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THE CALIBRATION OF CPX MEASUREMENTS USING NON-STANDARDISED TYRES

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ABSTRACT

In France, six CPX measurement systems are currently operating over the country for measuring tyre-road noise, among which five systems are mounted on self-powered test vehicles fitted with ordinary test tyres from the market. The test vehicles are preferred over trailers for their greater manoeuvrability and flexibility, especially in dense urban areas where noise issues are important. The comparability of the results measured by the different systems is of particular concern. The idea supported in the study is to develop a method for calibrating the measurements with these market tyres with respect to standardised measurements using SRTT tyres. A methodology was investigated through an experimentation performed with all the systems on 12 road sections with various surfaces on a test track. The reliability of individual CPX measurements was checked. The paper presents the experiment, the results, and discusses the feasibility of calibrating the CPX measurements using a market tyre on a reduced set of road surfaces, carefully selected for their acoustic characteristics.

Keywords: *acoustic, tyre-road noise, CPX, road pavement, test tyre, Round-Robin Test*

1. INTRODUCTION

The standardised CPX method [1] for measuring tyre-road noise emission is becoming the most popular method for assessing the acoustic performance of low noise surfaces. This is due to the great potential of the method to assess acoustic properties and homogeneity of the surface along an entire road section, and to operate on any kind of road, trafficked or not, urban or high speed, without any restriction regarding the road geometry or its surrounding.

In France, six CPX measurement systems are currently operating over the country, among which five systems are mounted on self-powered test vehicles fitted with ordinary test tyres from the market. The test vehicles are preferred over trailers for their greater manoeuvrability and flexibility, especially in dense urban areas where noise issues are important. The comparability of measured results using commercial tyres with standardized measurements using the standardized reference test tyre P1 (SRTT) recommended by ISO 11819-3 [2] is of interest. A previous Round-Robin Test (RRT) with similar devices, showed that using measuring systems with commercial tyres instead of SRTT, leads to different absolute noise levels, and that the differences depends on the pavements type. However, it is possible to classify pavements in a same ranking in terms of noise performances [3].

In the present study, a similar Round Robin Test was repeated with the objective of developing a method for calibrating the measurements using market tyres with respect to standardised measurements using SRTT tyres. A methodology was investigated based on the results on 12 road sections with various surfaces on a test track. Several options for the calibration are investigated.

2. THE ROUND ROBIN TEST

2.1 Participants and CPX measurement devices

The present study is based on a Round Robin Test (RRT) organized with four French operators (designated in this paper F1 to F4), the originality of which is to gather self-powered vehicles (SPV) and a Dutch operator (designated

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D1) implementing a two wheeled enclosed type trailer. As most of the SPV used in the RRT were different types of passenger cars, including one electric vehicle, they were using different test tyres, as described in Table 1. Nevertheless, all systems complied with the recommendations of ISO 11819-2 (concerning the position of the microphones and the procedure for measurement and processing).

Table 1. Tyres used during the RRT

Operator	Manufacturer & type	Size	Hardness (Shore A)
D1	Uniroyal SRTT	225/60R16	?
F1	Michelin ES+	195/60R15	67,4
F2	Michelin EV	195/55R15	74,5
F3	Michelin ES	195/55R15	63,2
F4	Continental CT	205/55R16	63

2.2 Test location and conditions

The Round Robin Test took place in Nantes, France, on the "Reference Test Track" of Université Gustave Eiffel. All sections of these test tracks are fitted with different pavements covering a broad set of road surfaces provided on the French road network. The tested pavements are listed in Table 2. The measurements were performed on the 31st of May and 1st of June 2022. Meteorological conditions were rather steady during the two days of experimentation: sunny weather with air temperatures ranging between 15 and 21°C. Note that a correction was applied to the global noise levels presented in this paper according the ISO TS 13471-1 standard, in order to express all the results at the reference temperature of 20°C. The number of runs performed by each operator on the different pavements is also listed on Table 2.

Table 2. Tested Pavements

Section	Pavement	Length (in m)	Number of runs
A	Porous AC 6	220	9
A'	Coarse surface dressing 14	50	9
N	DAC 6 ISO type	186	9
E1	DAC 10 (new)	252	6
E2	DAC 10 (old)	100	6
E3	SMA 6	150	6
F	High adhesion surface	246	6
L2	Coated sand	116	9
M1	VTAC 10	244	6
M2	VTAC 6, class 2	150	6
M3	VTAC 4	111	9
C1	Fine surface dressing	140	9
C2	Coarse surf. dressing 14	100	9

For all these configurations, measurements were performed both at the references speeds of 50 km/h and 80 km/h.

3. PRELIMINARY RESULTS

On each pavement section and for all the measuring devices, the results showed a very good repeatability over the runs, with differences of the order of a few tenth of decibels. Therefore, overall noise levels were evaluated as the arithmetic average of the noise levels measured at all runs. The results are presented in figure 1.

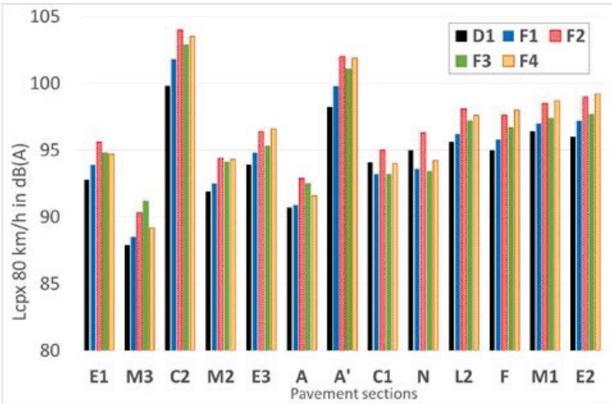

Figure 1. Overall CPX levels at 80 km/h on all pavement sections for the five devices.

As already observed in previous studies, the results are different due to the use of different test tyres.

The CPX noise levels of each device Fn (n=1 to 4) [L(Fn)] were compared to the measurements of the reference device D1 [L(D1)] at both reference speeds. A rather good linear correlation was observed, as illustrated in Fig. 2 for the device F1.

The statistical results are presented in Table 3 where for each French device, the slope [*a*] and the intercept [*b*] of the linear regression are indicated in the first two lines and the determination coefficient R^2 in the third line. Determination coefficients between 0.93 and 0.97 are observed. The last two lines present respectively the average absolute difference [Avg Δ] and the maximum absolute difference

[Max Δ] that are observed between the French and the Dutch devices for all 12 pavement sections. Both are expressed in A-weighted dB.

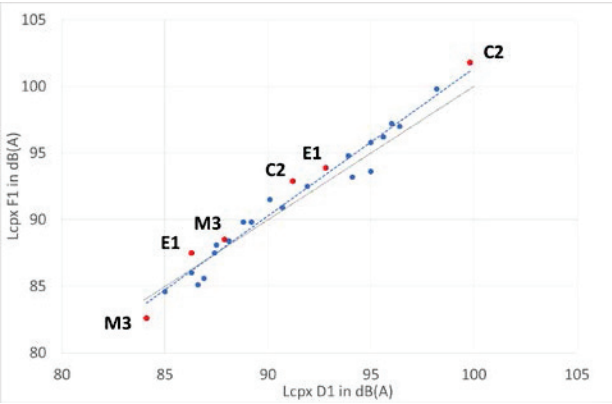

Figure 2. Overall CPX levels at 50 and 80 km/h measured by device F1 as a function of levels measured by reference device D1

Table 3. Statistical results of the correlation between noise levels measured with French results and Dutch results on the 12 pavements

Device		F1	F2	F3	F4
Regress.	***a***	1,111	1,097	1,082	1,195
coeff	***b***	-9.68	-6,43	-6,15	-16,05
R²		0,967	0,9745	0,9333	0,937
AvgΔ		0,9	2,4	1,7	2,0
MaxΔ		2,0	4,2	3,3	3,7

4. CALIBRATION PROCEDURE

4.1 Calibration with respect to one reference pavement

A first attempt is to calibrate the devices using a market test tyre on one reference pavement. This used to be the procedure recommended in a former French standard before 2017. The reference pavement was E1 sections in DAC 0/10, the most common pavement in France. In this case, the correction of measured noise levels is made according to equation (1):

$$L_{corr}(Fn) = L_{meas}(Fn) + L_{E1}(D1) - L_{E1}(Fn) \quad (1)$$

where,

- $L_{corr}(Fn)$ is the corrected CPX level for the device Fn on a specific section,
- $L_{meas}(Fn)$ is the measured CPX level with the device Fn on the same section,
- $L_{E1}(D1)$ is the measured CPX level with the reference device D1 on road section E1,
- $L_{E1}(Fn)$ is the measured CPX level with the device Fn on road section E1.

4.2 Calibration with respect to several reference pavements

4.2.1 Selected pavements

The calibration on 2, 3, 4 and 5 selected pavements was tested successively.

In the case of calibration on two pavements, the selected sections are M3 (semi-porous VTAC 4) and C2 (rough surface dressing) because they are respectively the quietest and the noisiest ones.

In the case of calibration on three pavements, the E1 is complementing the previous two, as a reference pavement of medium acoustic performance.

In the case of calibration on four pavements, the M2 section (semi-porous VTAC 6) is added as an intermediate quiet surface.

Finally for the calibration on five pavements, the E3 section (SMA 6) is added as another intermediate surface.

4.2.2 Correction procedure

The correction is made according to equation (2):

$$L_{corr}(Fn) = (1/a)\,[L_{meas}(Fn) - b] \quad (2)$$

Where

a is the slope of the regression line of $L_{meas}(Fn)$ as a function of $L_{meas}(D1)$ on the 2, 3, 4 or 5 selected pavements, and b is the intercept.

5. RESULTS OF THE CALIBRATION

5.1 Efficiency evaluation

The average and maximum absolute differences [resp. *AvgΔ* and *MaxΔ*] between the French and the Dutch devices for all 12 pavement sections are calculated and presented in Table 4 for the five calibration scenarios (single pavement correction, 2, 3 4 or 5 pavement corrections). When comparing with results in Table 3 for the initial case where no correction is applied, it can be observed that all the calibration procedures result in a decrease of the average difference between the devices.

Table 4. Average and maximum difference between noise levels measured with French results and Dutch results on the 12 pavements

	F1	F2	F3	F4
Single pavement correction (E1)				
AvgΔ	0.9	0.8	1.1	1,2
MaxΔ	2.6	2.5	3.6	3,8
Correction on 2 extreme pavements (M3, C2)				
AvgΔ	0.6	0.6	0.9	0.8
MaxΔ	2.5	2.1	3.8	2.9
Correction on 3 pavements (M3, E1, C2)				
AvgΔ	0.7	0.6	0.9	0.8
MaxΔ	2.6	2.1	3.8	3.0
Correction on 4 pavements (M3, M2, E1, C2)				
AvgΔ	0.6	0.6	0.9	0.8
MaxΔ	2.5	2.0	3.7	3.0
Correction on 5 pavements (M3, M2, E1, E3, C3)				
AvgΔ	0.6	0.5	0.8	0.8
MaxΔ	2.4	1.9	3.6	3.0

The calibration procedure on at least 2 pavements leads to a higher benefit with average differences lower than 1 dB(A) for all devices. The benefit of calibration on more than 2 pavements is negligible.

However the tendency observed for the maximum difference is not as clear, high values of *MaxΔ* are still present after the application of calibrations.

5.2 Final output

As an example, Fig. 3 shows the CPX noise levels measured at 80 km/h as in Fig. 1, but after calibration of the French devices with the 2 pavements calibration procedure. The results are closer for most pavements, despite some significant differences still remain for some pavements

6. CONCLUSIONS

The present study is a first attempt for calibrating CPX measurement devices using an ordinary test tyre from the market. The results suggest that the application of a simple correction can bring the measured CPX noise levels closer to the levels obtained with a SRTT test tyre. This correction can be derived from comparative measurements, at 50 and 80 km/h, preferably on 2 reference pavements with extreme performances (one quiet and one noisy). Further research will be performed in the future to optimize the choice of these reference pavements and to validate the approach on more trafficked road sections.

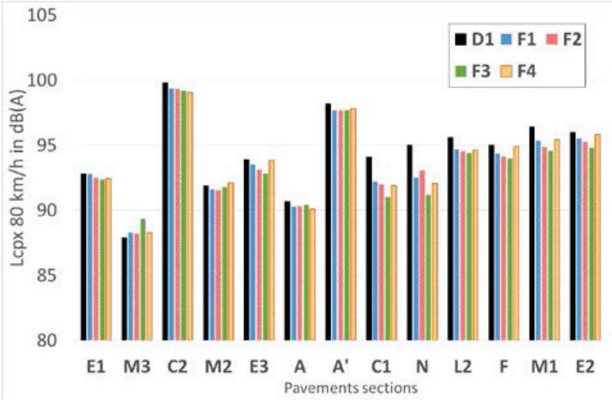

Figure 3. Overall CPX levels at 80 km/h on all pavement sections for the five devices after calibration by the 2-pavement procedure.

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