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A new methodology to assess sound power level of tyre/road noise under laboratory controlled conditions in drum test facilities

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ABSTRACT

Tyre/road interaction is the main source of noise emission caused by road traffic when cruising at speeds over 30 km/h. Several methods such as the Coast-By, the Close-Proximity, the Statistical Pass-By or the Controlled Pass-By have been used over recent decades to measure noise emission. However, since Regulation (EC) No. 1222/2009 on the labelling of tyres was published, only the method described in UNECE Regulation 117 concerning the approval of tyres with regard to rolling sound emissions, can be used in order to obtain tyre/road noise emission approved values. All these conventional methods have several disadvantages such as the lack of repeatability, the influence of environmental factors or the different results that can be obtained depending on the test track or the vehicle upon which the tests are carried out. A new methodology based on drum tests and the ISO 3744:1994 has been developed in order to avoid these limitations. This paper describes the new method including the positioning of microphones, calculating correction factors, characterising the background noise caused by the drum and obtaining the sound power level of a tyre when rolling against a drum.

1. Introduction

With regard to road traffic noise generation, the main source for a vehicle travelling over 30 km/h. is tyre/road noise. There are other noise sources such as wind turbulence, the engine or the vehicle's transmission that also contribute to road traffic noise. However, these other sources have little weight in the overall vehicle noise at medium and high speeds. Nowadays, aerodynamic exterior noise at speeds lower than 120 km/h is quite low [1]. Likewise, future power unit (engine and transmission) noise sources will be dramatically reduced because of the progressive introduction of electrical vehicles. In this scenario, reducing tyre/road noise will make the biggest contribution to lessening road traffic noise emission.

Several regulations have been published in the European Union in the last decade in order to reduce noise generated by the interaction of the tyre and road surface. The first one, UNECE Regulation 117 [2], was published in 2007 and describes the method to measure rolling sound emission for tyres. This method is based on ISO 13325 [3] Coast-By test method for measurement of tyre-to-road sound emission published in 2003. Afterwards, Regulation (EC) No. 661/2009 [4] establishes the rolling noise limits for tyres to be sold after 1st November 2012 under CE marking type approval. Finally, Regulation (EC) No. 1222/2009 [5] sets out a classification of tyres according to their noise emission values which can be obtained by means of the previously described method in UNECE Regulation 117. The Coast-By (CB) method, along with the Close-Proximity (CPX), the Statistical Pass-By (SPB) or the Controlled Past-By (CPB) methods have been considered in the standardisation work.

However, all these conventional methods for classification of tyres with respect to noise emission have several disadvantages and limitations among which the following ones are the most important:

- *Lack of repeatability*. As seems to be obvious, it is quite difficult to get the same results when tests are carried out by different test teams on different test tracks [6] and with different vehicles [7]. It is even relatively hard to get the same results with tests performed by the same test team on the same test track and vehicle as there are different factors which influence the results. In spite of correction factors for aspects like temperature, other variables such as wind speed and direction, background noise or changes over time [8] (e.g. on the tyres, the track or the vehicle itself due to wear and tear) cannot be easily weighted. Differences in reference speeds, vehicle categories and the

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effects of the road surface age and roughness may bring significant discrepancies in the final results [9,10].

- *Expensive method*. Carrying out a test under any of the previously mentioned conventional methods – i.e. CB, CPX, SPB or CPB- involves using a vehicle fitted with four tyres that need to be tested. Labour cost of fitting four tyres is four times higher than the cost of testing just one tyre. The same occurs with the tyres' cost itself. The vehicle's rims must be compatible with the tyres; otherwise four new rims must be fitted to the vehicle. Besides, at least two people need to be working on the test at the same time and a certain amount of fuel is consumed during the test. Finally, track tests take considerably more time to be carried out and that makes them more expensive. All of these factors make conventional methods much more expensive than the new methodology explained in this paper. In order to get a rough idea, actual prices given by accredited automotive test laboratories for a Coast-By track test are between three and four times more expensive than a tyre rolling resistance laboratory test (equivalent, in cost terms, to the new methodology suggested in this paper).
- *Time-consuming test*. The methodology described in UNECE Regulation 117 determines that, at least, four measurements shall be made on each side of the test vehicle at test speeds lower than the reference speed and at least four measurements at test speeds higher than the reference speed. This means that testing a vehicle requires more than 40 min. The same number of measurements can be done in 8 min employing the new methodology. Besides, assembling just one tyre in the drum is four times faster than fitting four tyres in the vehicle.
- *Measured magnitude*. The magnitude that is measured according to the previously mentioned regulations is sound pressure level. However, that depends on factors such as the environment in which the sound waves travel, attenuation or distance from the noise source. This does not happen to the sound power level, which is a magnitude that is inherent in the noise source and does not depend on other external factors [14]. Therefore, by measuring sound pressure it is not possible to quantify the sound power of the source unless the environment is strictly controlled and defined. This does not happen in the methodology described in Regulation 117 or in any other of the conventional methods previously mentioned.

In order to solve these problems, a new methodology based on drum tests and the International Standard ISO 3744 [11] has been developed. The ISO 3744 determines sound power levels of noise sources using sound pressure in an essential free field over a reflecting plane. This new approach combines the expertise of the ISO method with the experimental procedure developed at the research group's drum tyre test facilities (see Fig. 1).

While some research groups have tested tyre noise emission using drums [12], none of them have done so by means of a standardised specific engineering method for determining sound power level. On the contrary, all the previous tests have considered sound pressure.

This paper explains the methodology to locate the microphones and to obtain corrections for background noise K_1 and test environment K_2 according to ISO 3744. After that, it describes the drum test facilities and the instrumentation as well as how the tests are configured. Finally it shows and comments on the test results and ends with the final conclusions.

2. ISO 3744 based sound power level approach in drum tyre test facilities

The first step in locating the microphone positions is to define a hypothetical reference box which contains the noise source (see Fig. 2). The characteristic source dimension d_0 is calculated by the following Eq. (1):

Fig. 1. Research group's drum tyre test facilities.

$$d_0 = \sqrt{\left(\frac{L_1}{2}\right)^2 + \left(\frac{L_2}{2}\right)^2 + L_3^2} \tag{1}$$

The microphones are then placed on a hemispherical measurement surface that has to be centred in the middle of the reference box. The radius r of the hemisphere should fulfil the following condition:

$$r > 2 \cdot d_0 \tag{2}$$

As prescribed by the standard, microphones are distributed according to the coordinates shown in Table 1 and the microphone array on the hemisphere shown in Fig. 3.

However, microphones 1 and 6 have a greater contribution to the averaged sound level because of the tyre's directivity noise emission [13]. For this reason and so as to be able to carry out future comparisons with the results obtained by means of the experimental procedure to obtain sound power level of tyre/road noise under Coast-By conditions [14], the aforementioned microphone distribution was rotated 90° in an anticlockwise direction resulting in a distribution as shown in Fig. 4.

Different microphone stands were designed and positioned using CAD software according to ISO 3744 in order to fulfil the previous microphone array requirements for a 1 m. radius hemisphere (see Fig. 5). Afterwards, aluminium Bosch profiles were assembled

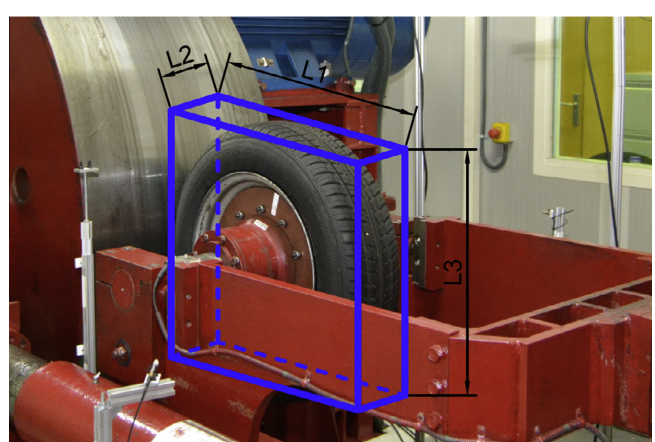

Fig. 2. Reference box.