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Influence of test conditions on tyre/road noise measured by the CPX method

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The CPX method (ISO/DIS 11819-2) was developed to measure the influence of tyre/road noise on different road surfaces, using one or two reference tyres mounted on a trailer/vehicle. In recent years, the CPX trailer has been used to compare the noise behaviour of different passenger car tyres using the tyre load (3200 N) and inflation pressure (200 kPa) specified in the standard. Several experts on tyre/road noise question whether this method is appropriate for such use, and specifically whether measured values can be compared with the labelling values. The labelling values are based on coast-by conditions as defined in ECE Reg.117, with a loading and tyre pressure that differs from the CPX method. To investigate the influence of the test conditions on the measured noise levels, two tests were conducted: 1) A test according to the specifications of ISO 11819-2 and 2) A test according to the specifications of ECE Reg.117, but with a CPX trailer instead of a vehicle. A total of 11 passenger car tyres have been tested, including two tyres designed for electric vehicles. Measurements have been done on 7 different SMA road surfaces. The paper presents both A-weighted overall noise levels and third octave band spectra.
The main conclusion is that the change in loading and tyre pressure did not improve the correlation with the label values.

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1 INTRODUCTION

Tyre/road noise is the dominating source of road traffic noise under most driving conditions. The tyre/road noise is generated by the contact between the tyre and the road surface. In order to maximally reduce this noise, both the influence of the tyre itself and the road surface have to be reduced. Earlier measurements[1, 2, 3] show that a combination of a low noise tyre and a low noise road surface can reduce the tyre/road noise in the range of 10-13 dB, compared to a noisy tyre and a rough road surface. However, it is clear that the influence of the road surface is the dominating factor.

Several methods and international standards exist to be able to compare measurement results of tyre/road noise between different organizations/laboratories/countries, etc. The main purpose of several of these methods is to measure the influence of the ***road*** surface.

In general, the methods can be divided into two categories; laboratory methods and road methods. The laboratory (drum) methods offer a precise and efficient method to measure different tyres on different replicas of road surfaces, under highly controlled environmental conditions. However, it is somewhat challenging to compare laboratory results with the tyre noise behaviour on real roads, as the measurement conditions may differ considerably.

Typical road methods are: Coast-by (CB), Statistical Pass-By (SPB), Trailer Coast-by (TCB) and Close-Proximity (CPX). The SPB and CPX methods are standardized method to compare tyre/road noise on different road surfaces. For the CPX method (ISO/DIS 11819-2 and ISO/TS 11819-3(WD)), two different types of reference tyres have been chosen to represent the typical noise behaviour of passenger car tyres (Uniroyal Tigerpaw SRTT) and truck tyres (Avon AV4). The method specifies a fixed load and tyre pressure.

Many countries have adapted the CPX method, using a specially built trailer, to perform such measurements.

2 OBJECTIVE OF INVESTIGATION

A CPX trailer gives the opportunity to mount different tyres and then compare the tyre/road noise generated on different road surfaces. If such surfaces are relatively close to each other, the use of the trailer offers an efficient method to compare a number of tyres within a short measurement period. However, if one would like to compare the measurement results for example with the noise labelling values of tyres, the differences in measuring methods must be taken into account.

In this investigation we studied the influence of different loading and tyre pressures for a range of passenger car tyres on road surfaces of different density in Norway. The objective has been to see if the noise ranking of tyres varies significantly if the load and tyre pressure are according to the CPX standard or according to the conditions defined by ECE Regulation No.117 (modified, by using the CPX trailer for the measurements).

The EU tyre labelling system for noise (EC 1222/2009) is based on the measurement conditions in ECE Reg.117.

3 TEST TYRES, TEST SURFACES AND TEST CONDITIONS

3.1 Test tyres

Table 1 lists the eleven passenger car tyres (Class C1) have been tested during this experiment. Tyres T1083 and T1095 are tyres especially developed for Electrical Vehicles (EVs) or commonly used by EVs.

Tyres T1071 and T1072 are winter tyres typically used on the European continent (but not so much in the Nordic countries). Table 1 also shows the EU noise label values.

Table 1 - Tyres used for testing

Tyre designation	Tyre description	EU Noise label Values, dB(A)
T1066	Wanli S-1200 195/60 R15 88H	73
T1067	Conti EcoContact 5 195/60 R15 88H	71
T1071	Vredestein Quatrac 3 195/60 R15 88V	68
T1072	Yokohama W.Drive 195/60 R15 88T	74
T1079	Bridgestone Ecopia ep001S 195/65 R15 91H	69
T1080	Michelin Energy Saver 215/55 R17 94H	71
T1081	Dunlop BluResponse 195/65 R15 91H	68
T1082	Michelin Energy Saver 195/65 R15 91H	70
T1083(EV)	Michelin Energy E-V 195/55 R16 91Q	70
T1093	Nokian Hakka Green 195/65 R15 95T	70
T1095(EV)	Dunlop ENASAVE 2030 175/55 R15 77V	69

3.2 Test pavements

The tests were performed on the E6 south of Trondheim, where a total of 7 different road surfaces were available. All the surfaces were of SMA type. The traffic load on the surfaces is about 8500 ADT, with approximately 10% generated by heavy trucks (2 or more axles).

Table 2 gives detailed information about all seven surfaces. Since all measurements were performed in 2014, it means that both NOR6 and NOR7 are newly laid surfaces, not exposed to winter conditions or studded tyres. Previous investigations in Norway[4] show that the tyre/road noise level ***increases*** around 2-3 dB on SMA surfaces after the first winter season. MPD values were measured approximately 3 months before this experiment.

Table 2 - Test pavements

Road designation	Surface type	Production year	MPD
NOR1	SMA11	2008	1.18
NOR2	SMA16	2012	1.52
NOR3	SMA11	2008	1.40
NOR4	SMA16	2010	1.44
NOR5	SMA16	2011	1.23
NOR6	SMA8[1)]	2014	-[2)]
NOR7	SMA11	2014	-[2)]

1) With Pmb 2) Not measured

In some national projects, we measured an MPD for new SMA8 and SMA11 surfaces. On average, the MPD values for 12 new SMA8 were 0.64 (variation from 0.46 to 0.75). For new SMA11 surfaces, the average MPD value equalled circa 0.75 on Norwegian roads.

3.3 Test conditions

The tyres were tested according to the following conditions:

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

According to the CPX standard, the load of the trailer shall be 3200 ± 200 N and with a tyre pressure of 200 kPa. While this standard specifies very little tolerance for the load, the ECE Reg.117 allows a broad range of loads.

ECE Reg.117 requires that each tyre on the test vehicle is 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. In summary, this regulation defines conditions where 4 tyres are mounted on a vehicle, and the measurements are made in coast-by conditions with the microphone placed 7.5 m from the vehicle. For C1 tyres, the reference speed is 80 km/h. A regression line determines the noise level for repeated measurement above and below the reference speed.

The measurements conditions in ECE Reg.117 specify the use of a vehicle. Since we have used a CPX trailer for our test, we call this a "modified ECE Reg117" test.

Based on the load index of each tyre, the load of the trailer was modified to meet the 75 ± 5% requirement, as close as possible. At the same time, the tyre pressure was modified. For C1 tyres, the reference tyre pressure is 250 kPa.

Since a CPX trailer was used, the measured noise levels are not directly compatible with the label values, since microphone positions are very different. Table 3 shows the added weight for the Reg.117 conditions and the percentage of the reference load and the conditions according to the CPX standard (actual measured load in kg per tyre). The load was measured separately for each of the tyres on the axle.

Table 3 - Test conditions

Tyre designation	Test load CPX [kg]	Test load, Mod. Reg.117 [kg]	% of reference load	Tyre pressure kPa
T1066	339	392	70	250
T1067	339	411	73	250
T1071	339	392	70	250
T1072	339	392	70	250
T1079	339	411	67	240
T1080	339	429	64	220
T1081	339	429	70	250
T1082	339	429	70	250
T1083(EV)	339	429	70	250
T1093	339	429	62	250
T1095(EV)	339	339	82	250

As the table shows, all tested tyres according to ECE Reg.117 were loaded within the requirement of 50 to 90% of the load given by the load index. Note that due to load restrictions of the trailer there should have been added approximately 100-140 kg of load to meet the 75 ± 5% requirement, with the tyre pressure used.

As table 3 shows, the tyre T1095 was already loaded with 82% of the load capacity, so no additional load was added for the Reg.117 test. The only difference was an increase in tyre pressure from 200 kPa to 250 kPa.

4 TEST RESULTS

4.1 Temperature corrections

All measurement results have been temperature corrected to a reference air temperature of +20 °C, using a generic correction factor of -0.10 dB/°C (as proposed by ISOWG27). However, for some of the tyres, the temperature dependency was measured individually by TUG/Gdansk[5], and for those tyres, the measured values are used, as shown in Table 4.

Table 4 - Temperature correction factors

Tyre designation	Temperature correction factor dB/°C
T1066	-0.114
T1067	-0.132
T1071	-0.100
T1072	-0.100
T1079	-0.139
T1080	-0.100
T1081	-0.141
T1082	-0.100
T1083(EV)	-0.039
T1093	-0.100
T1095(EV)	-0.100

4.2 Results of noise measurements

All tests were performed at 50 km/h only. In table 5, difference in noise levels between the two conditions are listed for the 7 road surfaces. Negative values indicate a measured lower level with the modified ECE Reg.117.

Table 5 - Measured increase (positive values) in noise level with the modified ECE Reg.117, compared to the CPX method

Tyre designation	NOR1 SMA11 [dB(A)]	NOR2 SMA16 [dB(A)]	NOR3 SMA11 [dB(A)]	NOR4 SMA16 [dB(A)]	NOR5 SMA16 [dB(A)]	NOR6 SMA8 [dB(A)]	NOR7 SMA11 [dB(A)]
T1066	1.27	1.01	1.05	0.35	0.23	0.90	0.27
T1067	1.18	0.97	0.81	0.97	1.06	0.60	1.05
T1071	0.91	0.92	0.94	1.23	0.91	0.34	0.65
T1072	0.27	0.27	0.34	0.35	0.23	0.90	0.27
T1079	1.81	0.84	1.03	1.14	1.16	0.75	1.17
T1080	0.45	0.38	0.32	0.33	0.33	0.51	0.30
T1081	0.53	0.17	0.30	0.52	0.33	0.01	0.32
T1082	0.23	0.10	0.33	0.32	0.31	0.53	0.39
T1083(EV)	0.14	0.07	0.39	0.27	0.31	0.64	0.23
T1093	0.14	0.15	0.31	0.27	0.34	0.50	0.44
T1095(EV)	0.01	-0.06	-0.04	0.04	-0.06	-0.05	0.01
Average	**0.63**	**0.48**	**0.53**	**0.62**	**0.53**	**0.50**	**0.54**

The **average** increase in noise levels for all tyres on all road surfaces is **0.55 dB(A)**.
The results are also shown in figure 1.
The only change in 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 a change in tyre pressure in this range. It is likely that the load influence is larger than the tyre pressure influence (in the range of 150 to 250 kPa).

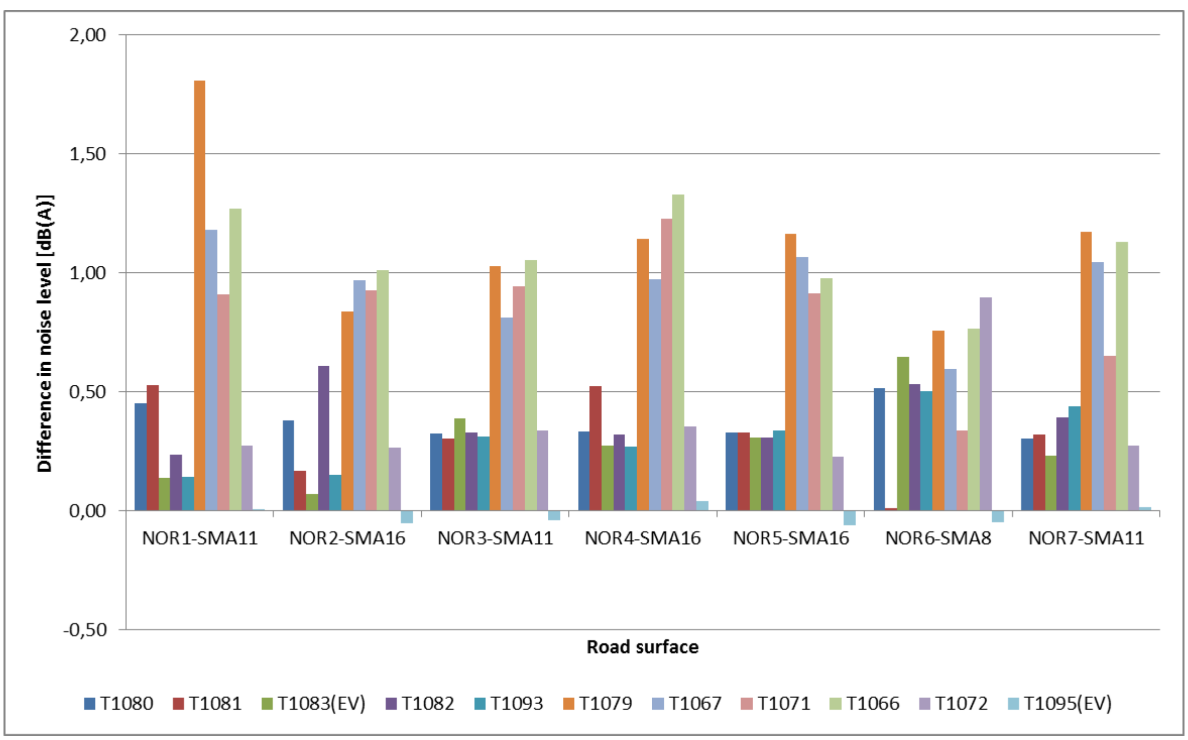

Fig. 1 - Difference in noise levels between the CPX method and the modified ECE Reg.117 method.

The results show that some of the tyres, and especially the EV tyre T1083 (Michelin Energy E-V) is very little influenced by the increase in the load.
The increased load and tyre pressure has a greater influence on tyres T1066, T1067, T1071 and T1079. On the rougher surfaces, the increase is around 1 dB(A) for these tyres.
It is interesting to notice that the influence of increased load and pressure is less on the smoothest road surface (NOR6-SMA8), than on the rougher surfaces. The ISO surface is a surface with maximum 8 mm aggregate size, and it can have an MPD value in the range of a new SMA8 surface in Norway.
In figures 2 to 5, the change in frequency spectra is shown for tyres T1079 and T1083(EV) on a rough surface (NOR4 SMA16 2010) and on a smooth surface (NOR6 SMA8 2014) is shown. Tyre T1079 is the tyre where the influence of load is highest, while T1083(EV) is one of the tyres where the influence of load is lowest (figure 1). The main increase in the noise level for T1079 is in the higher frequency range, from 800 Hz and upwards. The tyre T1083(EV) shows almost no change in the frequency spectra.
These results are consistent over all measured surfaces.

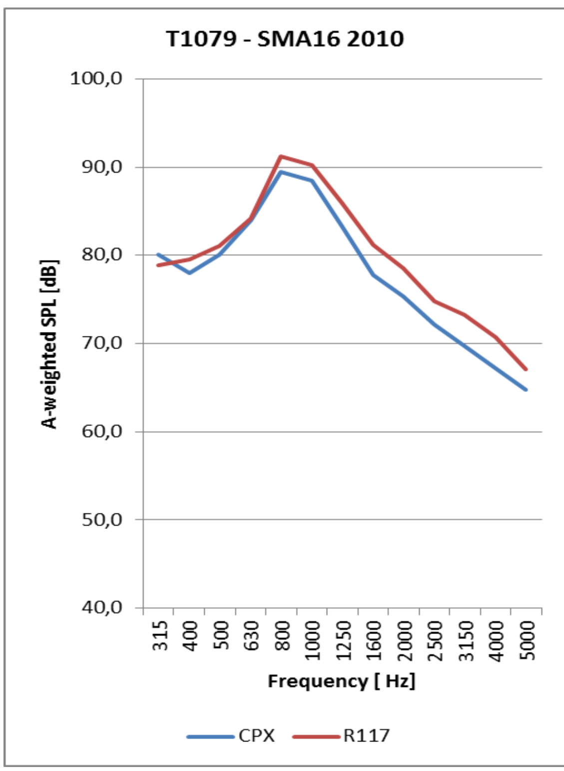

Fig.2 - T1079 on NOR4 SMA16

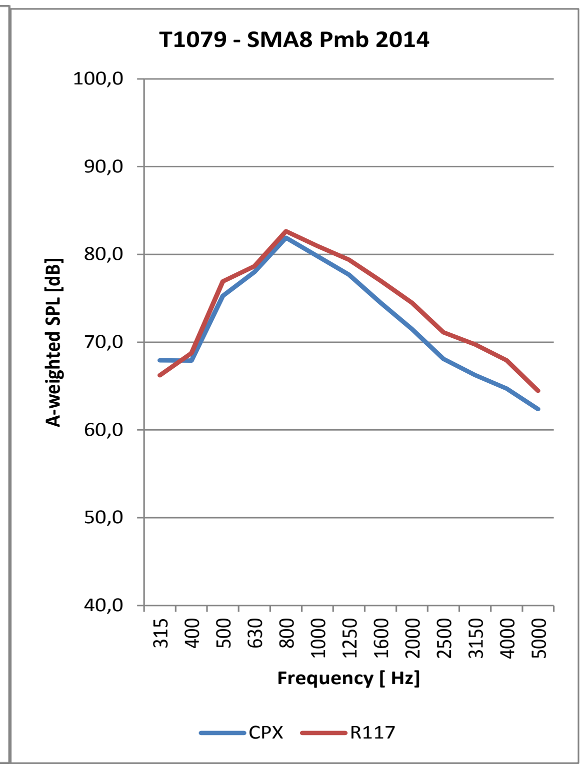

Fig.3 - T1079 on NOR6 SMA8

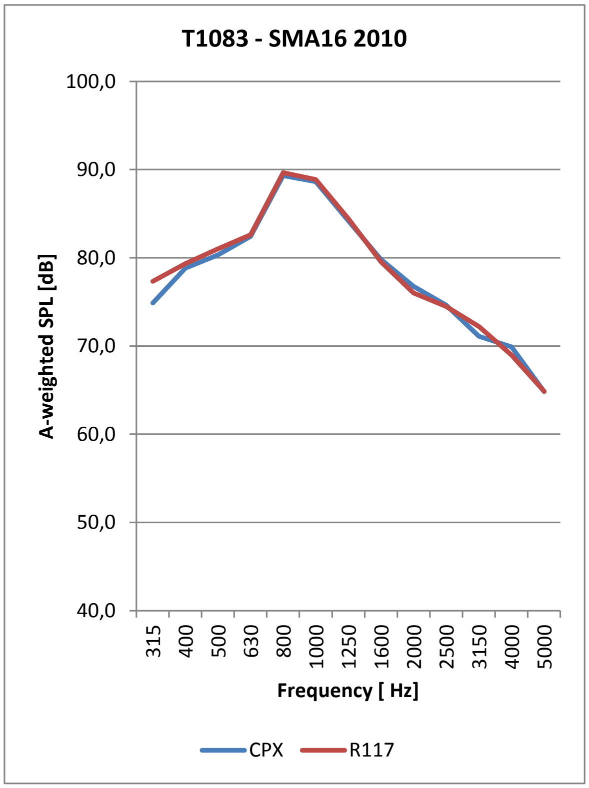

Fig.4 - T1083(EV) on NOR4 SMA16

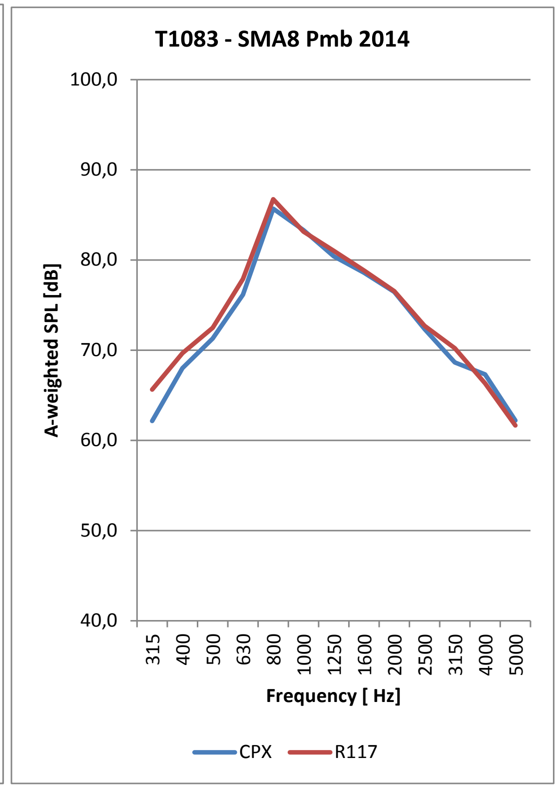

Fig.5 - T1083(EV) on NOR6 SMA8

4.3 Regression analysis

The regression analysis shows that the correlation between the two measuring methods are quite high, with a regression coefficient, r^2, varying from 0.71 to 0.95. Figures 6 and 7 show the regression analysis for two road surfaces; NOR4 SMA16 and NOR6 SMA8.

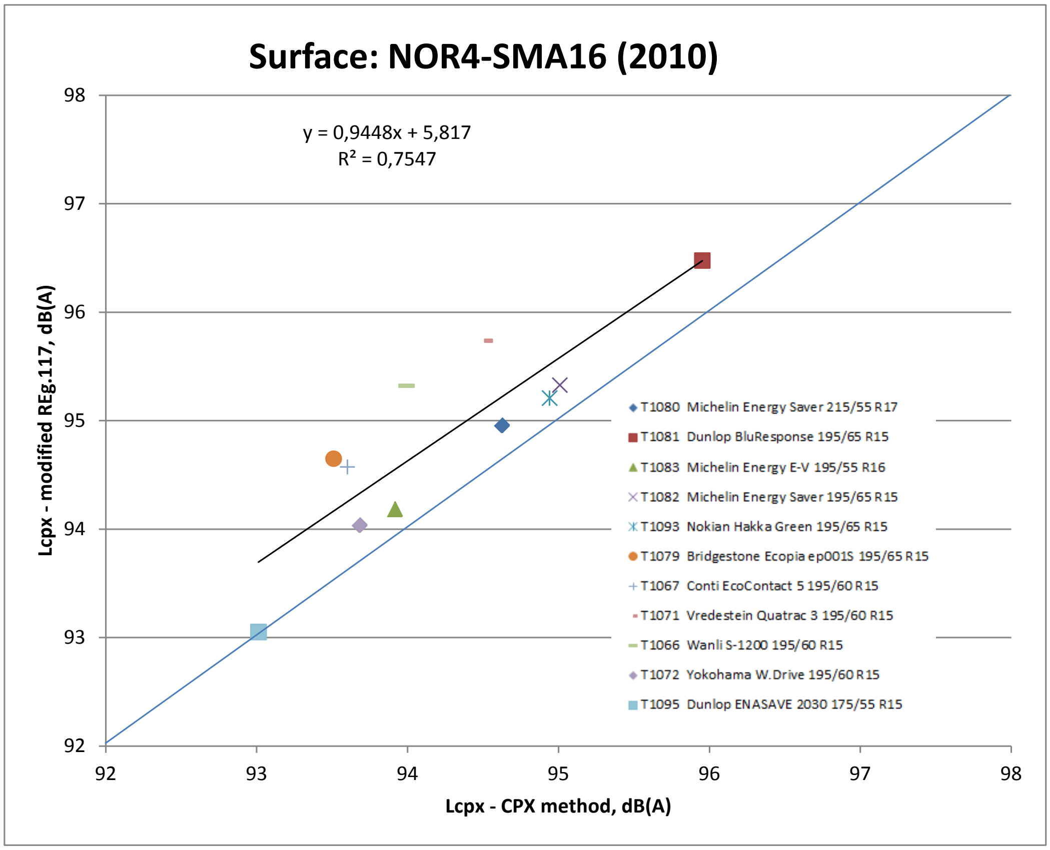

Fig.6 - Regression analysis for surface NOR4 SMA16

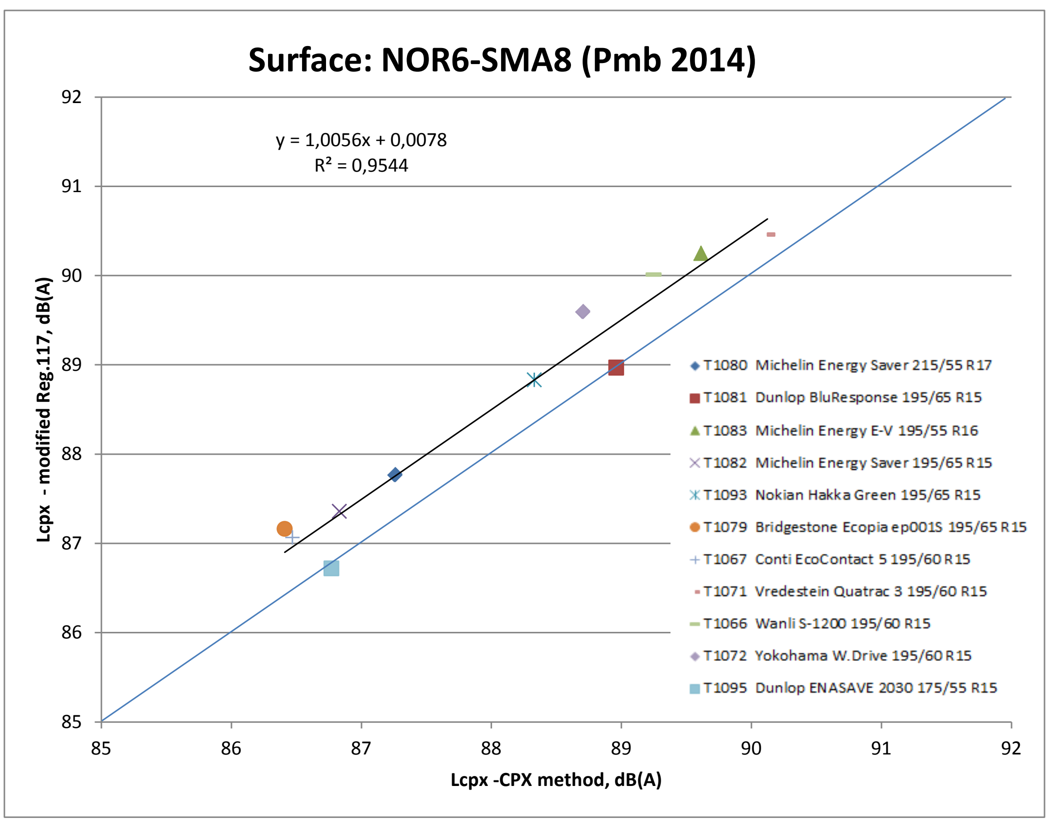

Fig.7 - Regression analysis for surface NOR6 SMA8

4.4 Ranking analysis

As stated in Chapter 2, one of the objectives of this investigation was to investigate the ranking of tyres under the 2 conditions. In figures 8 and 9, the ranking of tyres are shown for two of the surfaces (rough and smooth), NOR5 SMA16 and NOR6 SMA8.
As these figures and figures 6 and 7 from the regression analysis show, the ranking of the tyres is influenced by the 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.

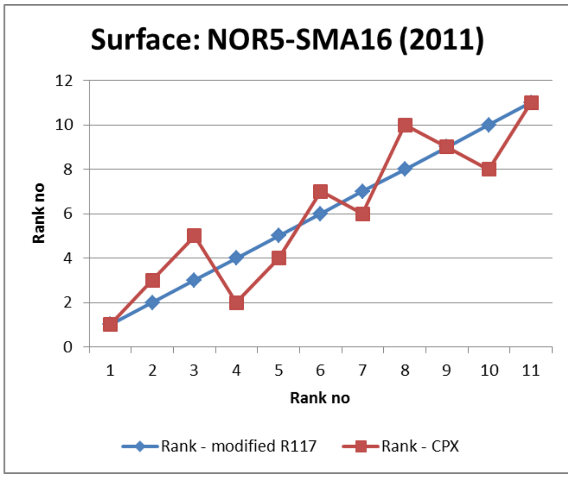

Fig. 8 Tyre ranking on NOR5 SMA16

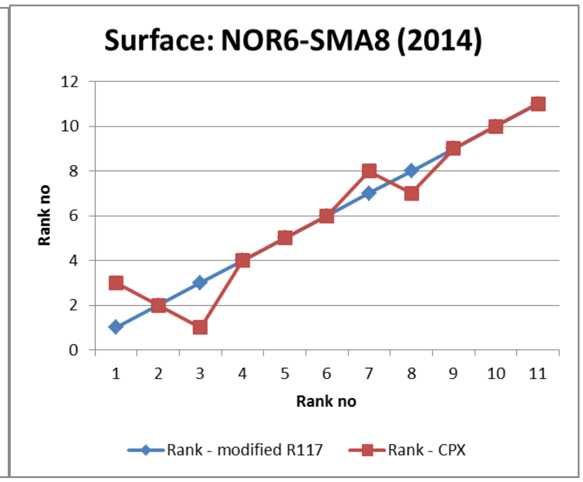

Fig.9 Tyre ranking on NOR6 SMA8

4.5 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 our measurements according to the modified R117 conditions have been mathematically adjusted in the same way. Since the labelling values are based on measurements on an ISO surface (smooth SMA8 type of surface), we have analysed the correlation between truncated levels on the NOR6 SMA8 surface and the labelled noise levels (table 1).

Figure 10 shows the correlation between the results on NOR6 SMA8 and label values. All the tyres have been measured on Polish road surfaces, including a SMA8 near Krakow (Gdow). In figure 11, the correlation between the results on the Polish SMA8 and the EU label vales are shown. Both these 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 road surfaces. Some of 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 is even worse, and in some cases also negative.

This test of load influence has been done at 50 km/h, while the label values are at the reference speed of 80 km/h. On most of the tested surfaces, measurements at both speeds have been made. The ranking of the tyres are almost the same and the noise levels are close to the 30·log(v) speed relationship.

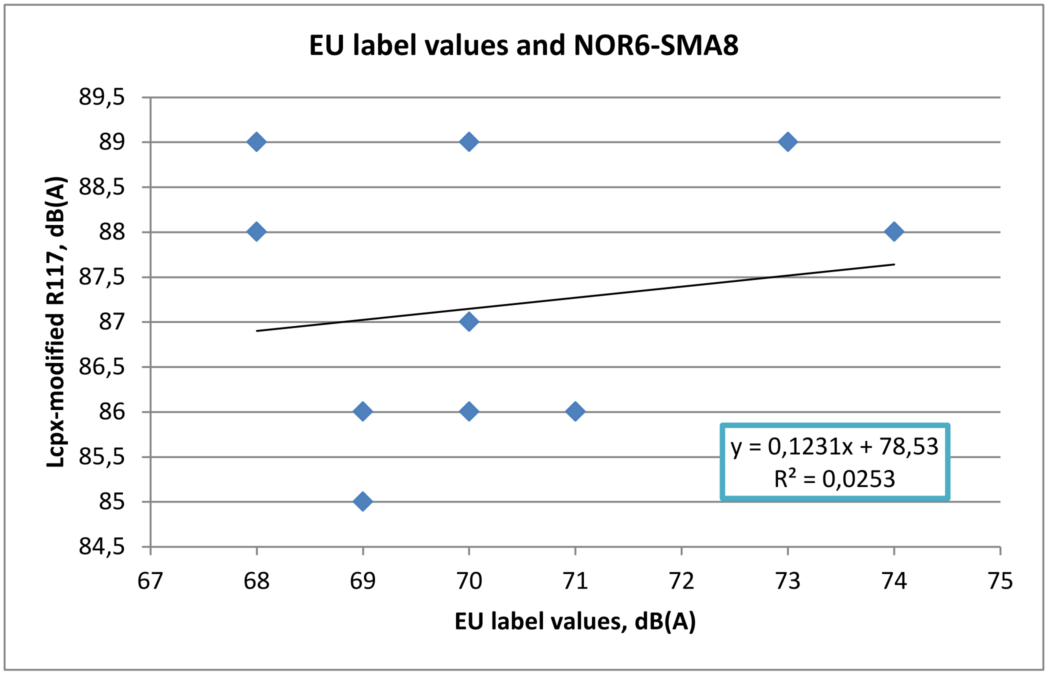

Fig.10 – Correlation between measurements on NOR6 SMA8 and EU noise label values

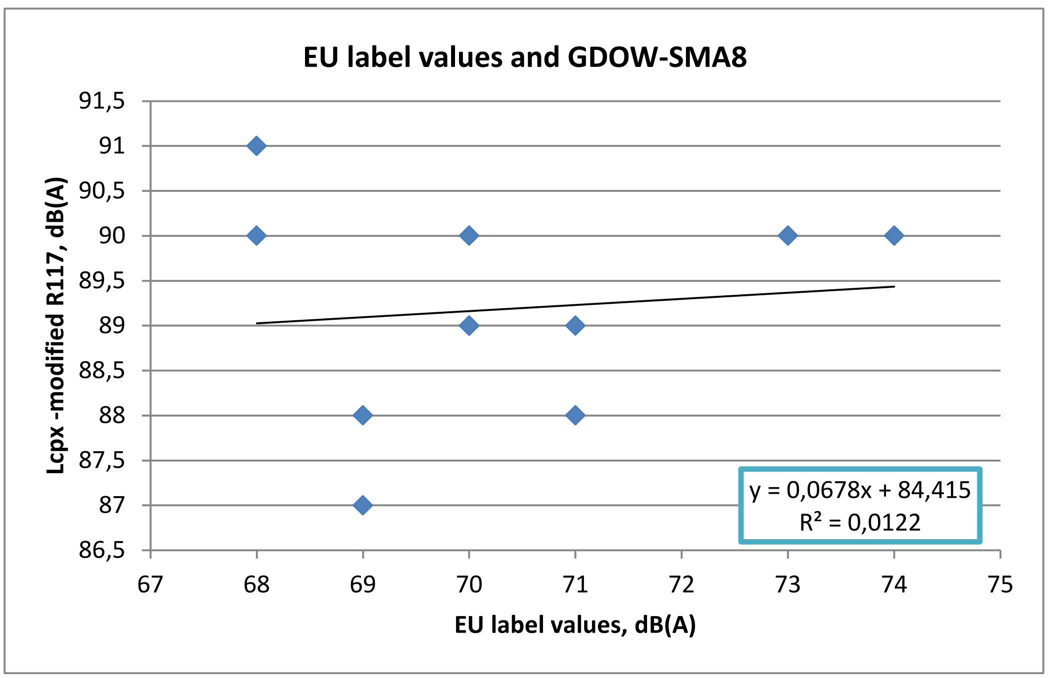

Fig.11 – Correlation between measurements on GDOW SMA8 and EU noise label values

In another experiment by TUG in Gdansk[6], 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 our experiment. TUG has also investigated the influence of load and tyre pressure on their drum facilities[7]. 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.

5 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, more energy efficient, and with less noise impact on the society. However, there is a concern that the present use of an artificial road surface (ISO 10844) 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.

The results of this experiment show that the noise level increase an average of 0.6 dB(A) with added load. Adding load also affects the noise ranking of tyres. The difference in test conditions between the CPX method and ECE Reg.117 do not explain the lack of correlation with the noise label values and measured levels on normally used dense surfaces.

6 ACKNOWLEDGEMENTS

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