurement of maximum overall level (A-weighted) does not reflect the subjective sensation.

TEST SITE TIRE NOISE MEASUREMENTS.

Tire noise depends of pneumatic type and structure, asphalt surface, speed of the vehicle and car used in test measurements, tire, ambient and asphalt temperature, microphone position, weather conditions, etc. Lots of different measurement conditions, involve do lots of measurements, and under this conditions is easy to have blurred results. In all measurements, the driver put the gear selector on neutral position and switch off the engine, before the car reach the 20 m line away microphones position (see figure 1). Other solutions like encapsulation of engine were no possible. Two measurements were made, one in each side of the test vehicle, (1.2m height and 7.5m away from the line pass of the vehicle) and for each speed (from 50 Km/h to 120 Km/h). In all measurements, more than 10 dB signal to background noise is guarantee.

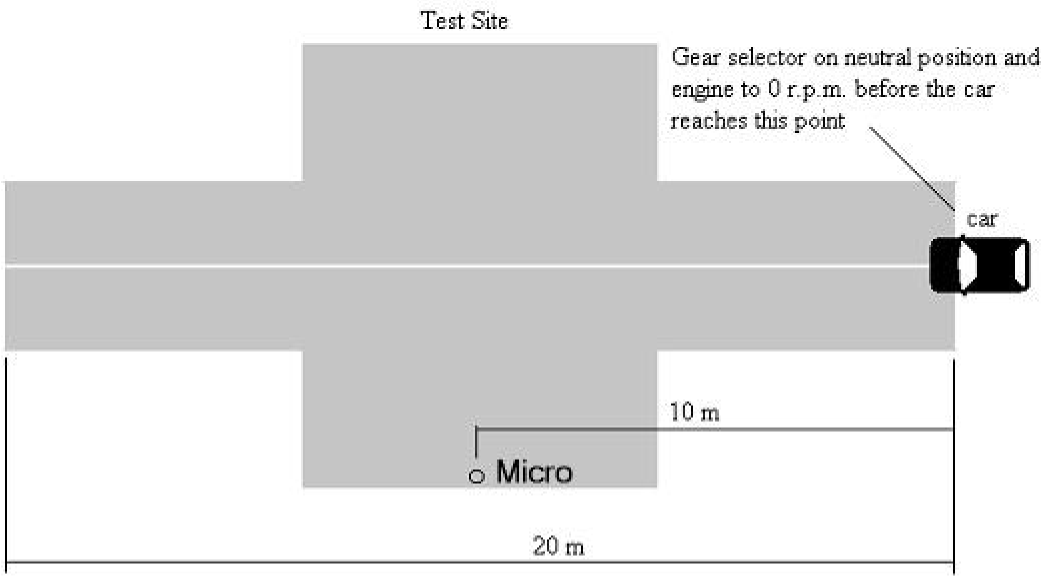

Fig. 1. Set-up for tire noise measurement in test site.

CONVENTIONAL ANALYSIS.

The shape of spectrum noise from tires shows some differences. Tire noise varies for each speed of vehicle. Is possible to perceive different sound. The pattern design causes a peak of noise between 550 Hz to near 1 KHz. A higher second peak appears at approximately 1.15 KHz. Figure 2 shows a sample of tire noise for a conventional tire at 50, 80 and 120 Km/h. The overall level is resumed in table 1.

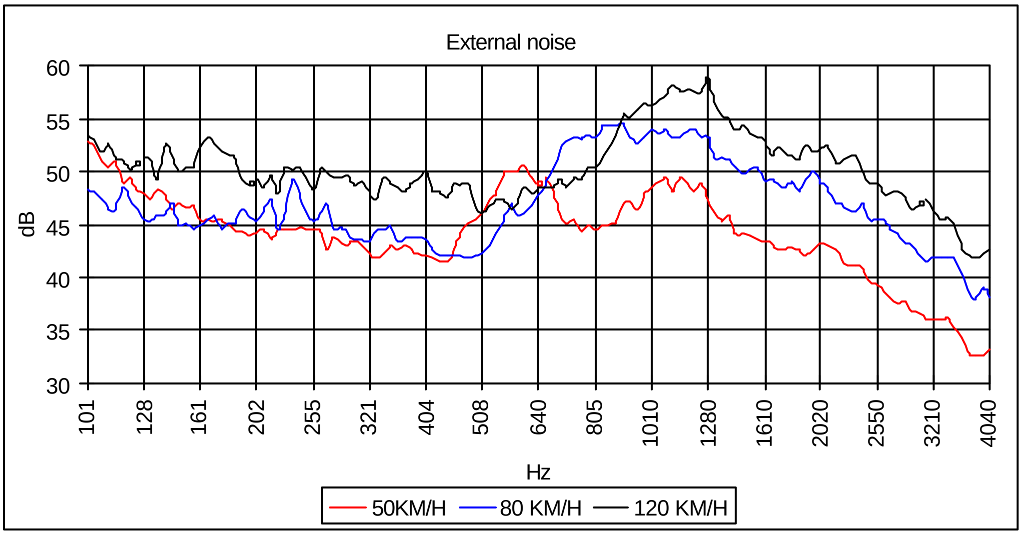

Fig. 2. Spectrum averaging of pass-by tire noise at different speeds.

	50	80	120
dBA	61.85	68.35	72.95

Different patterns design of tire produce different level of noise. Figure 3 shows two different tires with very different level of noise. The same track is used for measurements. Same car and mechanical and weather conditions in all measurements. The overall noise level is 68.8 dBA for PR-6 and 64,9 dBA for PR-9 tire. In this case the difference of noise levels are clear.

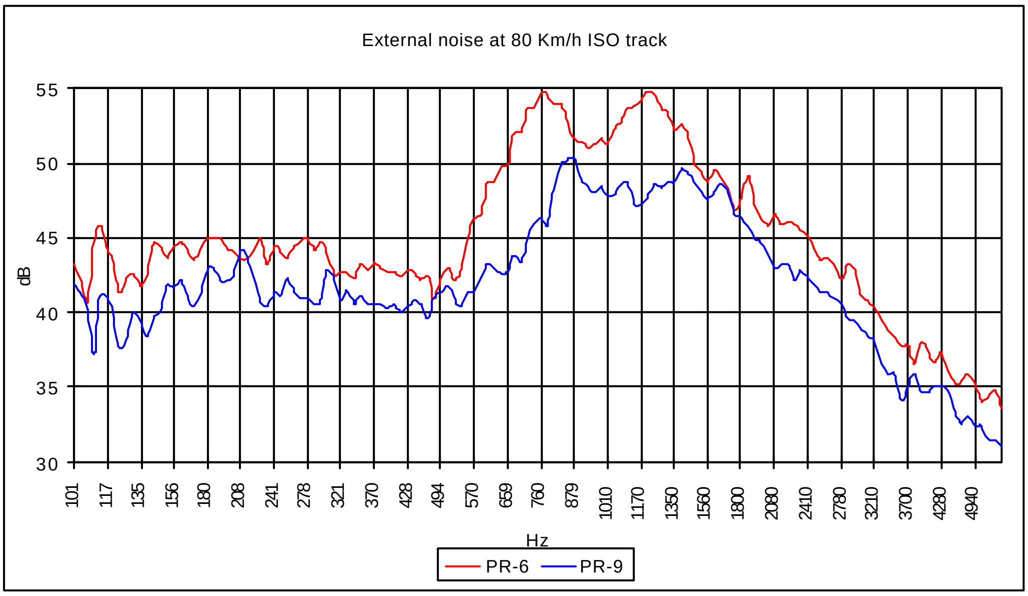

Fig.3. Two different tires at same speed produces different noise.

THE SLICK TIRE.

The target of tire manufacturers is to reduce emitted noise. A tire without footprint is so called “slick” tire. In opinion of manufacturers, slick tire is the noiseless of all. But the sensation when everybody uses this kind of tire is not agree with this appointment. Figure 4 shows the spectrum averaged of slick tire for different speeds.

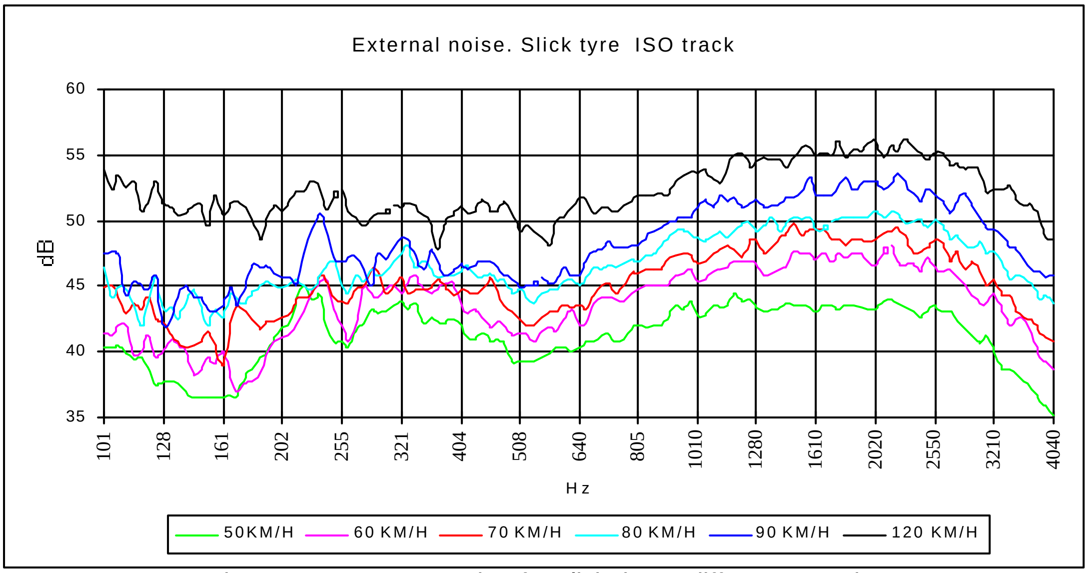

Fig.4. Spectrum averaging for slick tire at different speeds.

The shape of spectrum averaging of slick tire, looks very similar to the conventional tire. But some important differences are observed.

a. Slick tire not shows the rib's frequency as conventional tire shows.
b. The peak of maximum noise level is wider than conventional tire.
c. The maximum noise level of slick tire is lower than conventional tire.

Figures 5, 6 and 7 shows the different spectrum averaging at 50, 70 and 90 Km/h for conventional tires and slick tire. All of them are mounted in the same rim, same car with the same weight, same temperature of tire and asphalt and same weather conditions.

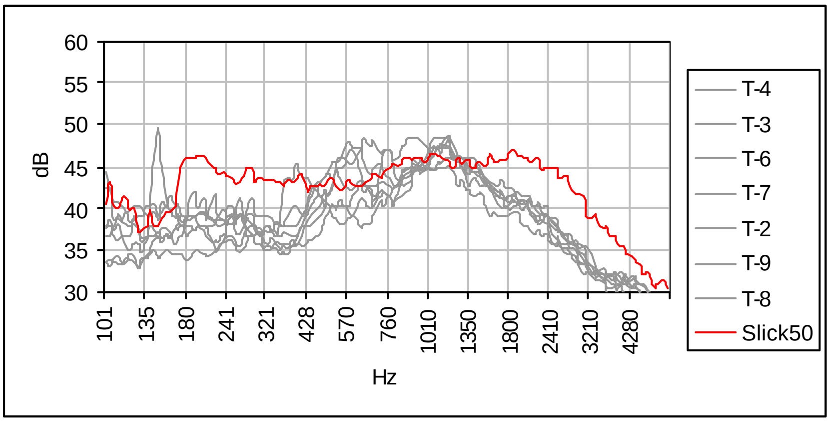

Fig.5. Spectrum averaging from slick tire vs conventional tire at 50 Km/h.

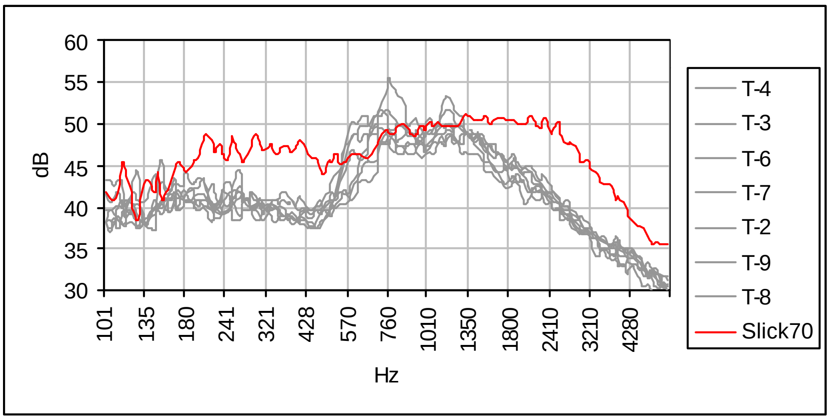

Fig. 6. Spectrum averaging from slick tire vs conventional tire at 70 Km/h.

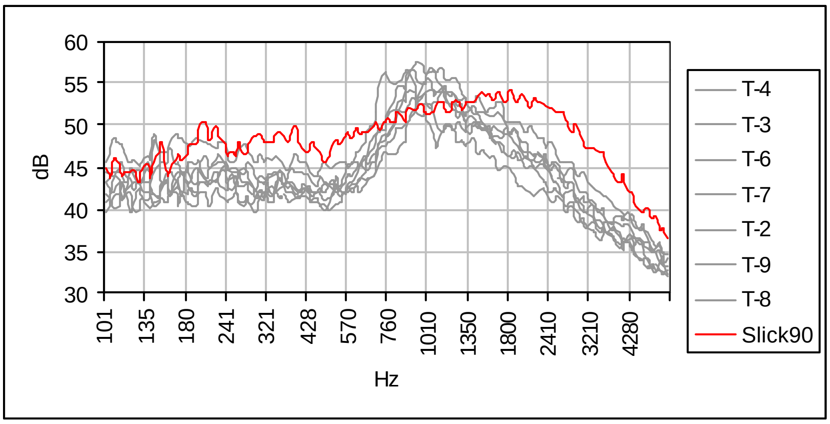

Fig. 6. Spectrum averaging from slick tire vs conventional tire at 90 Km/h.

As is shown in last figures, the shape of spectrum averaging for conventional tires peaks approximately at 1 KHz band. For slick tire the peak is smoother than conventional tire. The maximum noise level is lower for slick tire, but the overall energy is higher in slick tire than conventional tire. The noise level for slick tire for frequencies from 1.3 KHz to 5 KHz is approximately 5 dB higher than noise from conventional tire. Figure 8 shows a zoom around the maximum noise level for 50 Km/h. But the maximum level of conventional tire is higher than slick tire shows.

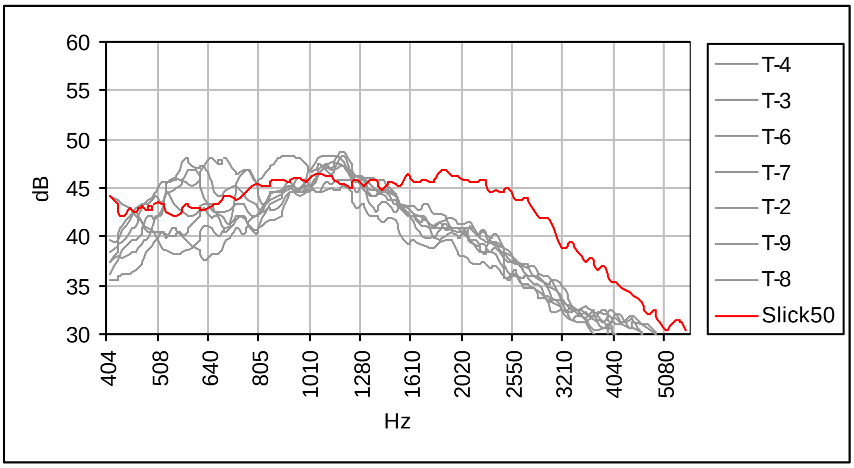

Fig. 8. Slick tire radiates more noise than conventional tire.

The shape of spectrum averaging for conventional tires decreases with a slope of 9 dB/Oct. and for slick tires decreases with a slope of 15 dB/Oct. Is clear that slick tire radiates more energy than conventional tire. This is true for all speeds tested from 50 Km/h up to 120 Km/h.

Next table shows the averaged values (A-weighted). Slick tire shows the higher values of noise for speeds from 50 and 70 Km/h. Some tires like T-4 or T-3 become noisy for high speed. The increment of noise for each type of tire is not linear with the speed of the car. According with this results slick tire radiates more noise than conventional tire.

dBAav	T-4	T-3	T-6	T-7	T-2	T-9	T-8	Slick
70 Km/h	67,7	65,7	61,9	66,7	66,5	63,8	63,3	61,2
80 Km/h	70,2	70,1	65,3	66,2	67,0	64,1	64,5	63,4
90 Km/h	71,2	71,7	69,5	67,9	68,3	67,3	65,9	66,1

Next table shows the values for spectrum averaging. Maximum and averaged values are compared. Conventional tires presents higher maximum noise values than slick tire for all speeds. But conventional tires shows lower averaged overall values than slick tires.

dBAmax	T-4	T-3	T-6	T-7	T-2	T-9	T-8	Slick
70 Km/h	72,8	74,6	61,9	72,6	73,4	71,4	72,2	75,1
80 Km/h	75,7	77,3	65,3	73,7	74,5	74,1	73,2	77,8
90 Km/h	77,1	77,7	69,5	75,3	76,1	75,1	74,7	79,2

The tables showed above, reflects the overall level (A-weighted) of all tires using two different indicators. First table is averaged values. This is the same indicator used for noise measurements in city. Average is near to the auditory perception than maximum values are.

The second table is maximum overall level (A-weighted). Comparing results between two tables, is clear than slick tire is the quiet of all when averaged values are measured, but is the noisy when maximum level is used.

THE HUMAN PERCEPTION.

The main target of noise control is reduce the noise emitted by sources. In this case of study the source is the tire noise. Human ear is sensitive to acoustic energy. Different frequencies produces different sensations also. The perception of noise not correlates only with maximum level. Energy is the main contribution to sensation of nuisance. For this reason slick tire is noisy than conventional tire, even when conventional tire shows higher peak noise level.

PSYCHOACOUSTICS.

Some aspects of sound can not to be reflected with "conventional" analysis. Psychoacoustics let us to know some aspects of the sound. Loudness is the more known indicator. Sharpness let to describe the energy of high frequencies respect to the energy in other frequency bands. Figure 9 shows sharpness function for conventional tires and slick tires at 70 Km/h Slick tires shows always more sharpness sound than conventional tire.

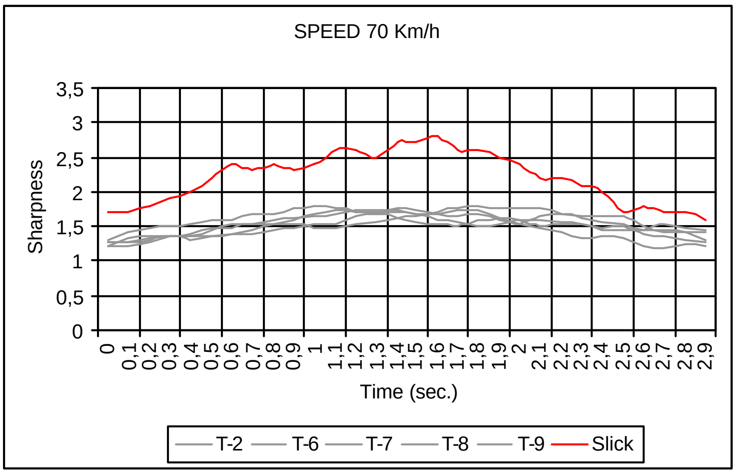

Fig. 9. Sharpness evolution for slick tire vs conventional tire at 70 Km/h.

As is shown in figure 9, sharpness from slick tire is notably higher than sharpness of standard tires. Higher level of sharpness produces more discomfort of sound. Sharpness from standard tires seems to be near independent of the speed of the car. For slick tires, sharpness function increases notably with speed.

CONCLUSIONS.

The overall level (A-weighted) seems not to be correct in order to reflect the nuisance perceived from tire noise. Slick tire shows the lower peak values, but higher energy level and consequently, more noise is emitted by tires.

Maximum levels of tire noise does not let us to classify the nuisance of this kind of source.

Is necessary a harmonization between measurements in test site and measurements in city. Measurements in test site must reflect the real condition of traffic in city.

Slick tire is the noisier of all tires. The main target of some manufacturers is to achieve less peak noise in order to pass the new standard, but this procedure probably is direct wrong because, the human ear is sensitive to energy of sound not to peak values.