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LOW NOISE TIRES FOR HYBRID AND ELECTRIC VEHICLES

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Low Emission Vehicles that are hybrid and electric cars may benefit from specially designed tires that are optimized for driving conditions typical for such vehicles. It is possible that in the future Low Emission Vehicles, especially passenger cars, will substitute conventional vehicles in all applications, however for the time being they are mostly used in urban and suburban areas. Urban traffic has a rather low demand for grip performance of tires due to relatively low speeds. At the same time it imposes high demands for low noise emission of tires, as traffic noise is one of the most difficult environmental problem in towns. For electric vehicles there is also a very high need to ascertain necessary vehicle's range of operation by lowering the rolling resistance of tires as much as possible. The paper discusses selected aspects of hybrid and electric tires' use and presents results of noise measurements performed for tires that are specially designed for LEV's or that are commonly used in such vehicles. The measurements were performed both at the laboratory using roadwheel facilities with drums covered by replica road surfaces and on the road by the Close Proximity Method. As supplementary information, to prove that there is no conflict between low noise and low rolling resistance tires, rolling resistance of tested tires is presented.

1. Introduction

Road traffic transportation has a major negative impact on the environment in all developed countries. Of special concern is the emission of greenhouse gases such as CO_2 and road traffic noise. Although presently the vehicles using internal combustion engines vastly dominate traffic in all countries, the prognoses predict intensive development of alternative designs, i.e. hybrid (HV) and electric (EV) vehicles. In many countries (for example in Norway) users of electric and hybrid vehicles are rewarded in certain ways, for example by being exempted from parking fees and city centre tolls or are permitted to use bus lanes.

Current development of passenger car tyres for electric and hybrid vehicles (classified al Low Emission Vehicles - LEV's) focuses on reduced rolling resistance, as beside high price of LEV's the relatively short range of operation for HV's and especially EV's is considered to be the most important obstacle for their common acceptance. At the same time, some new types of road surfaces are mainly developed to reduce road traffic noise. It seems that there is an unexploited potential for a combined technology that reduces energy consumption and road traffic noise in urban areas.

Tire/road noise is the dominant noise sources of modern vehicles. For passenger cars with internal combustion engines it starts to dominate other vehicle noise sources at speeds of 30-40 km/h. In case of electric and hybrid cars this trans-over speed is much lower as the power train noise is lower. Electric vehicles do not have any strong external power unit noise sources. At very low speeds, they are significantly quieter than vehicles with internal combustion engines. This is also the case for hybrid vehicles running in electric mode only. It has already been demonstrated that for speeds below 30 km/h the noise reduction for EV's is between 5 dB(A) and 15 dB(A) in comparison to classic cars of similar size[1]. In fact "soundless" electric cars are considered to be responsible for growing number of accidents and U.S. National Highway Traffic Safety Administration started to work on legislation requiring that LEV's driving below 18 mph (29 km/h) must emit artificial warning sounds[2]. At speeds more commonly used in urban conditions (between 30 and 50 km/h), the tire/road noise is dominating so EV and HV emit similar noise like vehicles with internal combustion engines. It would therefore be a great benefit if the tires and road surfaces could be optimized to reduce the noise to accepted level (safe but not annoying) as well as to reduce CO_2 under urban conditions. Unfortunately, it is not possible to design tires that would be noisy at very low speeds and quiet at high speeds as tire/road noise is proportional to the logarithm of speed.

The current state of the art for tires is that all the major tire manufacturers have or are about to introduce tires specially developed for electric and/or hybrid vehicles. Examples of such tires are the Continental e.Contact BLUECO; Bridgestone Ecopia EP001S, Michelin Energy E-V and the Nokian eLine. The main focus has been to develop tires with low rolling resistance, in order to increase operating range of low emission vehicles. Since many of these types of vehicles are mainly developed and designed for city traffic, and thus for speeds lower than 100 km/h, there is a still potential for making these tires also more silent. Normal passenger car tires must be designed to be safe at much higher speeds, often in excess of 200 km/h. This requirement imposes serious limitations on the design of tires and their noise characteristics, as the tires need more weight, increased rubber hardness, low profile ratios, etc.

2. Required characteristics of tires intended for use in hybrid and electric urban vehicles

Electric and hybrid vehicles intended for urban use impose specific requirements on tire design. In contrast to typical car tires that are often used for high speed highway driving, the urban tires are used with low and moderate speeds so dry or wet skid resistance and cornering stiffness are less important. On the other hand, low rolling resistance has top priority. Simulations performed at the Technical University of Gdańsk (TUG) have shown that a decrease of rolling resistance by 30% increases operational range of electric vehicle by 10% (in urban conditions and in suburban driving). It is also desirable to use low noise tires on vehicles driving in urban areas, as traffic noise abatement in towns is very complicated due to difficulties with sound barrier use.

Two tires specially designed for electric and hybrid cars and two typical summer tires for conventional vehicles are shown in Fig. 1. In order to reduce tire rolling resistance EV tires have reduced tread pattern thickness, a lot of rather shallow grooves and narrow sipes and very good quality rubber mix. Tire sidewalls and tread belt are very thin and flexible while tire aspect ratio is low. In order to achieve low rolling resistance tires for EV's and HV's should have as big diameter as possible.

There is no obvious conflict between constructional solutions used in low rolling resistance EV tires and requirement of low tire/road noise. However, it is interesting to investigate in detail whether this super low rolling resistance tires are less or more noisy than corresponding tires designed for conventional vehicles. Although tire/road noise may not be adversely affected by low rolling resistance construction, the handling properties, grip and wearing resistance of such tires may be inferior to standard designs.

Figure 1. Comparison of tires designed especially for electric vehicles (two tires on the left) and tires for conventional vehicles (two tires on the right).

3. Results of tire/road noise laboratory measurements

TUG uses two roadwheel facilities to test passenger car tires. One facility (Fig. 2) has a drum covered with replica of rough surface dressing designated as "APS-4" and experimental poroelastic road surface "PERS"[3,4] while other drum has replica of dense asphalt concrete with 12 mm aggregate size.

Figure 2. Tire/road noise testing on drum covered with replica road surfaces.

During the experiments, 15 classic tires and two tires designed for EV's and HV's were tested for noise. The A-weighted SPL's are shown in Fig. 3. The results indicate that tires for LEV's are NOT less noisy than tires designed for classic vehicles. In fact, on dense asphalt concrete (that is on rather typical road surface) and on experimental poroelastic road surface PERS noise emitted by those tires is on average level, while on very rough surface dressing the tires designed for LEV's are the noisiest.

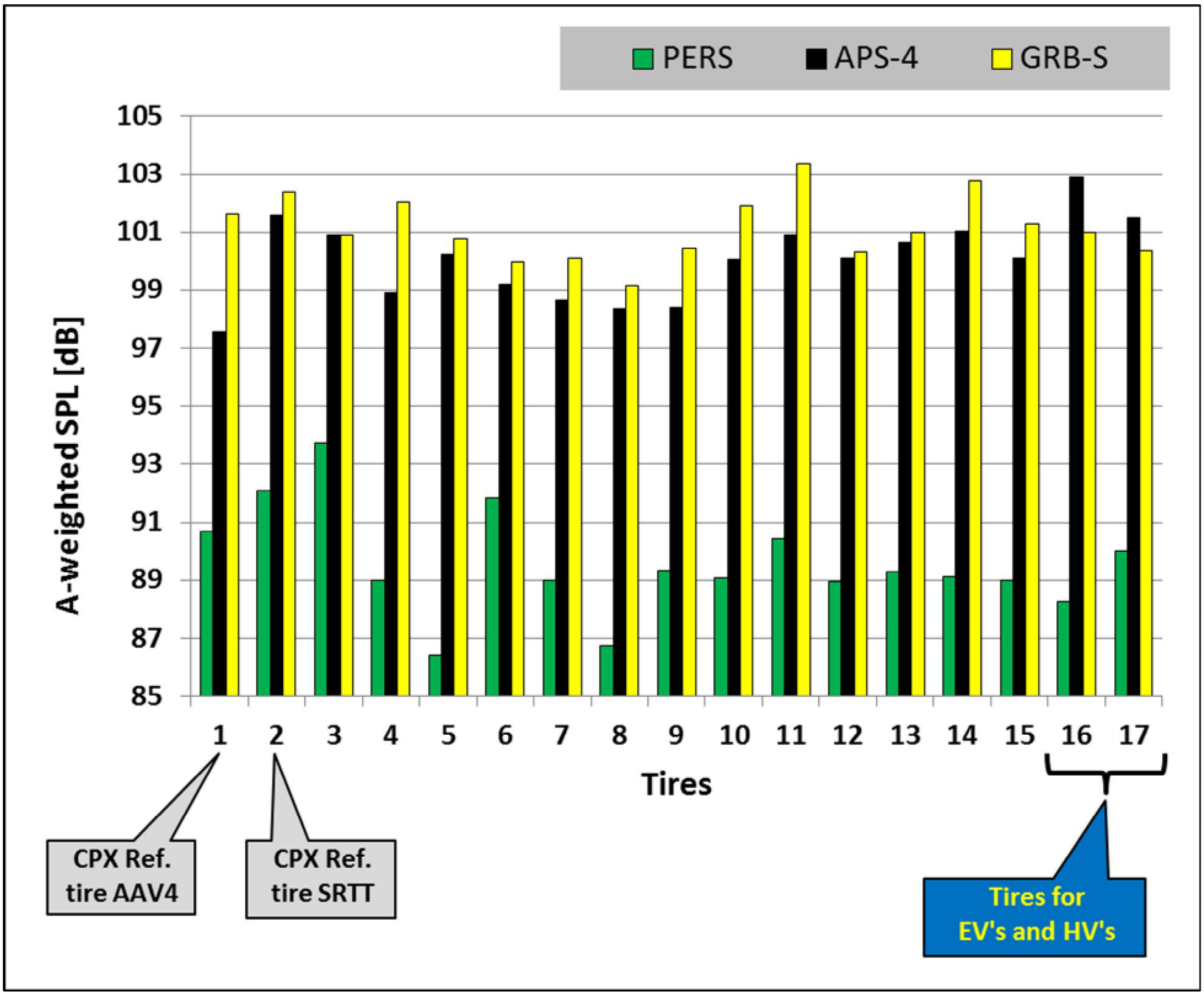

Figure 3. Results of laboratory tests of classic and LEV's tires; speed 80 km/h.

4. Results of tire/road noise measurements performed on the road

For road measurements the test trailer Tiresonic Mk.4 developed and manufactured at TUG was used (see Fig. 4). Tests were performed on the Stone Mastic Asphalt SMA 8 at speeds 50 and 80 km/h. The A-weighted SPL's are shown in Fig. 5. Tires designed for LEV's display similar noise levels like conventional tires and should be considered as "average" in relation to the noise emission. Measurements performed on experimental poroelastic road surface PERS-HET in Sweden (more data in section 5) support the conclusion about "average" noise properties of LEV's tires that are on the market.

Figure 4. Interior of the trailer Tiresonic Mk4 with opened semi-anechoic chamber.

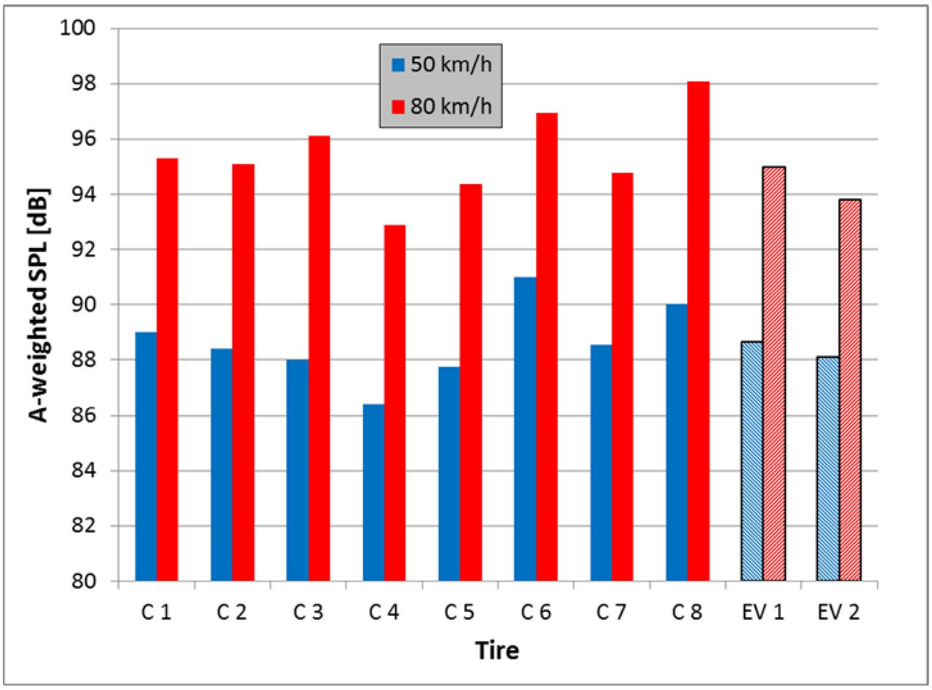

Figure 5. A-weighted SPL measured on road paved with SMA8 for conventional tires (C1- C8) and tires designed for LEV's (EV1, EV2).

5. Results of rolling resistance measurements

The most important feature specific to tires designed for Low Emission Vehicles is reduced rolling resistance in comparison to "conventional" tires. Rolling resistance of tires is very difficult to measure and there are only a few test vehicles that may perform such measurements on the road. One of them was developed at TUG - see Fig. 6.

Figure 6. Test trailer R^2 during rolling resistance measurements.

Rolling resistance of tires designed for LEV's was tested both on roadwheel facility and on the road. Relation between tire/road noise and rolling resistance on replica road surface APS-4 measured by torque method on the drum of 1.7 m diameter is shown in Fig. 7. In Fig. 8 relation between rolling resistance and tire/road noise measured on the experimental poroelastic road surface PERS-HET is shown. Both experiments confirm that tires specially designed for Electric and Hybrid Vehicles are characterized by very low rolling resistance coefficients.

6. Conclusions

Experiments reported above indicate that tires specially designed for LEV's are not particularly quiet. At best they emit tire/road noise of "average" level. One may speculate that there is still field for improvements. When, however, such tires are running on poroelastic road surfaces that are being developed for urban and suburban areas, the noise is very low. LEV's tires reduce rolling resistance considerably, leading to the increase of operational range of Electric Vehicles and saving energy costs.

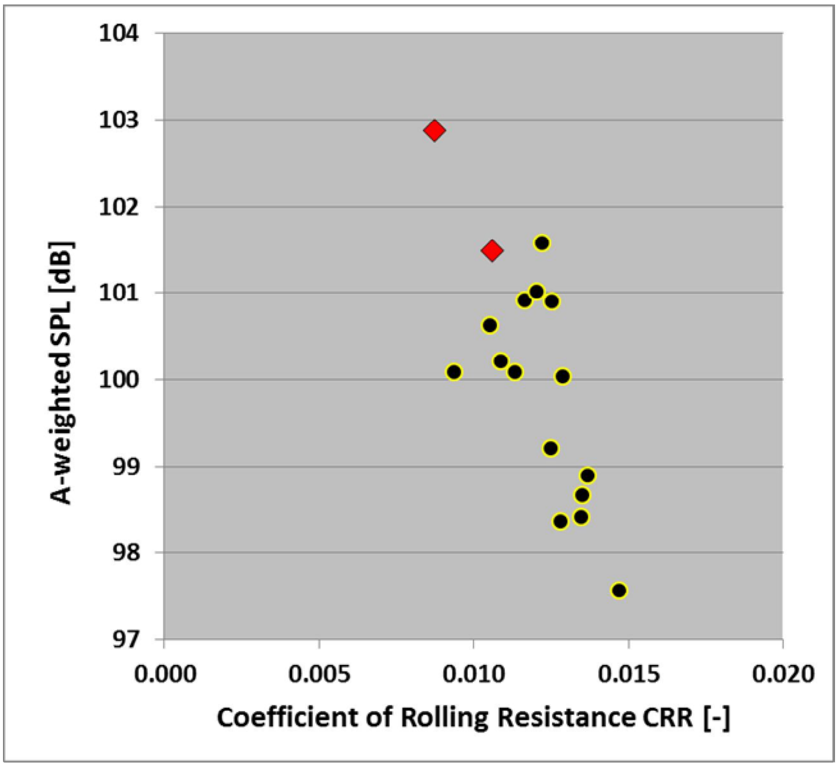

Figure 7. Coefficients of rolling resistance and noise emission for conventional (black dots) and LEV's tires (red diamonds) measured at speed 80 km/h on replica of rough surface dressing APS-4.

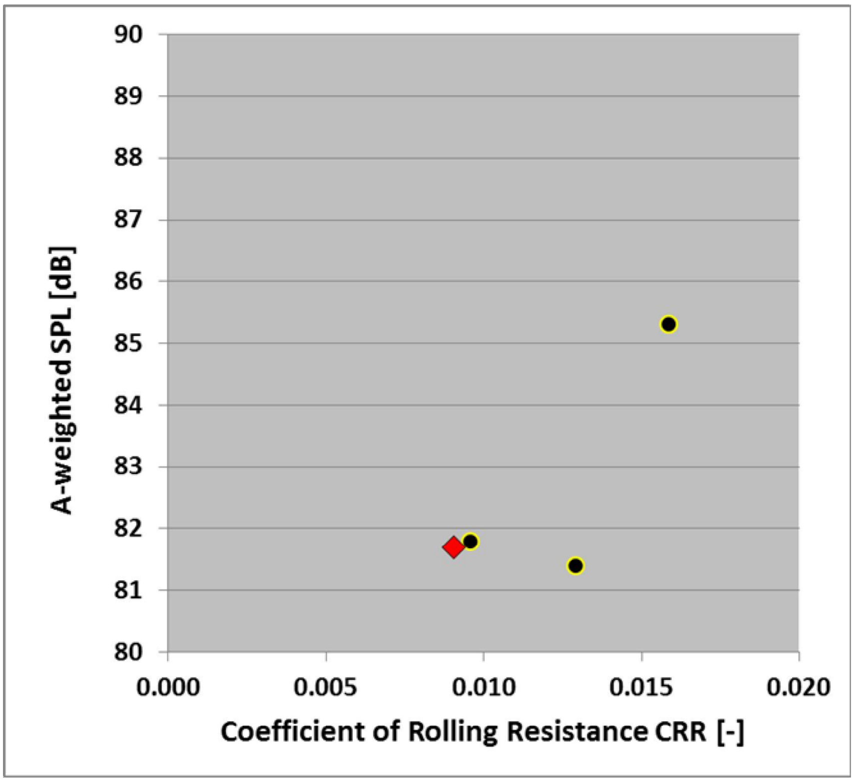

Figure 8. Coefficients of rolling resistance and noise emission for conventional (black dots) and LEV's tire (red diamond) measured at speed 50 km/h on experimental poroelastic road surface PERS-HET.

7. Acknowledgements

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