Comparison of road and laboratory measurements of tyre/road noise

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ABSTRACT

Tyre/road noise is one of the major environmental problems related to road traffic. There are several measuring methods of tyre/road noise that may be carried out on the road (for example Coast-down and Close Proximity Method) or in the laboratory (Drum Method). Road measurements are preferred for evaluations of pavement properties while laboratory methods are mostly used to evaluate tyres. One of the biggest problems associated with laboratory methods is to ascertain that tyre interfaces with pavement that has texture, porosity and mechanical impedance the same as with the real road surface. The paper presents results of tests performed by the Close Proximity Method (with test trailer Tiresonic Mk.4) and drum method where very similar or exactly the same surfaces are used. The reported measuring program includes tests performed on an innovative poroelastic road surface called PERS.

Keywords: Tyre/road noise, Measuring methods, Comparison

I-INCE Classification of Subjects Number: 11.7.1

1. INTRODUCTION

Tyre/road noise is nowadays one of the most important issues related to the tyre and road interface. Intensive investigation of noise generated by rolling tyres started in the sixties of the twentieth century. At that time every researcher used his/her own methodology of measurements so comparison of the results was not easy. Basically two different groups of measuring methods started to evaluate after a while. One group, preferred by tyre manufacturers was based on indoor measurements with use of roadwheel (drum) facilities, and road measurements preferred by road constructors and road authorities. Drum measurements were relatively easy to perform and all measuring conditions were straightforwardly controllable, with exception of pavement characteristics. A lot of early measurements were made on plain steel drums or at the best on drums covered with sand-paper like material called "Safety Walk". Of course results obtained on plain steel surface or "Safety Walk" were not at all representative to real road conditions but equipping drums with replica road surfaces was very difficult and expensive. Road measurements at first were based on ISO 362 standard that was intended to evaluate overall noise from different types of vehicles. In order to separate noise generated by tyre/road interaction from other noise sources the acceleration pass-by required by the standard was being replaced by coast-by. In the 1970s first trailers intended for tyre/road noise measurements began to appear [1, 2].

At present, the following methods are in use:

- the **Drum Method** (tyre rolls on the test drum, usually on its outer surface that is covered by replica road surfaces having the same texture as real road pavement of a certain kind, microphones are placed close to the tyre/pavement interaction zone);
- the **Coast-By Method** (vehicle equipped with test tyres coasts-down on the test pavement, microphones are placed 7.5 m or 15 m from the centre of the test track);
- the **Close Proximity Method "CPX"** (test tyre is mounted on trailer or on ordinary vehicle and the microphones are mounted "on-board", very close to the tyre/road interaction zone;
- the **Trailer Coast-By** (a hybrid method using a specially designed trailer that coasts-by during measurements and microphones positioned on the road side).

All measurements reported in this paper were performed on facilities owned by the Technical University of Gdańsk, Poland. Laboratory tests were performed on three different drum facilities:

drum of 1.5m diameter (see Fig. 1) covered by replica of Dense Asphalt Concrete with 16 mm chippings called "GRB-S", drum of 1.7m diameter (see Fig. 2) covered with replica of Surface Dressing 8/10 mm designated as "*APS-4*" as well as Poroelastic Road Surface "*PERS*" and finally drum of 2.0 m diameter (see Fig. 3) covered with replicas of ISO Reference Road Surface "*ISO*", Dense Asphalt Concrete 16 mm "*DAC16*" and PERS [3]. During laboratory tests, thet tyres were loaded to 3.2 kN and inflated to 200 kPa (cold).

Road measurements were performed by the Tiresonic Mk.4 trailer shown in Fig. 4. Load and inflation pressure during road tests were always the same like during laboratory measurements.

Figure 1 – Roadwheel Facility with drum 1.5 m diameter

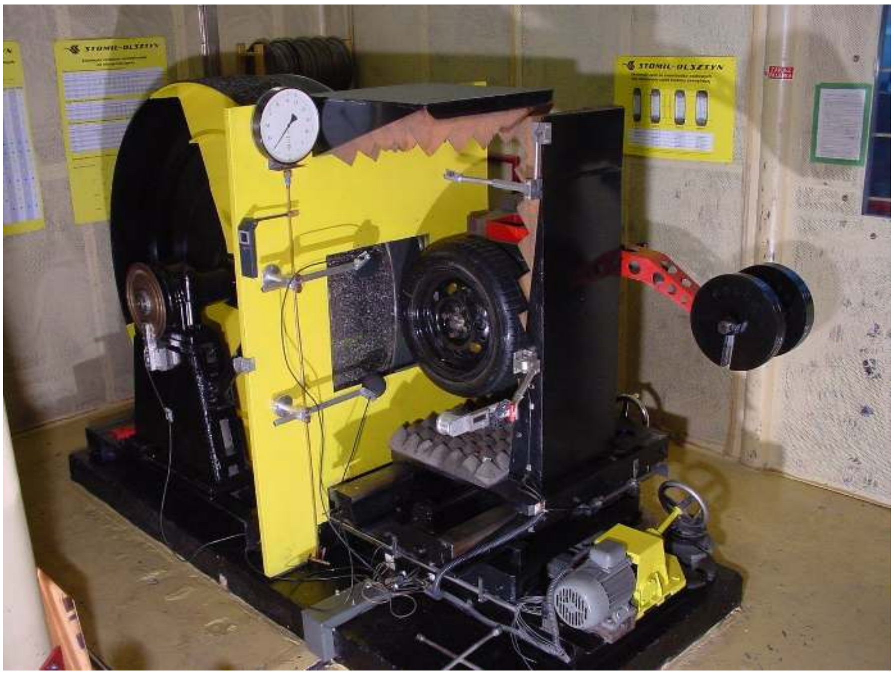

Figure 1 – Roadwheel Facility with drum 1.7 m diameter

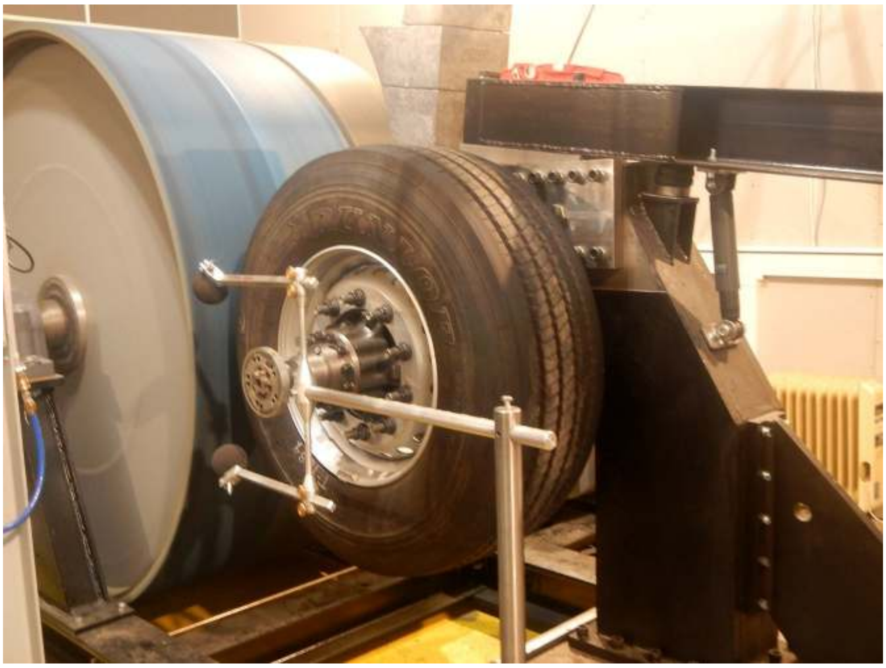

Figure 3 – Roadwheel Facility with drum 2.0 m diameter

Figure 4 – Test trailer *Tiresonic Mk.4*

2. TEST TYRES

During experiments reported in this paper four tyres were tested. The tyres are described in Tab. 1. The set of tyres included two standard reference tyres required by ISO 11819-2 designated here as SRTT and AAV4 as well as tyre MCPR that is used by TUG as informal reference tyre for rolling resistance measurements and finally tyre BLUE that was specially designed for electric vehicles [4].

Table 1 – Description of test tyres

Tyre	SRTT	AAV4	MCPR	BLUE
Manufacturer	Uniroyal	Avon	Michelin	Continental
Tread	Tiger Paw	AV4	Primacy HP	BLUECO
Size	P225/60R16	195R14C	225/60R16	195/60R18
Load index	97	106/104	98	
Speed index	S	N	V	

3. COMPARISON OF CPX AND DRUM RESULTS

Direct comparison of drum and CPX measurements is usually very difficult because of problems with fitting real road surfaces on outer drums. Centrifugal forces acting on pavement slabs mounted on the outer surface of the drum may tear away the slabs creating great danger to the facility, measuring system and the staff. The only drum facility, known to this authors, that is used for tyre/road noise tests and at the same time is "immune" to this problem is inner drum at BASt, Germany.

Technical University of Gdańsk uses replica road surfaces that closely resemble texture of given road surface. The replicas are made using negative, semiflexible casts molded on existing road surfaces. Replicas constructed this way at TUG represent ISO reference surface and Dense Asphalt Concrete with 16 mm chippings. In the case of replica of surface dressing (chip seal) it was possible to obtain material that is constructed in an identical way like real road surface but instead of bituminous binder, flexible polyurethane glue was used. The material is designated "APS4" and is flexible and strong enough to resist centrifugal forces and wear induced by the test tyres.

Testing of Poroelastic Road Surfaces (PERS) within 7th Framework Programme PERSUADE made possible to use exactly the same pavement on the road and on the drum, as PERS is very strong and flexible enough to be curved and bonded on the test drums. Exactly the same material was used on drums 1.7 m, 2.0 m and on the road test section in Linkoping, Sweden.

All CPX and drum tests were performed with the same load, inflation and microphone placement, although the drum method is not formally standardized and customarily the measurements are performed according to the rules specified for CPX, whenever possible. Comparison of results obtained on surface dressing by CPX method with results obtained on the drum facility on replica APS4 are presented in Figures 5 - 8.

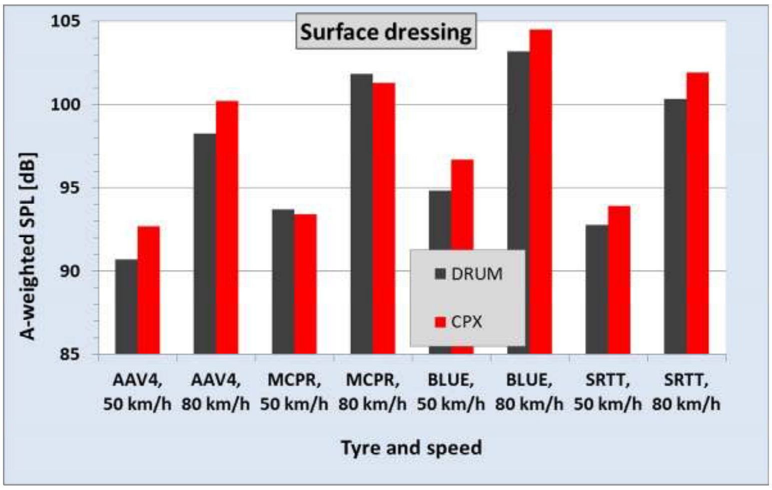

Figure 5 – Comparison of overall A-weighted Sound Pressure Levels obtained by CPX method on surface dressing and by laboratory method on the drum covered with replica APS4

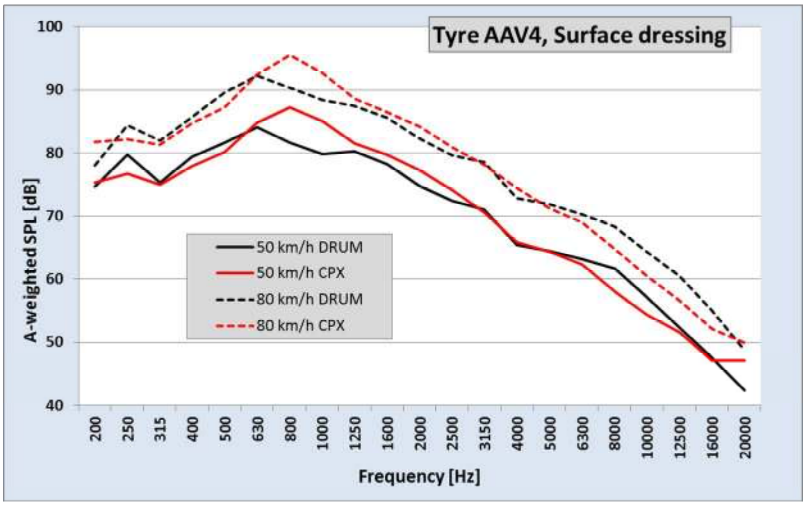

Figure 6 – Comparison of A-weighted spectra for tyre AAV4 obtained by CPX method on surface dressing and by laboratory method on the drum covered with replica APS4

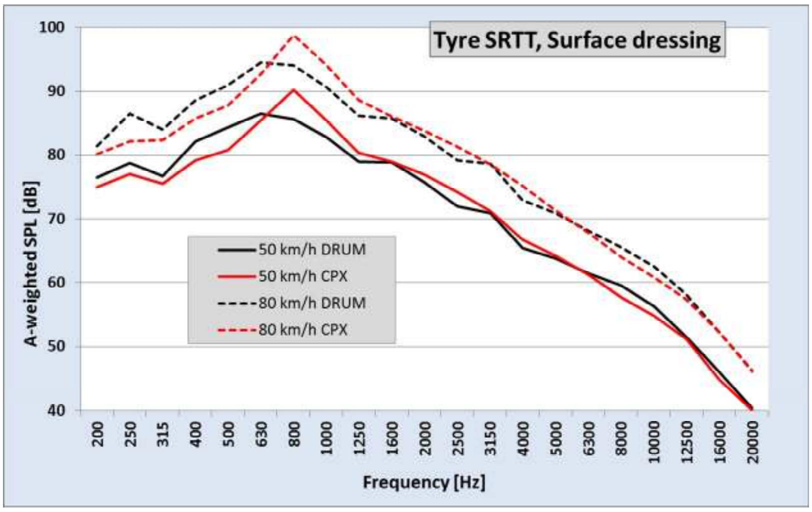

Figure 7 – Comparison of A-weighted spectra for tyre SRTT obtained by CPX method on surface dressing and by laboratory method on the drum covered with replica APS4

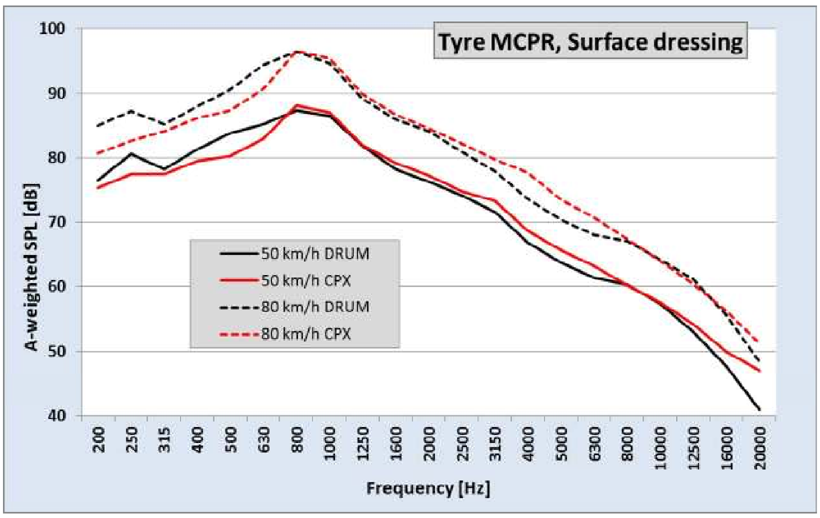

Figure 8 – Comparison of A-weighted spectra for tyre MCPR obtained by CPX method on surface dressing and by laboratory method on the drum covered with replica APS4

The figures indicate that differences between A-weighted overall levels obtained on the road and in the laboratory in the case of surface dressing and its replica are in range of - 0.5 to 2.0 dB. For most tyres the levels obtained on the road are higher than in the laboratory, but in one case (tyre MCPR) it is the other way around. Spectra obtained by different methods are rather similar, but during CPX measurements for tyres AAV4 and SRTT levels for frequency range 800 - 1000 Hz are above levels obtained in the laboratory. For tyre MCPR the spectra are very similar for all frequency range.

Similar comparisons of road measurements on Dense Asphalt Concrete DAC16 and replica road surface GRB-S on 1.5 m diameter drum are presented in Figures 9 - 11. Differences in A-weighted Sound Levels for this surface are in most cases within ±1 dB, with exception of 80 km/h for tyre SRTT where drum measurements show levels 1.7 dB higher than CPX measurements. Spectra obtained during drum measurements have very similar shape to CPX spectra for frequencies below 2000 Hz, but for higher frequencies the levels measured on the drum are higher. It is speculated that this phenomenon is caused by rubber film sticking to the replica that is not present on the road. When listening to the noise generated on the drum it is possible to hear noise typical for stick-snap [1] that is not present on the road.

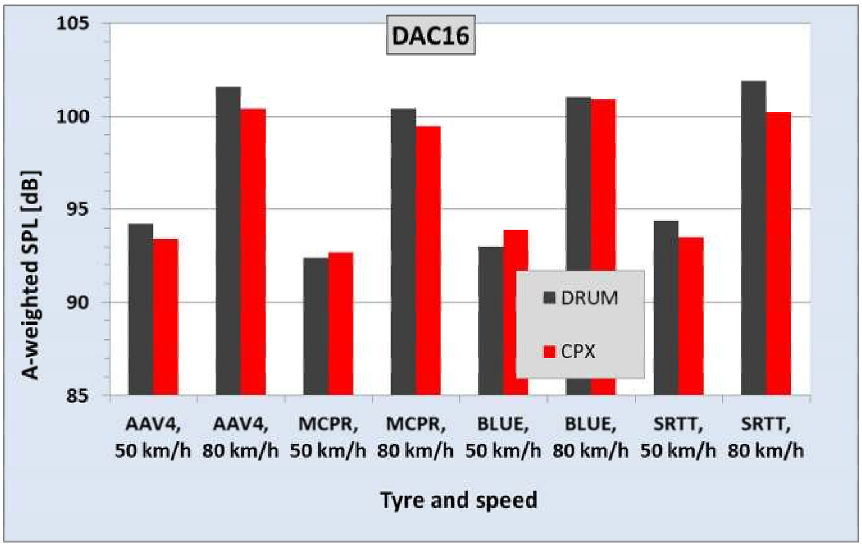

Figure 9 – Comparison of overall A-weighted Sound Pressure Levels obtained by CPX method on Dense Asphalt Concrete DAC16 and by laboratory method on the drum covered with replica GRB-S

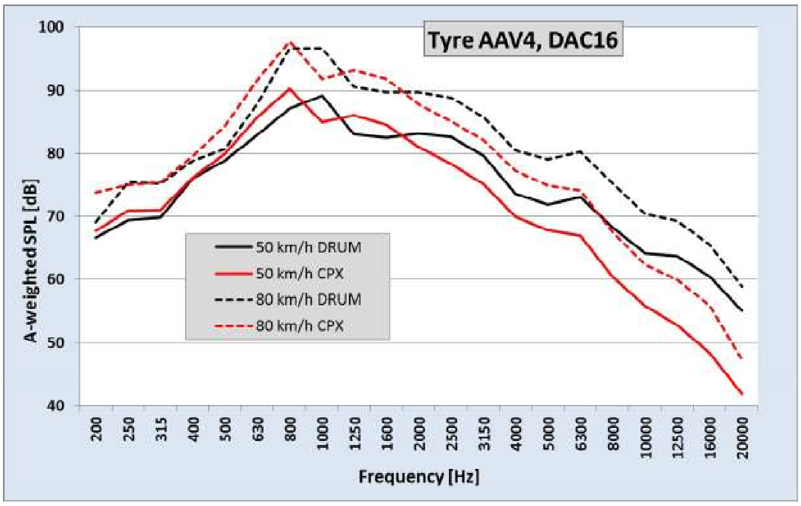

Figure 10 – Comparison of A-weighted spectra for tyre AAV4 obtained by CPX method on Dense Asphalt Concrete DAC16 and by laboratory method on the drum covered with replica GRB-S

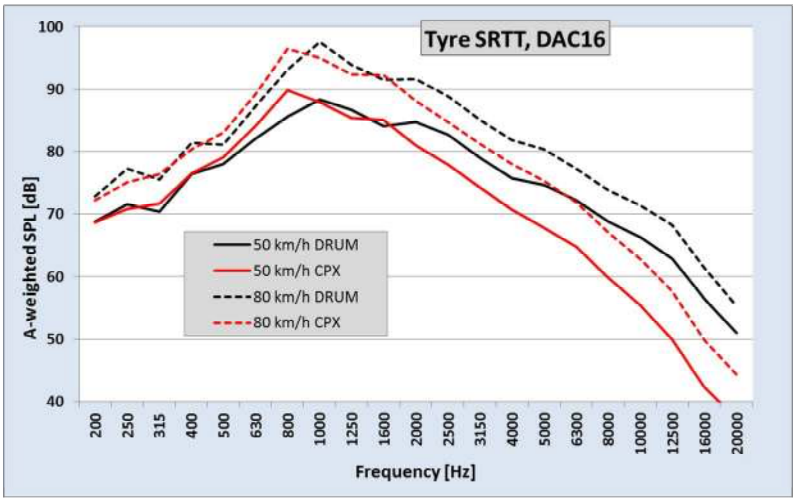

Figure 11 – Comparison of A-weighted spectra for tyre SRTT obtained by CPX method on Dense Asphalt Concrete DAC16 and by laboratory method on the drum covered with replica GRB-S

Figures 12 - 14 present results obtained on poroelastic road surface. Overall A-weighted Sound Levels show very good agreement between CPX and drum measurements. In most cases levels measured by CPX method are higher than measured on the drum. Also noise spectra are very similar. There is however rather consistent increase of levels for CPX measurements in the low frequency range. This may be attributed to turbulence noise that may become important in case of very low tyre/road noise.

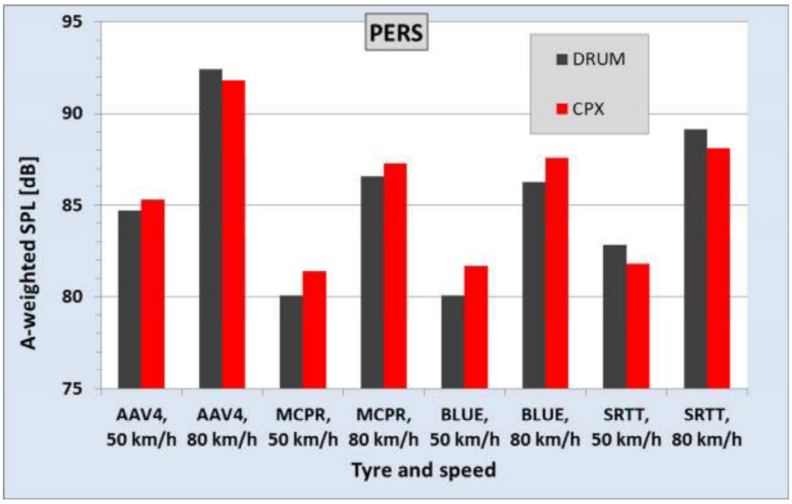

Figure 12 – Comparison of overall A-weighted Sound Pressure Levels obtained by CPX method on PERS during CPX and drum tests

4. CONCLUSIONS

Results presented in this paper show that the drum method is capable of providing useful results provided that drum of the roadwheel facility is covered with replica road surface of texture very similar to the real road. A-weighted Sound Levels obtained by the drum method are in most cases within ±1 dB from levels measured by CPX method. Ranking of tyres is generally preserved. Spectra show also good similarity, but for certain frequencies levels may differ up to 4 dB. The most obvious reason for the differences are: drum curvature, contamination of the surface of replica and different conditions of sound propagation in the trailer and on the roadwheel facilities.

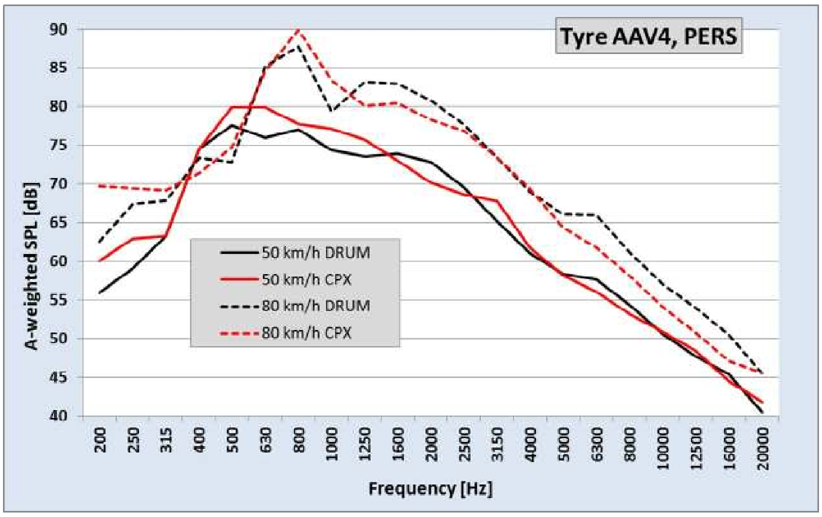

Figure 13 – Comparison of A-weighted spectra for tyre AAV4 obtained by CPX method on PERS during CPX and drum tests

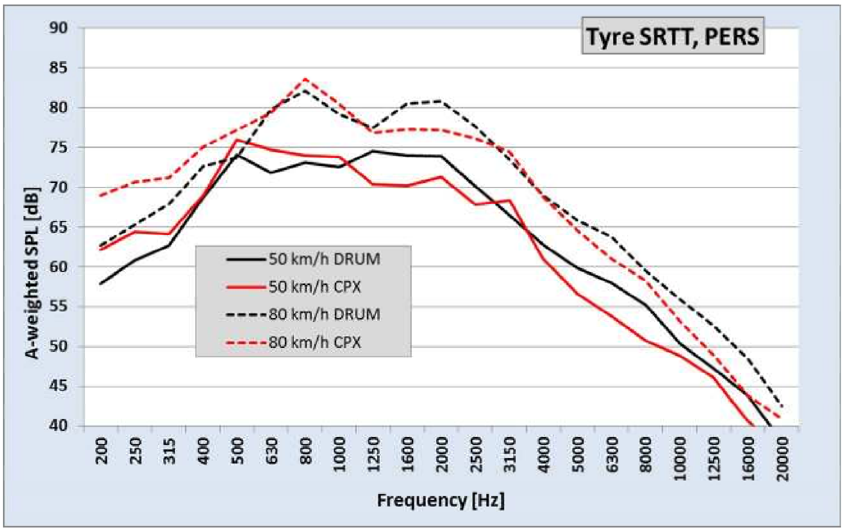

Figure 14 – Comparison of A-weighted spectra for tyre SRTT obtained by CPX method on PERS during CPX and drum tests

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