INFLUENCE OF MEASURING CONDITIONS ON TYRE/ROAD NOISE

Jerzy Ejsmont[1], Truls Berge[2], Beata Świeczko-Żurek[1]

[1]Technical University of Gdańsk, Poland
jejsmont@pg.gda.pl beazurek@pg.gda.pl
[2]SINTEF, Trondheim, Norway
truls.berge@sintef.no

Abstract
A decisive factor for the development of tyres and road surfaces is the ability to conduct representative and reproducible measurements of selected characteristics related to the interaction of tyres and road surfaces. In terms of tyre/road noise measurements in Europe two methods described in ISO/FDIS 11819-2 and ECE Regulation No.117 are used. The latter is compulsory for assigning the tyre noise labels. The methodologies differ in both load and tyre inflation pressure, positioning of microphones (on-board versus stationary) and distance from the microphones to the test tyres. Within the Polish-Norwegian project LEO two research institutions - SINTEF, Norway and Technical University of Gdańsk, Poland conducted a series of road and laboratory tests to determine the effects of measuring methodology, inflation pressure and tyre load as well as road pavement on noise levels and sound spectra. The obtained results were also compared with the information stated on the tyres' labels. Analysis of the results indicates that changing test parameters such as load and inflation pressure has an important impact on the noise emitted by tested tyres. It was also found that the tyre/road noise measured on typical European road surfaces correlates very poorly with the noise labels of tyres. This observation puts into question the correctness of the procedures described in Regulation No 117. It seems that the methodology for determining noise values, which are the basis for the labelling, should be substantially amended and should be based on one of the typical road pavements.

Keywords: tyre/road noise, measurements, standards.

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1 Introduction

Tyre/road noise is in most cases the dominant noise source for modern cars (especially electric cars) and trucks. In the last decades of the 20th century, essential progress in tyre/road noise abatement was achieved. One of the key factors allowing to make road surfaces and tyres "less noisy" was the introduction of standardized measuring methods. At present, the following test methods are in use: laboratory methods based on roadwheel facilities and road methods including Coast-By (CB), Statistical Pass-By (SPB), Trailer Coast-By (TCB) and Close-Proximity (CPX). Measurements according to the close proximity method may be performed in a classical way, which is with two independent microphones, or by the On-Board Sound Intensity method (OBSI).

Different standards specify different test conditions and this may influence results of tyre/road noise evaluations. Both absolute sound pressure levels and tyre (pavement) ranking may suffer. This paper reports tests performed by SINTEF, Norway and Technical University of Gdańsk (TUG), Poland that were intended to compare tyre/road noise measured according to conditions required by the ECE Regulation No. 117 (Coast-By method) [1] and conditions required by ISO 11819-2 standard (CPX method) [2]. There are many research studies showing that measurements performed according to Regulation No. 117 give results that are not representative for typical conditions in Europe and the USA [3, 4, 5].

There are several parameters influencing tyre/road noise [6]. The most important are: tyre characteristics (like size, rubber hardness, belt stiffness, tread pattern), road characteristics (like texture, porosity, stiffness, road wetness) and operating parameters (speed, load, inflation pressure, temperature). In the case of measurement methods that are nominated to evaluate tyre quality (for example to assign proper environmental labels), the measurements should be carried out on **representative** road surfaces. Representative road surfaces may differ in different regions so certain generalization is necessary.

In Figure 1 comparison of results obtained by the coast-by method for six different tyres (two summer, two winter without studs, one studded winter tyre and one slick) on three very different road surfaces is presented. The results indicate that ranking of tyres tested on different road surfaces is different. This observation highlights the importance of a proper selection of road surface for evaluation of tyre acoustical performance.

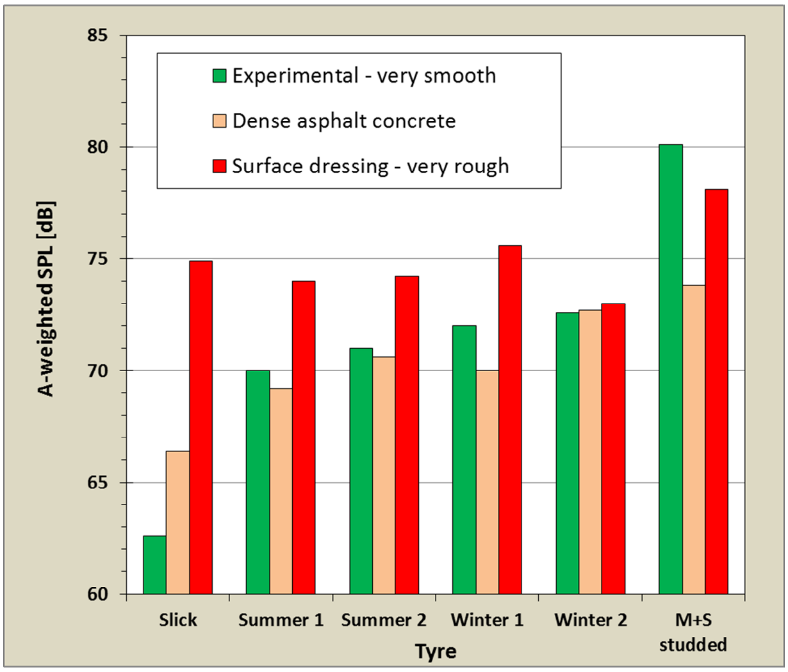

Figure 1 – Influence of road pavement on A-weighted SPL at 70 km/h measured by the cost-by method.

Measurements performed on typical US roads by OBSI method [7] indicate that noise generated by tyre/pavement interaction varies considerably depending on the pavement (see Figure 2) so neglecting road surface and evaluating tyre acoustical properties on atypical pavement leads to non-representative results.

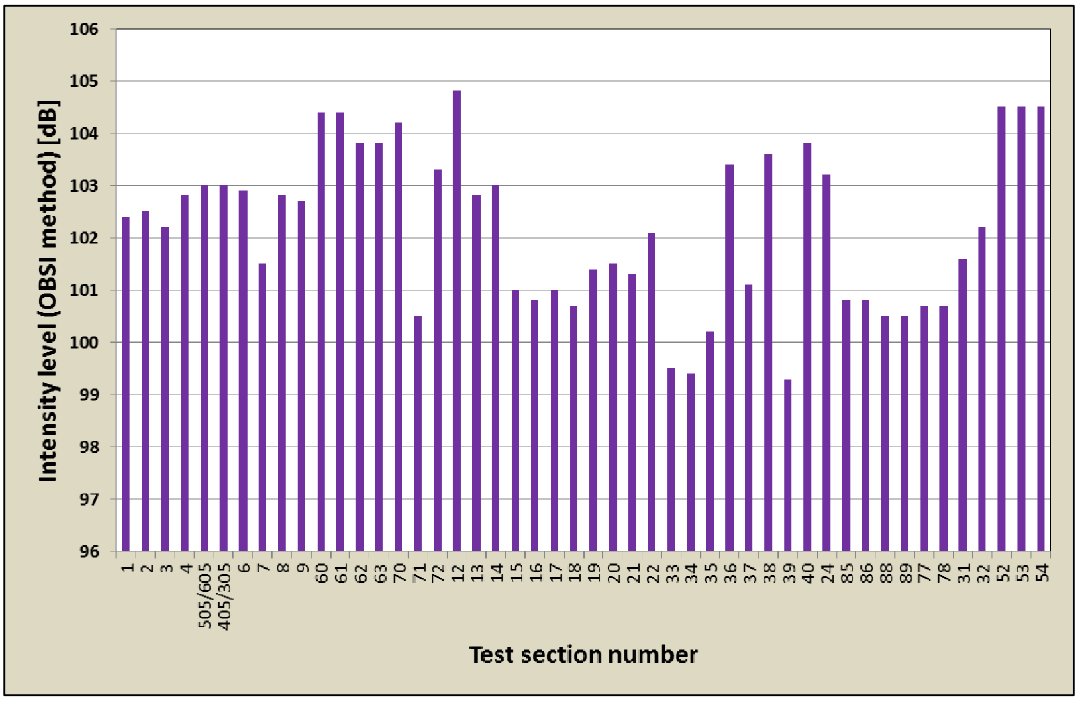

Figure 2 – Influence of road pavement on Sound Intensity Levels measured by OBSI method on 47 representative US road pavements. Test tyre: Standard Reference Test Tyre (SRTT).

According to different studies [6, 8] doubling of passenger car tyre load leads to an increase of A-weighted Sound Pressure Level (SPL) by 0.5 to 2.5 dB. What is interesting, the noise increase is bigger on smooth surfaces than on rough ones. At the same time an increase of tyre inflation pressure by 20% may lead to a decrease of noise up to -0.4 dB or an increase of noise up to 2.4 dB. This indicates that both load and inflation pressure play an important role in tyre/road noise generation, thus they must be properly standardized in tyre/road noise measuring methodologies.

2 Tyre/road results obtained for different loads and inflation pressures

Within the LEO project [9,10] SINTEF has been studying the influence of different loading and tyre pressure for a range of passenger car tyres on different dense road surfaces in Norway. The objective has been to see if the noise ranking of tyres varies much if the load and tyre pressure are in accordance with the CPX standard or if it changes using the conditions defined by ECE Regulation No.117 (modified, by using the CPX trailer for measurements).

Eleven passenger car tyres (Class C1) including two tyres designed for Electric Vehicles (EV) have been tested during the experiment. The tests were performed on the E6 highway south of Trondheim, where a total of 7 different dense road surfaces were available. All the surfaces were of SMA type. The traffic load on the surfaces is about 8500 ADT, with approximately 10 % heavy trucks (2 or more axles). The tests have been made with the CPX trailer of the Norwegian Public Roads Administration, built in 2005 by M+P in the Netherlands (see Figure 3). The tyres were tested according to the following conditions:

1) ISO/FDIS 11819-2 (CPX standard).
2) ECE Regulation No.117 (modified conditions)

Figure 3 – CPX test trailer used by SINTEF.

According to the CPX standard, the load of the trailer should be 3200 ± 200 N and the tyre pressure of 200 kPa. While this standard specifies a very tight tolerance for the load, the ECE Reg.117 allows a broad range of loads. Each tyre on the test vehicle should be loaded to 50% - 90% of the reference load as indicated by the load index of the tyre. The average test load of all tyres mounted on a vehicle should be 75 ± 5% of the reference load. Basically this regulation defines conditions where 4 tyres are mounted on a vehicle, and the measurements are made in coast-by conditions with the microphone 7,5 m from the vehicle. For C1 tyres, the reference speed is 80 km/h. The noise level is determined by a regression line for repeated measurement at higher and lower speeds than the reference. The measurements conditions in ECE Reg.117 specify the use of a vehicle. Since a CPX trailer has been used for this test, it is named a "modified ECE Reg117" test. Since a CPX trailer was used, the values of the measured noise levels are not directly compatible with the label values, because microphone positions are very different.

In Figure 4, the results of the measurements are summarized. The figure shows the difference between A-weighted Sound Pressure Levels obtained by at the ECE Reg. 117 conditions and CPX (ISO/FDIS 11819-2) conditions. The results show that some of the tyres, and especially the EV tyre T1083 is very slightly influenced by the increase in the load. The only change in the measurement condition for tyre T1095(EV) is a change in tyre pressure from 200 to 250 kPa. There is no influence on the noise level due to the change in tyre pressure in this range. Some of the tyres are more influenced by the change of load and tyre pressure than others, as for the tyres T1066, T1067, T1071 and T1079. On rougher surfaces the increase is around 1 dB(A) for these tyres.

One of the objectives of the reported investigation was to examine the ranking of tyres under these 2 conditions. In Figures 4 and 5, the rankings of tyres are shown for two of the road surfaces NOR5 - SMA16 (rough) and NOR6 - SMA8 (smooth). As these figures show, the rankings of tyres are influenced by different loading. However, the general trend is that the shift in ranking is rather small for most of the tyres, and that the quietest group of tyres and noisiest group of tyres are the same for both measurement conditions.

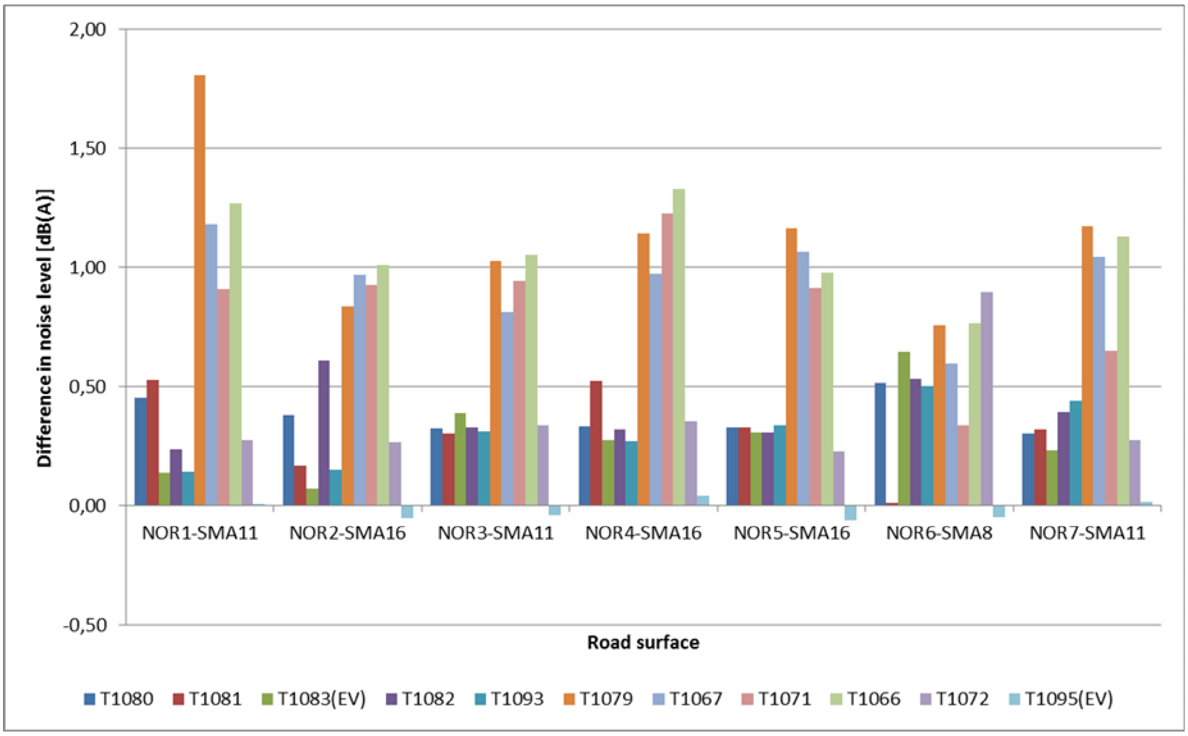

Figure 4 – Difference in noise levels between the modified ECE Reg.117 and CPX conditions.

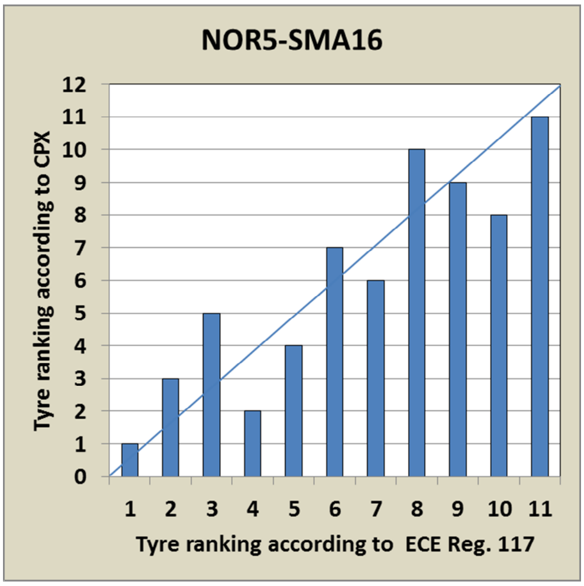

Figure 5 – Tyre rankings on rough surface.

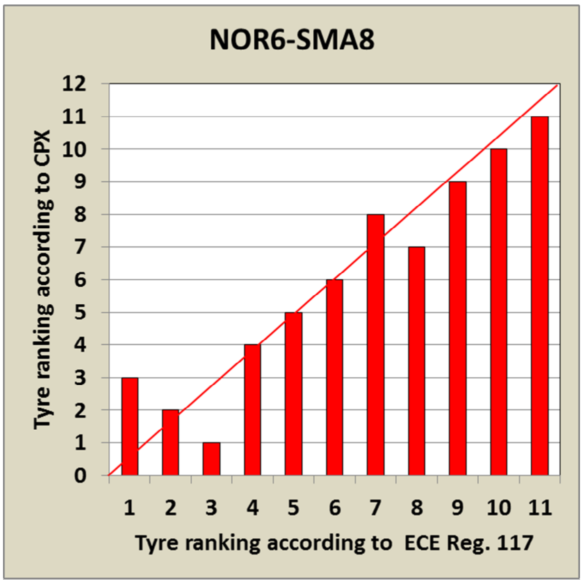

Figure 6 – Tyre rankings on smooth surface.

3 Correlation with EU noise label values

When tyres are tested according to the EU noise labelling regulation, the noise levels are rounded down to the nearest integer and then a value of -1 dB is subtracted, due to measurement uncertainty.

The noise levels from measurements according to the modified R117 conditions have been mathematically adjusted in the same way as the procedure in the labelling regulation. Since the labelling values are based on measurements on an ISO surface (smooth type of surface with "negative texture"), the correlation between truncated levels on the NOR6 SMA8 surface (that is also rather smooth) and the labelled noise levels has been analyzed.

In Figure 7 the correlation between the results on NOR6-SMA8 and label values is shown. As all of the tyres have also been measured in Poland on different surfaces including a SMA8 near Krakow (Gdów) it was possible to correlate also Polish results with label values - see Fig 8. Both figures show the lack of correlation between the ranking of tyres based on the label values and the actual ranking of tyres on the measured, very typical road surfaces. The tyres with the lowest label values, 68 dB(A), are among the noisiest tyres on all the surfaces. On some of the rougher Norwegian road surfaces, the correlation was even worse, and in some cases, it was even negative!

In another experiment by TUG in Gdansk [3], 12 tyres were measured on a range of road surfaces. The investigation included both drum (replica of ISO surface) and road measurements (SMA8). The analysis showed similar lack of correlation between the EU label values and the measured CPX noise levels as found in road experiments reported in this paper. TUG has also investigated the influence of load and tyre pressure on the roadwheel facilities [4]. The measurement included load and pressure conditions according to the CPX standard and according to ECE Reg.117. The main conclusion was that the difference in load and pressure could not explain the lack of correlation with the label values.

It must be mentioned however, that tyre inflation pressure required by ECE Reg. 117 is rather low in comparison to the common practice and car manufacturers' recommendations. For example for FORD MONDEO IV loaded with two passengers the recommended tyre pressure is: 250 kPa for front tyres and 230 kPa for rear tyres. This car uses 215/50R17 size tyres that in standard version have Load Index (LI) of 91 (615 kg) and in reinforced version LI=95 (690 kg). For such tyres, the inflation pressure required by ECE Reg. 117 is as follows:

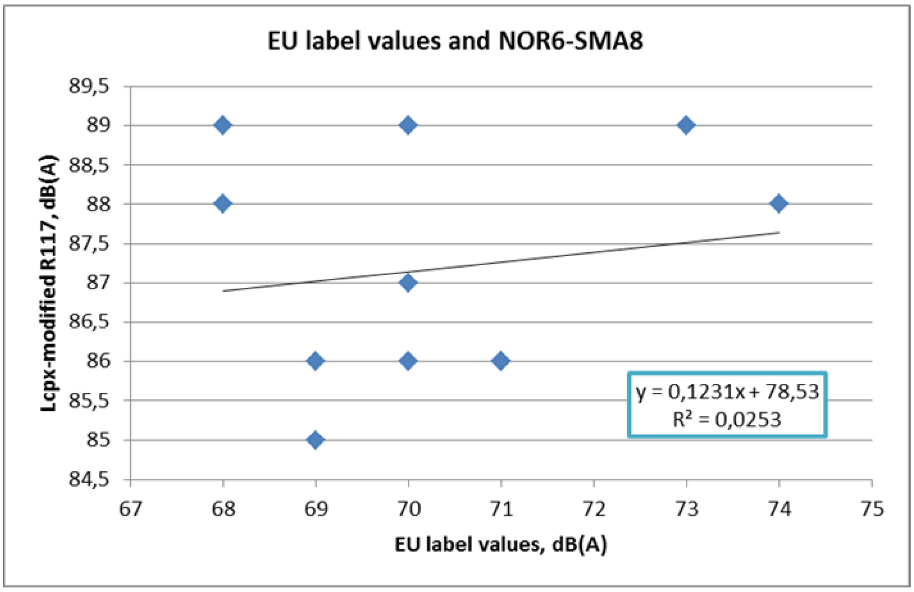

Figure 7 – Difference in noise levels between the modified ECE Reg.117 and CPX conditions tested on Norwegian road.

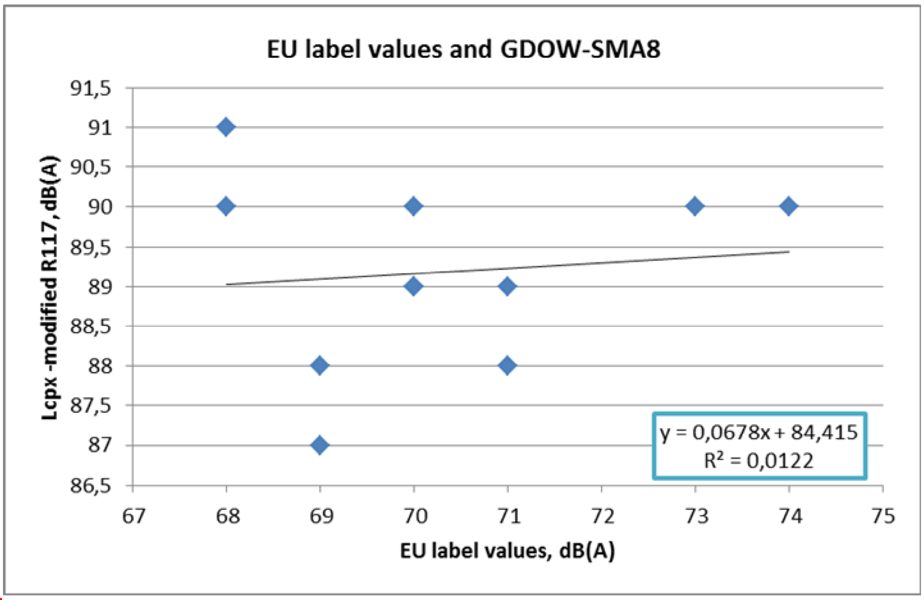

Figure 8 – Difference in noise levels between the modified ECE Reg.117 and CPX conditions tested on Polish road.

Front: standard tyres from 170 kPa to 185 kPa, reinforced tyres from 165 kPa to 180 kPa; rear: standard and reinforced tyres 150 kPa. The difference between inflation pressure required by ECE Reg. 117 and inflation pressure recommended by Ford is 70 - 80 kPa. This means that during measurements according to ECE Reg. 117 the tyres are seriously underinflated.

4 Conclusions

The main purpose of the EU labelling system is to inform the general public about the external noise level of a specific tyre brand and name, together with the rolling resistance and wet grip (letter codes). The intention is to give the consumer a possibility to choose tyres which are safe, give less energy consumption and less noise impact on the society. However, there is a concern that the present use of an artificial road surface (ISO 10844:2014) as a basis for the noise value, may cause a sub-optimization of tyre noise performance. The lack of correlation between the label values and noise ranking on normally used road surfaces can reduce the effect of introducing low noise tyres on the market, based on the label values only. Probably also unrealistic tyre inflation pressure required by ECE Reg. 117 has adverse effect on the representativeness of labels. In the opinion of these authors the regulation should be changed and the method should be based on more realistic measuring conditions. Algorithm of inflation pressure calculation should result in higher pressures and ISO 10844:2014 test pavement should be replaced by pavement typical for modern road network. Examples of pavement that should be considered are: SMA8 for Europe or 12.5 mm Dense Graded Superpave for the USA.

Acknowledgements

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