Tyre/road noise of passenger car tyres, including tyres for electric vehicles – road measurements

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Summary

The paper presents the results from CPX measurements of tyre/road noise performed for selected passenger car tyres, including the tyres especially designed for electric vehicles. The tyres have been measured when rolling on several typical road surfaces in Norway and in Poland. In addition, the tyres have been measured on some very low noise road surfaces, such as the poroelastic road surface (PERS). The measurement results show that there is a potential reduction of tyre/road noise of 5-7 dB, when using optimized tyres for electric vehicles in combination with low noise porous surface. Introducing a poroelastic surface, the noise reduction potential is even higher: 10-12 dB. On the Norwegian road surfaces, only two tyres developed for electric vehicles have been measured. However, one of these tyres proved to be the quietest on most surfaces, approximately 2 dB below the average.

PACS no. 43.50. Rq

1. Introduction

In the last couple of years, electric vehicles (EV) have been more commonly used in urban traffic in some countries like Norway. Currently, there are more than 40 000 electric vehicles in Norway and about 15 % of all new vehicles sold are pure electric vehicles. Major economic and user incentives like no VAT, free use of taxi/bus lanes, free parking and free charging of batteries are the main reasons for this popularity. EVs used to be rather simple and small city cars with a limited driving range. Today, the most popular EVs are Nissan Leaf, Tesla Model S, VW eGolf, VW eUP!, BMW i3 and Mitsubishi i-MiEV. For some of these cars special tyres have been developed to increase the driving range, by lowering their rolling resistance (RR). This has been done by narrowing the width, increasing the tyre diameter and optimizing tyre tread, etc. These measures have also a potential to reduce the rolling noise.

Within the Polish-Norwegian research project LEO ("Low Emission Optimised tyres and road surfaces for electric and hybrid vehicles"), a measurement program on tyre/road noise has been conducted on various road surfaces in Norway and in Poland. The aim has been to demonstrate which combination of tyres and road surface yields the lowest noise levels in order to show the potential noise reduction, and also the potential energy reduction.

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2. Measurement lay-out

2.1 Equipment

Basically, the measurements have been made with the CPX trailer of the Norwegian Public Roads Administration. This is a two-wheeled trailer with an enclosure, built by M+P in 2005. Additional measurements in Poland have been made by the Technical University of Gdansk (TUG), with their one wheel CPX trailer, Tiresonic Mk4.

2.2 Measuring method

The measurements have been made according to ISO/DIS 11819-2. However, this method is primarily developed to measure the tyre/road noise influence on road traffic noise, using standardized reference tyres (currently Uniroyal Tiger Paw SRTT and Avon AV4). In the LEO project we aim to compare the noise levels of different tyres on different road surfaces, as well as with the EU label values. Therefore, it was decided to increase the weight of the trailer and the tyre pressure, to meet the requirements of the tyre regulation as given in ECE Reg.117. In this regulation, the load shall be 75 ± 5% of max. load and the tyre pressure 250 kPa. This modification was only done on the Norwegian trailer. During the measurements performed using the Polish trailer the tyre load was fixed to 320 kg and inflation pressure were adjusted to 200 kPa for all tested tyres.

On surfaces, were the posted speed was 80 km/h, measurements at both speeds of 50 and 80 km/h have been performed. On surfaces were posted speed was below 80 km/h, only measurements at 50 km/h were possible. As the noise ranking of the tyres did not change much with increased speed, only the results obtained at 50 km/h are presented in this paper.

2.3 Tyres

In table 1 and 2, the tyres tested respectively by SINTEF and TUG are listed. The tyres T1083, T1076 and T1120 are especially designed to be fitted on EVs (mainly due to low rolling resistance). Tyre T1095 (Dunlop ENASAVE 2030) is widely used in Norway on the EV Nissan Leaf, but can also be found on cars with combustion engines.

2.4 Air temperature correction

In earlier projects, different temperature corrections factors had been proposed and used, depending on the type of road surface. These corrections for dense surfaces varied between -0,03 and -0,08 dB/°C [1]. However, recent investigations [2] have shown that for dense surfaces, the correction should be somewhat larger. The proposal from ISO WG27 is to use a correction factor of -0,10 dB/°C for dense surfaces and -0,05 dB/°C for porous ones. In the ROSANNE project several of the tyres listed in tables 1 and 2 has been measured by TUG under different temperature conditions on the same road surface [3]. The air temperature varied from +

Table 1. Tyres tested by SINTEF

Tyre type	Tyre no	Tyre manufacturer and line	Dimensions
EV tyres	T1095	Dunlop ENASAVE 2030	175/55R15 77V
	T1083	Michelin Energy E-V	195/55R16 91Q
Conventional tyres	T1066	Wanli S-1200	195/60R15 88H
	T1067	Conti EcoContact5	195/60R15 88H
	T1071	Vredestein Quatrac 3	195/60R15 88V M+S
	T1072	Yokohama W.Drive	195/60R15 88T M+S
	T1079	Bridgestone Ecopia ep001S	195/65R15 91H
	T1080	Michelin Energy Saver X Green	215/55R17 94H
	T1081	Dunlop Sport BluResponse	195/65R15 91H
	T1082	Michelin Energy Saver X Green	195/65R15 95T
	T1093	Nokian Hakka Green	195/65R15 95T

Table 2. Tyres tested by TUG

Tyre type	Tyre no	Tyre manufacturer and line	Dimensions
EV tyres	T1076	Conti e.Contact BLUECO@	195/50R18 90T
	T1083	Michelin Energy E-V	195/55R16 91Q
	T1120	Bridgestone Ecopia EP500	155/70R19 84Q
Conventional tyres	T1066	Wanli S-1200	195/60R15 88H
	T1067	Conti EcoContact5	195/60R15 88H
	T1071	Vredestein Quatrac 3	195/60R15 88V M+S
	T1073	Avon ZV5	195/65R15 91V
	T1081	Dunlop Sport BluResponse	195/65R15 91H
	T1077 SRTT	Uniroyal Tiger Paw	225/60R16 97S
	T1063 AAV4	Avon Supervan AV4	195R14C 106/104N

3 to + 28 °C in this experiment. Based on this updated information, the correction factors applied for dense surfaces are given in table 3. For all the porous surfaces, the correction factor of -0,05 dB/°C was used. The reference temperature is +20 °C.
It is interesting to see that the noise levels for tyre T1083 was found to be very little sensitive to air temperature changes [3].

Table 3. Temperature correction factors

Tyre no	Correction factor
T1083 (EV)	-0,039
T1095 (EV)	-0,100
T1066	-0,114
T1067	-0,132
T1071	-0,100
T1072	-0,100
T1079	-0,139
T1080	-0,100
T1081	-0,141
T1082	-0,100
T1093	-0,100

3. Measurement results

3.1 Measurements performed by SINTEF

A total number of 14 surfaces (7 in Norway and 7 in Poland) were included in the test program. All the surfaces were on trafficked roads. The surfaces in Norway consisted of one SMA8, four SMA11 and two SMA16, (see table 4). The NOR6-SMA8 and the NOR7-SMA11 were newly laid surfaces, not exposed to winter conditions and studded tyres.
The surfaces in Poland included one double layer porous surface (GDOW-DPA), two SMA8, three SMA11 (the surface designated KOS-SMA11-R was with the addition of rubber to the bitumen) and one experimental poroelastic surface PERS-PL1. This surface was laid within the PERSUADE project [4]. Unfortunately, the surface had to be removed shortly after our measurements, due to material break up.
The measurement results are shown in table 4. The results obtained on typical Norwegian surface, NOR1-SMA11 (4 years old) are shown in figure 1. The results from a selected Polish surface, PG-SMA8-GDR (2 years old when measured), are shown in figure 2. The tyres developed for EVs are marked in the figures.

3.2 Measurements performed by TUG

In table 5, the results from the measurements with the TUG trailer are shown. These results cannot be directly compared with the results with the Norwegian trailer, due to differences in measuring conditions (single wheel trailer, with different load and tyre pressure).
Figure 3 shows the results obtained on the PG-SMA8-GDR surface. The results on the double layer porous surface GDOW-DPA are presented in figure 4.

Table 4. SINTEF measurements at 50 km/h. Blue colour is for EV tyres

50 km/h	TEST TYRE										
ROAD SURFACE	T1066	T1067	T1071	T1072	T1079	T1080	T1081	T1082	T1083	T1093	T1095
NOR1-SMA11	94,1	93,2	94,0	92,3	93,2	93,3	95,4	93,5	92,5	93,8	91,4
NOR2-SMA16	95,6	94,9	95,9	94,3	94,87	95,4	96,4	95,8	94,3	95,5	93,5
NOR3-SMA11	95,2	94,4	95,5	93,8	94,3	94,7	96,3	95,3	94,1	95,1	92,9
NOR4-SMA16	95,3	94,6	95,7	94,0	94,6	95,0	96,5	95,3	94,2	95,2	93,1
NOR5-SMA16	95,4	94,9	95,8	94,1	94,8	95,1	96,6	95,6	94,5	95,6	93,1
NOR6-SMA8	90,0	87,1	90,5	89,6	87,2	87,8	89,0	87,4	90,3	88,8	86,7
NOR7-SMA11	92,7	91,1	92,9	91,4	90,9	91,2	93,6	91,8	90,9	92,4	89,8
PG-SMA8-GDR	90,5	88,8	91,8	90,6	89,3	90,1	91,4	90,4	90,0	90,4	88,1
GDOW-DPA	89,4	86,9	89,4	88,1	88,4	88,1	89,7	88,6	88,0	89,0	86,2
GDOW-SMA8	90,7	88,8	91,7	90,6	88.9	90,0	91,4	90,0	90,7	90,7	87,8
PERS-PL1	83,6	82,8	84,7	83,8	84,1	84,2	84,6	84,0	83,7	84,0	82,1
PERS-PL1-REF-SMA11	93,7	92,7	93,9	92,4	92,3	94,0	95,4	94,1	93,2	94,6	91,0
KOS-SMA11-R	91,8	90,5	91,5	90,4	89,6	90,6	92,9	91,5	90,0	91,9	88,3
KOS-SMA11	92,1	91,7	92,1	91,2	91,4	91,5	94,3	94,4	90,9	94,6	88,7

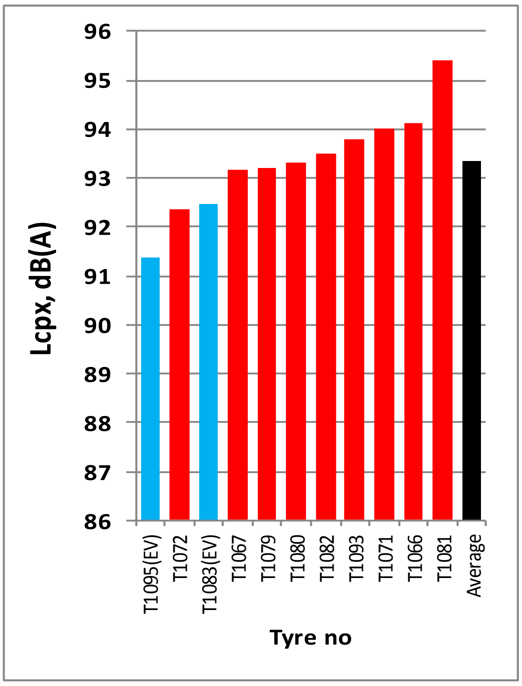

Figure 1. SINTEF, NOR1-SMA11

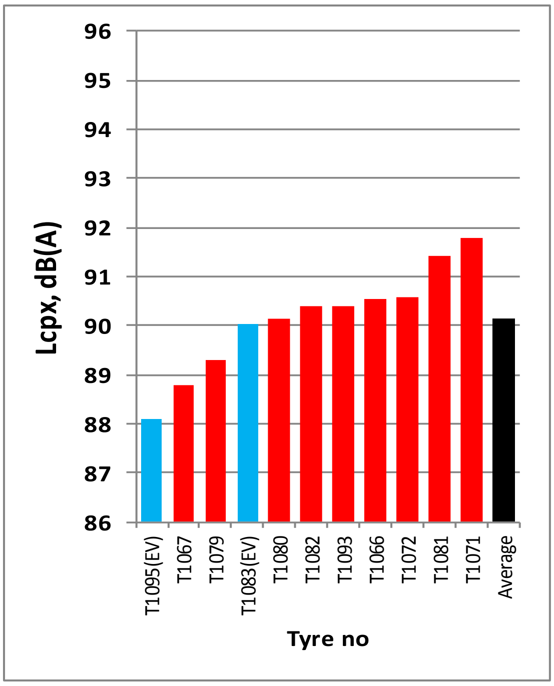

Figure 2. SINTEF, PG-SMA8-GDR

Table 5. TUG measurements at 50 km/h. Blue colour is for EV tyres, gray for standard reference tyres

50 km/h	TEST TYRE												
ROAD SURFACE	T1063 AAV4	T1066	T1067	T1071	T1073	T1076	T1077 SRTT	T1079	T1081	T1083	T1087 AAV4	T1097 SRTT	T1120
PG-SMA8-GDR	89,6	88,3	87,3	88,7	85,5	88,0	88,4	87,2	89,6	89,3			
GDOW-DPA						86,3					87,9	86,9	85,1
PERS-PL1						83,3					82,1	82,0	81,4
PERS-PL1-REF-SMA11						92,9					92,6	92,2	90,2
KOS-SMA11-R	91,0					89,7	90,2			89,7			
KOS-SMA11	91,2					89,8	90,3			90,3			

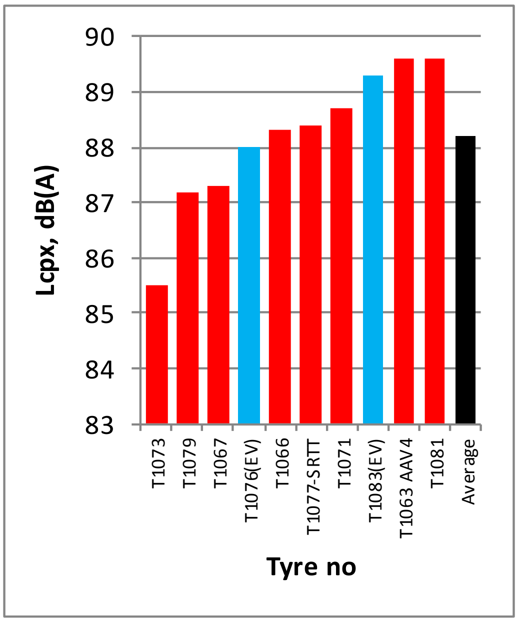

Figure 3. TUG, PG-SMA8-GDR

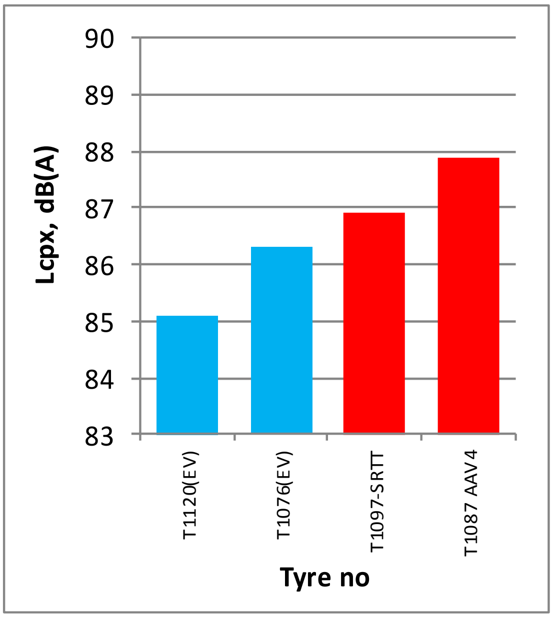

Figure 4. TUG, GDOW-DPA

4. Discussion of results

Measurements with the Norwegian trailer show that one of the tyres especially designed for EVs, tyre designated T1095, Dunlop ENASAVE 2030 is the quietest tyre on almost all surfaces tested. However, this is the narrowest tyre (175/55) and also the load of the tyre was the lowest of all (about 20% lower than average), which may be an important parameter. In general, this tyre gives a tyre/road noise level about 2 dB below the average of the other tyres tested. The other EV tyre (T1083) was found to be 0,5-1,0 dB quieter than the average of conventional tyres on the Norwegian surfaces. On the Polish surface, T1095 was again the quietest tyre, while the other EV tyre was close to the average (figure 2).

However, measurements with the TUG trailer on the SMA8 surface (figure 3) showed an average performance of the EV tyre T1076, while T1083 had a noise level of about 1 dB above the average. One should remember that the tyre load was equal for all tested tyres despite on differences in their max load index.

Table 4 shows that the Dunlop EV tyre (T1095) on the poroelastic road surface (PERS-PL1) has a noise level that is 14,5 dB lower than the noisiest tyre (T1081) on the noisiest road surface (NOR5-SMA16). Comparing the same tyres on the poroelastic surface with the levels on the old SMA11 surface at the location of the PERS, we find the same difference (14,2 dB). Comparing the results on the Norwegian SMA11/SMA16 surfaces with the Polish double layer surface (GDOW-DPA), the difference is in average about 5-7 dB.
Both SINTEF and TUG did measure on the PG-SMA8-GDR surface (in Gdansk, Poland). The tyres selected were somewhat different, and also the tyre load and inflation pressure were different. Thus the obtained noise levels cannot be directly compared. However, the difference between the quietest tyre and the noisiest one is about the same value of approximately 4 dB.

TUG has measured a few tyres on some of the other Polish surfaces (table 5). On the double layer porous asphalt surface the Conti e.Contact tyre (T1120) was about 2 dB below the SRTT tyre (figure 4).

5. Conclusions

The conducted measurements show that there is a potential for reduction of tyre/road noise using tyres especially developed for EVs, combined with low noise road surfaces (porous surfaces or surfaces with smaller chipping sizes). Both in Norway and in Poland, the potential reduction is in the range of 2-3 dB. Introducing a poroelastic surface, the potential reduction seems to be even larger - up to 10-12 dB in comparison to commonly used SMA11/16 surfaces.

The measurements with the Norwegian CPX trailer were performed with load and tyre pressure according to the ECE Reg.117. The results did show that EV tyres can be in the low noise range, comparing to the average of conventional tyres. However, the number of tested tyres were too small, to make firm conclusions.

In parallel to the reported road measurements a similar laboratory tests were conducted at the Technical University of Gdańsk on roadwheel facilities equipped with five different road replica surfaces. All tests were performed using the same load and inflation pressure according to the ISO/DIS 11819-2 standard. The obtained results showed that tyres developed especially for electric vehicles generate similar tyre/road noise like tyres for conventional vehicles [5]. They are neither quieter nor noisier, although their construction and dimensions may differ.

Those findings are similar to results obtained during road measurements performed by TUG as both tests, road and laboratory, were performed with the same measurement conditions – the same tyre load and inflation pressure were applied for all tested tyres.

Acknowledgements

The measurements were performed within the Polish-Norwegian research project LEO "Low Emission Optimised tyres and road surfaces for electric and hybrid vehicles" funded by the Polish National Centre for Research and Development (NCBiR) within the Polish-Norwegian Research Programme, CORE (Grant Agreement 196195/2013).

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