Noise Generated by Tyres Designed for Electric Vehicles - Results of Laboratory Experiments

Jerzy Ejsmont[1]
Beata Świeczko-Żurek
Stanisław Taryma
Piotr Mioduszewski

Technical University of Gdańsk, Mechanical Faculty, ul. Narutowicza 11/12, 80-233 Gdańsk, Poland

Summary
A few years ago, electric and hybrid vehicles were rarely seen on public roads and were considered more as exotic curiosities or even as a sign of extravagance than a practical means of transport. Nowadays the situation has changed significantly. This was caused both by the technical development and legislative actions, as well as the organizational nature promoting the purchase and use of low-emission vehicles. Electric vehicles have a completely different sound emission characteristics than conventional cars. At low speeds, the electric and hybrid vehicles driven in electric mode are almost noiseless. Ironically, the noise levels of electric vehicles are so low, that they constitute a safety threat as cars approach pedestrians without audible warning noise. In the USA, the legislative work is in progress to introduce obligatory fitting of electric vehicles with devices emitting warning sound when moving at speeds below 30 km/h. Technical development of electric vehicles has created a need of tyres dedicated for them. These tyres are primarily characterized by low rolling resistance, because tyre rolling resistance essentially affects the range of vehicles, especially at low and moderate speeds. It is believed that a relatively small driving range of electric vehicles is a major obstacle in their dissemination. Tyres for electric cars generally differ from conventional ones in sizes, patterns and heights of the tread. Due to these differences, the noise generated by those tyres may also vary. This paper presents the results of laboratory measurements of tyre/road noise of tyres specially developed for electric and hybrid vehicles. The tests were performed at the Technical University of Gdansk, Poland on the roadwheel facilities equipped with replica road surfaces including an experimental poroelastic road surface - PERS. A wide selection of tyres was tested, including tyres of sizes significantly different from commonly found in conventional cars.

PACS no. 43.50.Ed

1. Introduction

Electric cars designed for urban use impose different requirements on tyres and road pavements than conventional vehicles. First of all, city vehicles are not intended for high speed driving and what is more, generally they are not frequently exposed to ride in very difficult road conditions (unpaved roads or deep snow). What follows, it allows a lower tyre grip for electric vehicles, a lower lateral stiffness, and even less resistance to wear. If traffic of heavy vehicles is limited, the road surfaces in urban areas are less subjected to heavy loads than highways and rural roads, thus high texture and high load capacity are not required. On the other hand, low rolling resistance is critical, as the most important problem of small electric cars is, in addition to their higher price, a very small operating range causing the need for frequent and time consuming battery charging. With a few exceptions practical range of electric vehicles is limited nowadays to 150 - 180 km. More and more leading tyre manufacturers, recognizing this problem, design special tyres for electric vehicles that exhibit ultra-low rolling resistance.

[1] jejsmont@pg.gda.pl

To reach this goal, the Electric Vehicle (EV) tyres have certain particularities that may, or may not, influence also other important tyre parameters including tyre/road noise. This paper presents some of those particularities and compares tyre/road noise emitted by EV tyres in relation to other market tyres.

2. How EV tyres differ from tyres for "general use"

There is no single solution leading to a low rolling resistance tyre, so the influence of several constructional parameters must be considered and balanced. Some of the most important ways leading to achievement of tyre rolling resistance decrease are listed below.

- big outside diameter,
- big width,
- low aspect ratio,
- hard rubber compounds,
- low hysteresis of carcass and tread materials,
- stiff belt,
- thin tyre sidewalls,
- small tread elements and many sipes (lamellas),
- low tread depth.

According to [1] all of the mentioned tyre properties influence, or may influence tyre/road noise.

3. Test tyres and pavements

All measurements reported in this paper were performed at the Technical University of Gdańsk on roadwheel facilities with drums of 1.5m, 1.7m, and 2.0m diameter [2]. Drums of the facilities were covered with replica road surfaces reproducing texture of different road pavements. Details of the replicas are presented in Tab. I.
Four tyres specially designed for electric vehicles were selected and used during the experiment. They are described in Tab. II and shown in Fig. 1.
Nine tyres were selected to represent typical market tyres for passenger cars. Their data are also included in Tab. II.
During the measurements tyres were loaded to 320 kG (3 140N) and inflated to 200 kPa (capped inflation pressure). Tests were performed at speeds: 50, 80 and 100 km/h.

Table I. Replica road surfaces used during measurements.

Symbol	Surface Type	Location	Description
DACr15	Replica of Dense Asphalt Concrete	Roadwheel Facility 1.5m	Polyester laminate replica made on the basis of ECE/GRB recommendations
PERSr17	Poroelastic road surface	Roadwheel Facility 1.7m	Porous surface made on the basis of mineral and rubber aggregate and polyurethane resin. Pavement suitable for road and drum use, very smooth and flexible.
DAC16r2 0	Replica of dense asphalt concrete with 16 mm aggregate	Roadwheel Facility 2.0 m	Polyester laminate replica made on the basis of a typical DAC 16 mm (rather high texture)
ISOr20	Replica of ISO reference surface	Roadwheel Facility 2.0 m	Polyester laminate replica made on the basis of the reference road surface ISO 10844 (medium texture)
APS4r17	Replica of surface dressing 8/10 mm aggregate	Roadwheel Facility 1.7m	Polyurethane /mineral replica of a single layer surface dressing 11 mm (very high texture)

Table II. Test tyres.

Type of tyre	Designation	Tyre description
EV	**T1075**	Continental, Econtact BLUECO, 195/50R18
	T1083	Michelin, Energy EV Green, 195/55R16
	T1095	Cunlop, ENASAVE 2030, 175/55R15
	T1113	Bridgestone, ECOPIA EP500, 155/70R19
Conventional vehicles	**T1064**	Michelin, PRIMACY HP, 225/60R16
	T1066	Wanli, S-1200, 195/60R15
	T1067	Continental, ECOCONTACT 5, 195/60R15
	T1071	Vredestein, QUATRAC 3, 195/50R15
	T1081	Dunlop, SPORT BLURESPONSE, 195/65R15
	T1087	Avon, AV4 SUPERVAN, 195R14C
	T1093	Nokian, HAKKA GREEN, 195/65R15
	T1097	Uniroyal, TIGER PAW, P225/60R16
	T1112	Pirelli, CINTURATO P1, 195/60R15

4. Results of tyre/road noise measurements

Results of measurements reported in this section are corrected for temperature deviations from the nominal temperature of 20ºC. The results clearly indicate, that for all tested speeds the ranking of tyres is very similar (see Fig. 2) so in the following part only data for 80 km/h are presented. In Fig. 2 and the following figures results for electric vehicles tyres are marked with blue color while others are red. There are also labels "EV" on bars representing EV tyres.

Figure 1. Tyres designed for electric vehicles.

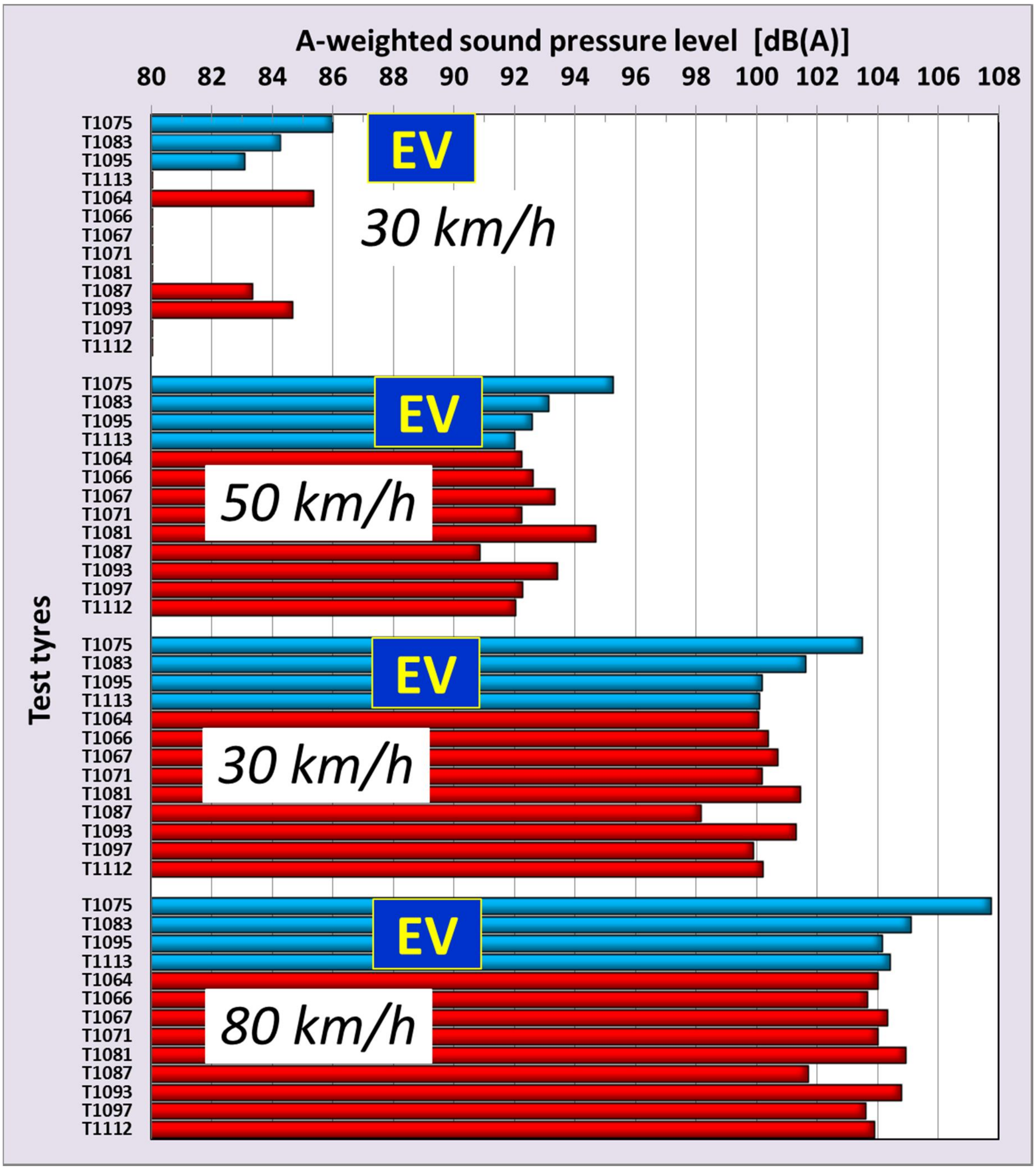

Figure 2. SPL for tyres rolling on APS4r17

Similar tests were also performed on other replicas and the results (for 80 km/h) are presented in Figures 3 - 6. Due to budget restriction not all tyre/pavement combinations were tested.

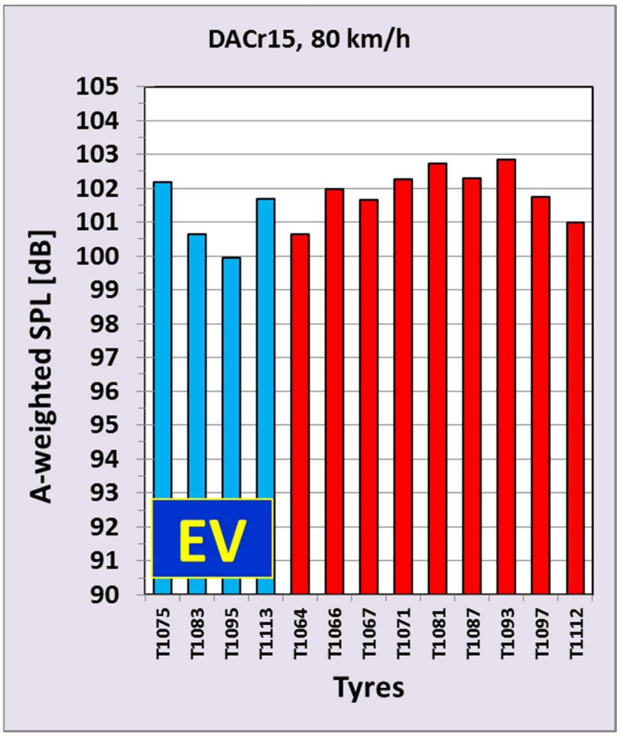

Figure 3. SPL for tyres rolling on DACr15.

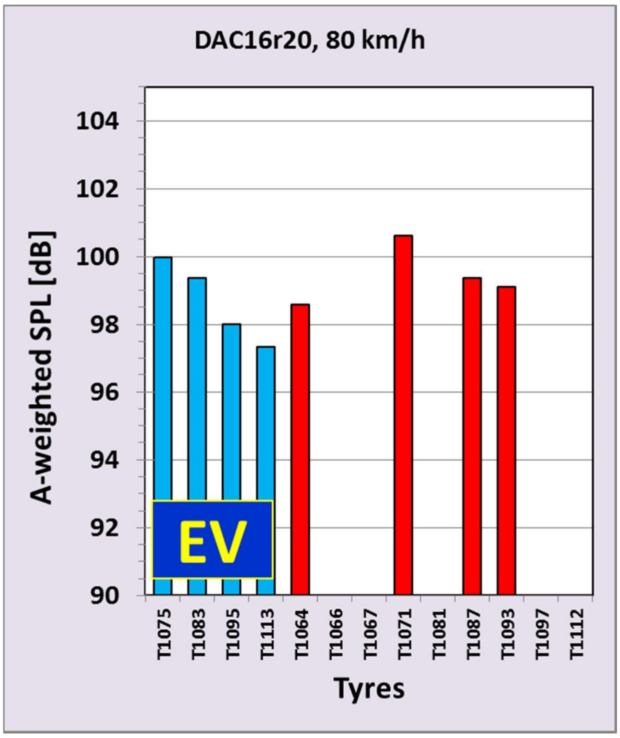

Figure 4. SPL for tyres rolling on DAC16r20.

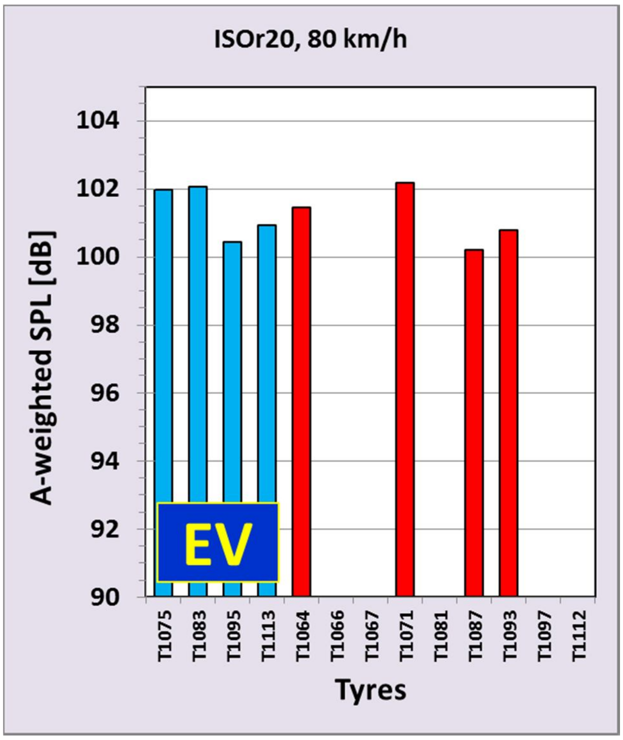

Figure 5. SPL for tyres rolling on ISOr20.

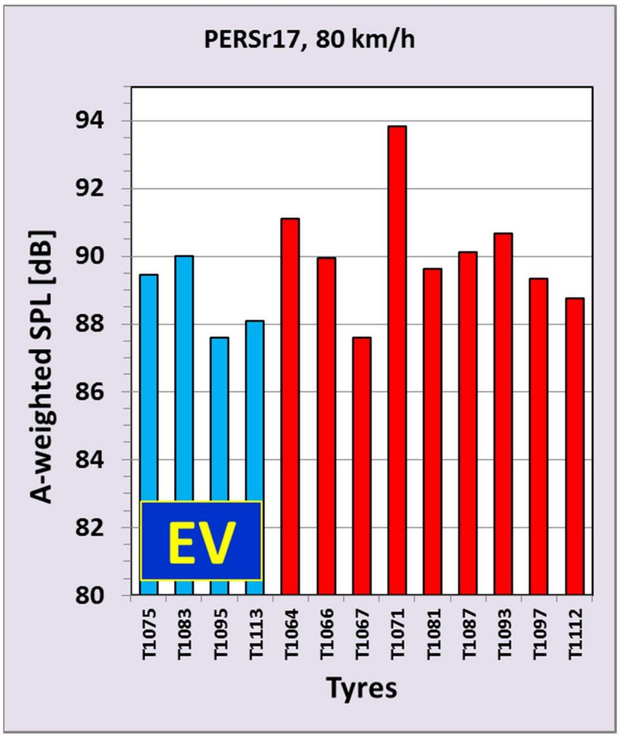

Figure 6. SPL for tyres rolling on PERSr17.

The results indicate that EV tyres, as a rule, generate similar tyre/road noise like tyres for general use. Their are neither very silent nor very noisy although their construction and dimenssions may differ. Table III summarizes the results and contains average sound pressure levels obtained on different pavements. Neverheless one tyre (T1113) of very special dimenssions - 155/70R19 is clearly less noisy than other tyres. It results from its big outer diameter and narrow tread. This tyre is intended for electric car BMW i3, that is a car that was designed ground up as an electric car. This made possible to use tyres of very different size than in conventional small and medium cars.

Table III. Averaged results (for 80 km/h).

Pavement	Tyre type	Averaged A-weighted SPL [dB]
APS4r17	AV	101.3
	general use	100.2
DACr15	AV	101.1
	general use	101.9
DAC16r20	AV	98.7
	general use	99.4
ISOr20	AV	101.4
	general use	101.2
PERSr17	AV	88.8
	general use	90.1

It is interesting to note, that tyres for electric vehicles are, in average, less noisy than general use tyres when rolling on poroelastic road surfaces. Such surfaces are being developed for noise reduction in urban areas. It seems that they team up well with EV tyres.

5. Rolling resistance of tyres designed for electric vehicles

Technical University of Gdańsk performed road and laboratory rolling resistance tests of tyres designed for electric vehicles. Selected results obtained in the laboratory are presented in Fig. 7. Tyres were tested according to ISO 28580 [4] on pavements DAC16r20 and APS4r17.
Coefficients of Rolling Resistance of tyres designed for electric vehicles are 15 - 20% lower than for general use tyres. This may induce 5-8% decrease of energy consumption for cars driving with low and medium speeds [5].
Tyre T1095, that is designed for electric vehicles has higher rolling resistance coefficient than three other EV tyres. This is however related to its small size. Small tyres exhibit higher rolling resistance than tyres with big outer diameter. Neverheless this tyre is not worse than bigger tyres for general use.

6. Conclusions

Tyres intended for electric vehicles generate noise similar to general use tyres. Small decrease of noise may be, however seen for narrow tyres with big outer diameter that may be more common in future electric vehicles due to their low rolling resistance.

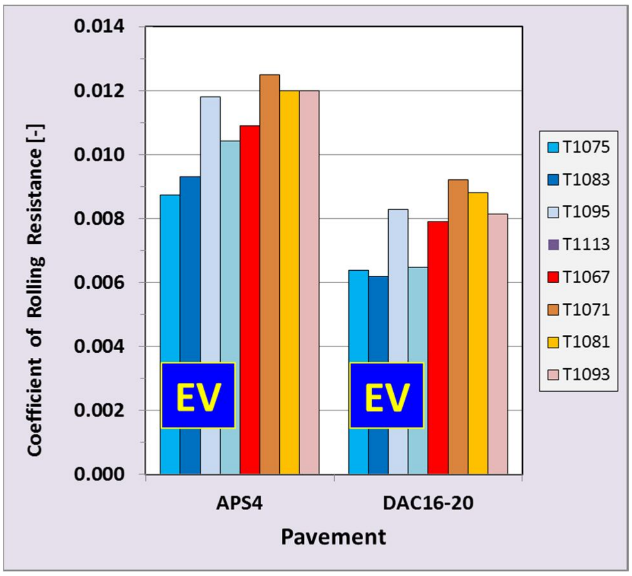

Figure 7. Coefficients of rolling resistance.

Acknowledgement

This project has been funded by the Polish National Centre for Research and Development (NCBiR) within Polish-Norwegian Research Programme CORE, project LEO (Grant Agreement 196195 /2013).

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