

# Measuring Tyre Rolling Noise at the Contact Patch

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**Abstract.** This paper deals with noise generated by road traffic. A focus is concentrated solely on one of its sources related to tyre/road interaction referred as rolling noise. The paper states brief overview of various approaches and methods used to measure this particular source of road traffic noise. On the basis of literature reviews, a unique device has been designed. Development of the measuring device and possibilities of its usage are described in detail in this paper. Obtained results of noise measurements can then be used to design measures that increase safety and a lead to better comfort on the road.

## 1. Introduction

Road traffic brings not only benefits for society but also some negatives. Roadway noise pollution and air pollution are definitely some of these negatives. The way how can we mitigate the negatives is, due to rising vehicles per capita, an important topic and also an actual topic for several last years.

When we focus just to roadway noise pollution, we still have quite complex problem to solve. The source of roadway noise is not one specific phenomenon, but several phenomena occurring together. We can identify many sources of noise pollution on each vehicle, like an engine, a gearbox, breaks, an exhaust system, a vehicle body or vehicle tyres. This paper aims to describe the phenomenon of tyre/road contact, where rolling noise is generated [1].

## 2. Rolling noise - background

Principles of tyre/road noise generating are fairly complex. A contact patch is an area where tyre treads and a road interact. While tyre tread blocks travel around the tyre, they hit the road on the contact patch. Energy created by this impact together with other noise source generating mechanisms is radiated as sound. Other several aspects further enhance the radiated sound. Rolling noise is dominant part of roadway noise, especially when vehicles are moving medium to high speeds. For passenger cars it is above 40 kmh<sup>-1</sup>, for trucks above 65 kmh<sup>-1</sup>. In case of a vehicle moving faster than 200 kmh<sup>-1</sup> aerodynamic noise of a vehicle body starts to be dominant [2, 3].

## 3. Noise measurement approaches

Rolling noise generated at the tyre/road interface is studied since the 1970s. Results from numerous studies done since then were used as the basis to identify and understand the mechanisms of generating and radiating rolling noise. These results were then used for the development of materials and technologies which affect rolling noise on both sides of the contact patch [1, 4].

Due to that it was necessary to develop exact methods for noise measuring of tyre/road interaction. Generally, there are 3 known approaches [5].



### *3.1 Wayside noise measurements*

The static approach by the wayside limits measuring to one point, one cross section, of a road. In addition to that measuring methods define further requirements for the surrounding of measured cross section or for the traffic flow. Measuring higher number of cross sections, or to obtaining high number of measurements, with this approach is time consuming.

### *3.2 On-board noise measurements*

On the other side the on-board approach (measuring the contact patch of a tyre of a moving vehicle/trailer on a road) allows examination of any part of a road network, which is limited just by capacity of a measuring device or range of a measuring vehicle (trailer). This approach can be easily and repeatedly used to specific sections of a road exposed to surrounding conditions. In case of occurrence of deviations or long-term trend of measured values, it is possible to localize the problem and realize follow-up examination, which will help to reveal causes.

### *3.3 Laboratory Drum noise measurements*

Last described approach uses laboratory drum methods. The significant drawback of this approach is that a real wearing course is not used, testing is done on the recreation of a wearing course with similar texture. That is also the reason why the approach cannot be applied to the real road structures. This approach is more suitable for researching causes and mechanisms of rolling noise on the tyre side. By using laboratory drum it is possible to follow exact same track, which is unreal in actual traffic. Based on the description of approaches and due to the research planning, the on-board noise measurement approach was selected.

## **4. Onboard measuring methods**

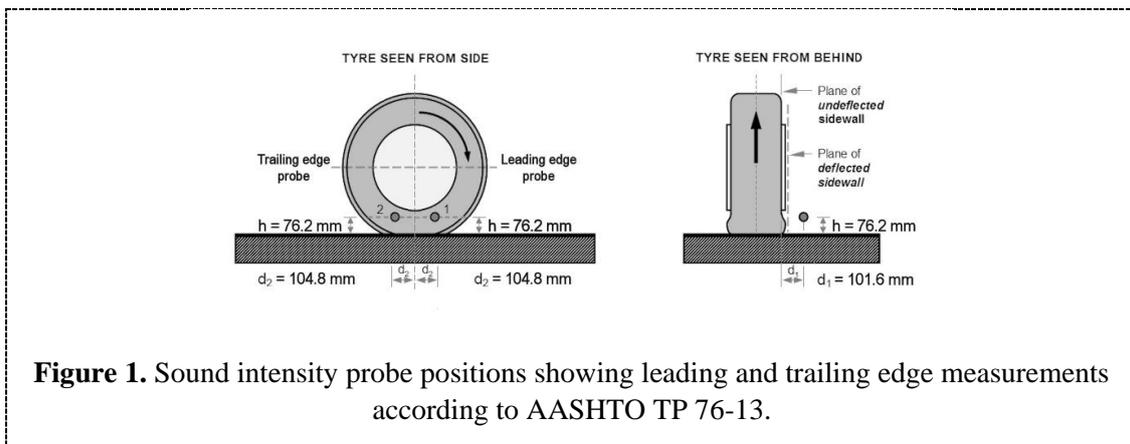
For qualification and evaluation of rolling noise at a tyre/road interface are mostly used two variables. Sound pressure level (SPL) and sound intensity level (SIL). In Europe is for measuring noise of tyre/road interface used Close-ProXimity method (CPX), where sound pressure level is measured. However, in the United States is used On-Board Sound Intensity method (OBSI), which is based on measuring sound intensity level. Both methods are described in certified standards [6, 7]. While both methods use same units (decibels – dB), they are not directly comparable. Both methods use different acoustic variables and also the sensors on measuring devices are placed in the different distance from a noise source.

### *4.1 On-board Sound Intensity (OBSI) method*

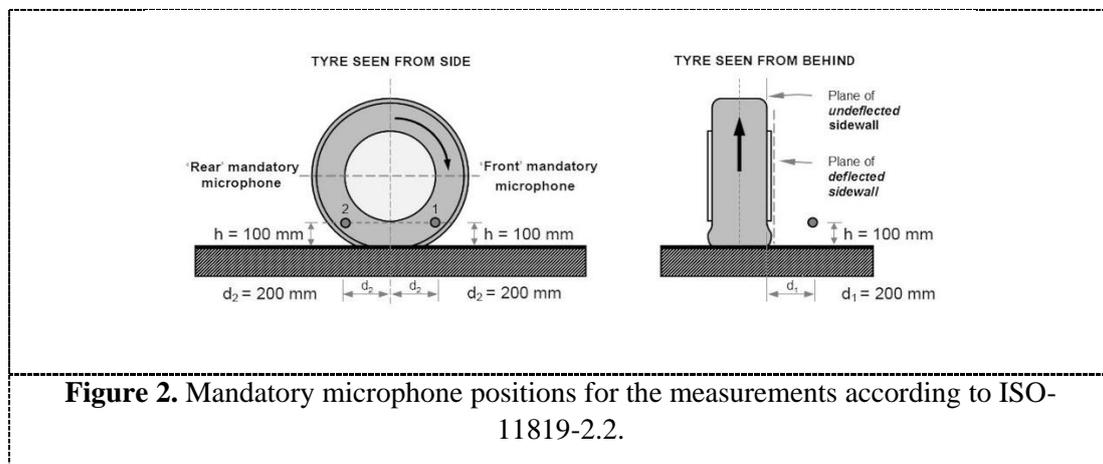
Some text. The method is described in standard AASHTO TP 76-13 [7]. It is based on the method developed to assessing vehicle noise by General Motors Company in the 1980s in USA. Measuring is done by 2 acoustic probes placed in required distances in relation to the front and rear edge of the tyre/road contact patch (Figure 1). Acoustic probes contain two microphones placed in described distances, which measure sound intensity level (SIL). Sound intensity is a vector dimension, with value and direction. Both probes are oriented towards the contact patch.

### *4.2 Close-ProXimity (CPX) method*

This method (CPX), defined by standard ISO 11819-2 [6], was designed as a complement to the Statistical Pass-By method (SPB), to compare different properties of different wearing courses. CPX method is based on measuring with at least 2 (mostly 3 or 5) microphones placed in close proximity to the tyre/road contact patch (Figure 2). During measurement Sound Pressure Level (SPL) is measured. Sound pressure level describes different conditions at different locations. Sound pressure doesn't have any direction; it is a scalar. Due to that measuring method CPX is more sensitive to interfering sound sources.



**Figure 1.** Sound intensity probe positions showing leading and trailing edge measurements according to AASHTO TP 76-13.



**Figure 2.** Mandatory microphone positions for the measurements according to ISO-11819-2.2.

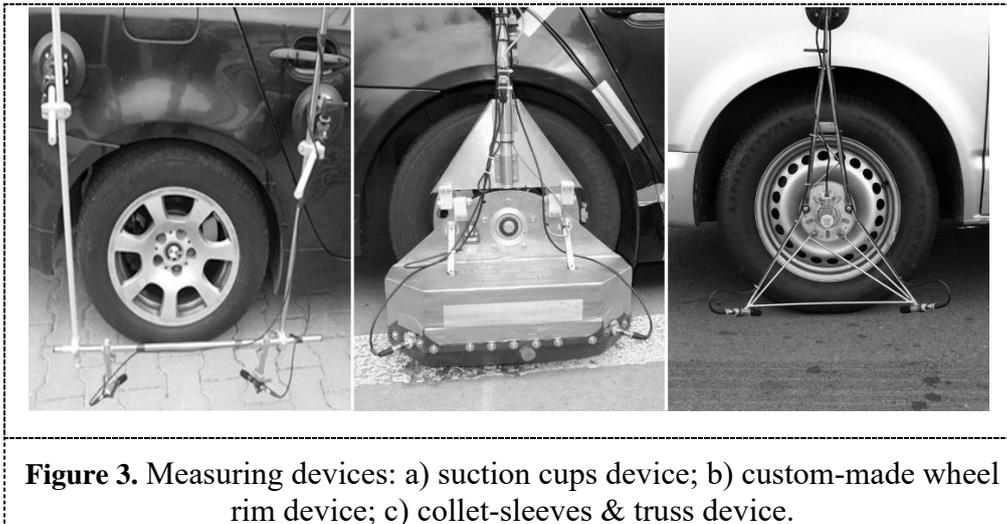
## 5. Design and development of the measuring device

The first roadway noise measuring attempts at our institute were done in the 1990s. Since the very beginning the development was aimed to on-board measuring. The first developed measuring device can be described as “behind the tyre” (BTT). An acoustic sensor was attached to the measuring vehicle, nearby a rear mudflap, and in that position it measured sound pressure (SP).

### 5.1. Suction cups device

The first version of a device measuring on both ends (front and rear) of the contact patch was designed in 2012. The approach to measuring the sound pressure level was preserved. For measuring sound pressure were chosen couple of microphones placed according to a draft used in the standard for Close Proximity method (CPX) issued in 2000 [8]. For a construction of the measuring device was used a mounting system RK Rose+Krieger. Aluminium beams and joints were used to create the structure which holds measuring microphones in the prescribed positions (Figure 2). Whole structure is attached to a vehicle body by two vacuum suction cups (Figure 3a).

The measuring structure was equipped with the couple of microphones iSEMcon type EMM-13D082/H-P48/RM connected to an external 2-channels audio card M-AUDIO Fast Track Pro. The card was connected via USB to a laptop with SpectraPLUS software. The software saved audio recording and also was used for the evaluation. The structure was also equipped with an acoustic transmitter using 2500 Hz frequency. The transmitter was used for marking important points (start, end, change, etc.). An independent GPS device was used to record a position and a speed of the measuring vehicle.



**Figure 3.** Measuring devices: a) suction cups device; b) custom-made wheel rim device; c) collet-sleeves & truss device.

### 5.2. Custom-made wheel rim device

In 2014 upgrade of measuring device was done, its target was to eliminate some of the shortcomings. Construction of the measuring device was changed, adjusted was also the device mounting to a vehicle and the process of evaluation. The measuring device was attached directly to one of the spinning wheels and not to a vehicle body. Into the custom made rim an aluminium disc was inserted, later the disc was changed to a performed aluminium hoop. Before measurement a bearing was installed into the hoop, on the other side of the bearing were attached microphones. These microphones were placed under cover, which hold them in position and which also should help with an elimination of background noise from unwanted sources (Figure 3b). Due to a custom made software, evaluation was done immediately after measuring. The software was based on National Instruments – Labview. Every noise level entry was registered together with an actual time and a distance. Both values were provided by Hall probe which was also attached to the bearing. The software allowed inserting sings during measuring (“Z” – start, “K” – finish, “Z” – change, etc.). Data stored in this specific format saved us time later with post-processing.

### 5.3. Collet-sleeves & truss device

Series of measurements demonstrated that the cover doesn't have positive impact to shielding interfering noise sources. Due to that another adjustment of the measuring device was realize in 2016. Concept of mounting the measuring device to the active wheel was preserved, but realization was redesigned. The bearing is now mounted by collect-sleeves to wheel nuts' heads. The cover with microphones was replaced with the subtle truss structure (Figure 3c). Hall probe was replaced by GPS/GNSS unit. That enables evaluating software assign precise location to measured noise levels, in addition to time and chainage. Measuring device was complemented by two temperature sensors. The infrared sensor Optris CS LT used to measure a temperature of a road in track of the measuring wheel and the temperature sensor Papouch TMU-USB to measure a temperature of surrounding air. Measured temperature values are used for correction of measured noise values to the reference temperature 20 °C. Mentioned parameters can be observed in real time, including an actual sound pressure level measured by each microphone. Due to linking GPS location and signs registered by the device operator, it is possible to verify sing's location and importance on a map underlay.

## 6. Conclusions

The paper describes the development of the measuring device used to measure rolling noise at the tyre/road interface at the Institute of Road Structures, Faculty of Civil Engineering, Brno University of Technology. The measuring device combines a lightweight and a simple construction of American OBSI devices together with parameters of the CPX method used solely in Europe. This solution allows

easy and fast mounting and demounting onto the measuring vehicle. The measuring device is used to the noise comparison of different wearing courses and different road equipment, like road marking. The paper describes the development of the measuring device used to measure rolling noise at the tyre/road interface at the Institute of Road Structures, Faculty of Civil Engineering, Brno University of Technology (VUT). The measuring device combines a lightweight and a simple construction of American OBSI devices together with parameters of the CPX method used solely in Europe. This solution allows easy and fast mounting and demounting onto the measuring vehicle. Results are verified before and after a measurement by a single-frequency sound calibrator ISEMcon SC-1 Microphone Calibrator. The unit generates a 1 kHz reference tone at 94 and 110 dB SPL. Using calibration results, calibration constants for each of microphones are changed in a user interface of the measuring device. Numerous measurements were performed during the development of the measuring device, using both CPX method and the measuring device. The CPX-lorry without anechoic chamber accredited for the rolling noise measurements according to ISO-11819-2 [8] was used. Comparing CPX results to the results of the on-board measuring device developed by VUT, differences on homogenous surfaces were constant. Absolute sound pressure level difference was between tenths and ones of decibels, depending on the generation of VUT's measuring device.

## 7. Acknowledgments

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