FACTA UNIVERSITATIS
Series: **Working and Living Environmental Protection** Vol. 2, N° 2, 2002, pp. 115 - 122

ACOUSTICS EMISSION VALORIZATION OF TYRES BY SOUND INTENSISTY METHOD

UDC 534.61

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Abstract. *The quality of tires is producer determinant in order to justify partner confidence and to have success on the word market of tires. The significant contribution of tire noise generation mechanisms to the overall noise level of motor vehicles causes that noise level is the important indicator of the quality and technological level of both tires and tire production process. The noise source acoustical information is obtained by measurements, which are valid if conducted by use of standardized equipment under predefined condition and if the results represent defined acoustical quantity. In this paper is given review of international standards for determination of noise source acoustical activity, based on sound pressure measurement under predefined conditions in determined acoustical environment. Also, the suggestion was made for valorization of noise source acoustical emission by two-microphone method of sound intensity measurement in situ. The shown examples of mapping sound intensity indicate that the sound intensity technique is very reliable tool for identification and valorization of source and tire noise generation mechanisms.*

Key words: *acoustic emission, tyre noise, sound intensity, generation mechanisms*

1. INTRODUCTION

Road traffic noise originates not only in the power units of vehicles, including engine, exhaust, air intake and transmission, but also in the interaction between tires and road surface, so called tire/road noise. During the latest decades tire/road noise has been recognized as one of the most significant parts of road traffic noise [1]. Due to differing speed dependences of the various noise components, tire/road noise generally dominates over the other sources altogether above 40km/h for passenger cars and about 60km/h for trucks in non-interrupted traffic [2].

It has therefore become necessary to imply suitable noise reduction measures on tires as well as road surfaces that do not impose safety problems. Many of these measures rely on

Received December 03, 2002

appropriate measuring methods and the major noise reduction on the tire are often obtained through the cumulative effects of several minor reductions, maybe in the order of 1-3 dB that are generally impossible to register without an accurate and sophisticated measuring technology. It is also a natural desire for scientific, engineers and authorities that something measured at a time X at a place A can be reproduced at a time Y at a place B and also that the measurement be representative of some general and relevant noise situation [3]. Standardized measurement method are also very useful in more advanced research programs, such as studies of noise generation mechanisms and identification of dominant noise sources.

Generally, the noise source acoustical information is obtained by measurements, which are valid if conducted by use of standardized equipment under predefined condition and if the result represents defined acoustical quantity. Two quantities, which complement one another, can be used to describe the sound emission of noise source. One of them is the sound power level and the other is the emission sound pressure level at the specified position. The prime descriptor, according to the European directive, 89-392-EC [4], is the A-weighted emission sound pressure level. Today, measurement of emission sound pressure levels at the specified position are carried out according to the ISO 11200-series [5] which require specially defined test rooms or, in case of field measurements, calculated corrections for the environment to be corrected from the measured values.

For a plane progressing wave the sound intensity level equals the sound pressure level. It would principally be possible to measure free filed sound pressure levels in a diffuse field simply by approximating them with the sound intensity. Also sound intensity measurements may be used to localize noise source and to construct the intensity maps showing regions of high and low noise radiation and also in which direction the energy flux.

Starting from the fact that the sound intensity as energy vector describes besides the amount of the sound energy its direction as well, the valorization method of tire acoustical emission is developed. In this paper the examples whose results confirm the excused choice of this measurement method will be given.

2. ACOUSTIC EMISSION VALORIZATION ACCORDING TO ISO 11200-SERIES

Each of the methods of determining acoustical emission described in ISO 11200-series is applicable to all kinds of noise source. The choice of method is governed by technical and practical limitations. The general guide to the choice between the different methods is illustrated in figure 1 [6].

ISO 11201 specifies an engineering method of measurement an is applicable to noise sources for which the following requirements apply:

a) noise sources that are normally operated in conditions of an essentially free field near one or more reflected planes, so that noise testing can be carried out in situ
b) noise sources that are movable to the extent that they can be installed under such conditions for the purpose of noise testing
c) noise sources installed under conditions such that stated requirements concerning background noise and test environment are met for which no environmental correction is applied
d) noise sources for which work stations can be defined

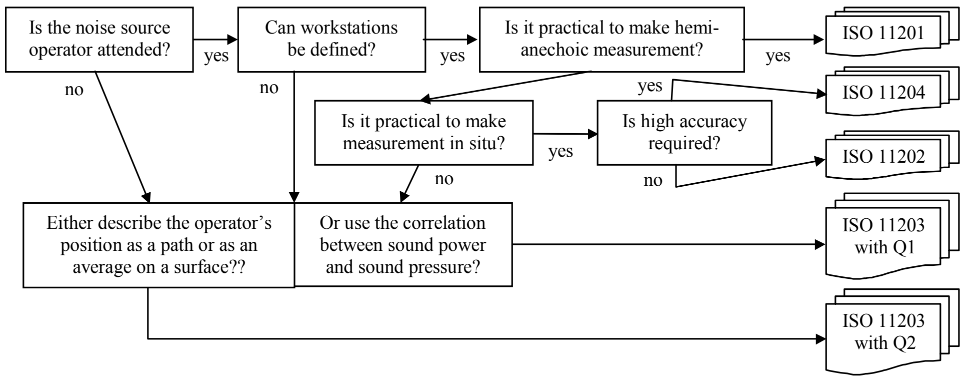

Fig. 1. Flowcharting guide for the choice of methods for determining acoustical emission of noise sources

ISO 11202 specifies an survey method of measurement an is applicable to noise sources for which the following requirements apply:

a) noise sources that cannot be installed in an essentially free field over a reflected plane
b) noise sources installed under conditions such that stated requirements concerning background noise and test environment are met and a simplified environmental correction can be applied
c) noise sources for which work stations can be defined

ISO 11203 specifies a method for deterring the emission pressure level from the sound power level and is applicable to noise sources for which the following requirements apply:

a) noise sources for which sound power level data are available
b) noise sources for which work stations are not defined
c) noise source which either radiate sound omnidirectionally or are normally located close to a wall
d) noise source for which either a close correlation between the sound power and emission sound pressure has been defined by experiment or work stations can be represent as points or paths on a surface enveloping the noise source

ISO 11204 specifies a method of measurement that yields accuracy which, depending on measurement environment is either of engineering or survey grade and is applicable to noise sources for which the following requirements apply:

a) noise sources that cannot be installed in an essentially free field over a reflecting plane
b) noise sources installed under conditions such that stated requirements concerning background noise and test environment are met
c) noise sources for which work stations can be defined

3. ACOUSTICAL EMISSION VALORIZATION USING SOUND INTENSITY MEASUREMENTS

For a plane progressing wave the sound intensity equals the sound pressure level. Also at some finite distance from a source in a free field the sound intensity will be nearly equal to the sound pressure [7]. In a diffuse sound field the sound will come from all directions and the vector sum will be close to zero that is the sound intensity will be very small. If a sound source is placed in a room, the sound intensity at a specified position will be the sum of the intensity of the direct wave from the source and the intensity of the reflected waves. If the reflected waves make a diffuse sound field the intensity of that field will be negligible. The only intensity left will be that of the direct wave. Thus it would be principally possible to measure free field sound pressure levels in a diffuse field simply by approximating them with the sound intensity [8]. A traditional microphone will record the direct plus diffuse sound while an intensity probe will approximately record the direct sound only.

There are some problems though. A perfectly diffuse sound field does not occur in reality and the diffusivity varies from room to room. The intensity level outside of the direct filed therefore never becomes zero and the determination of what is diffuse enough can become troublesome. Also directivity of the sound source and the intensity probe plays an important role. If a lot of sound intensity is emitted in other directions then in the direction of the microphone the reflection of ceiling, walls and floor will make it difficult to measure the true direct levels. Also here it is difficult to differentiate between different sound sources and varying environment.

A sound intensity probe consists basically two microphones located close to each other and may be close to the noise source and the probe together with the signal processing system may measure the sound intensity coming from the a certain direction.

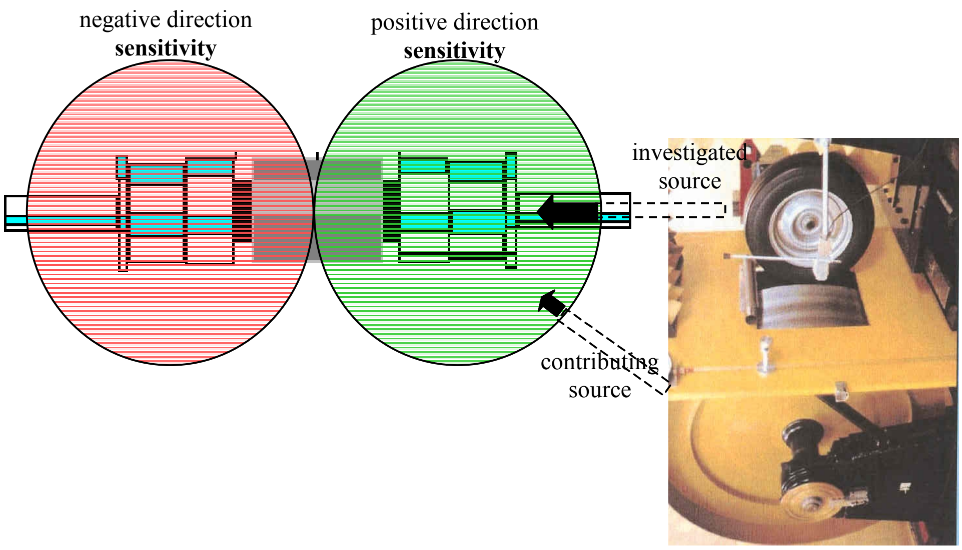

Fig. 2. Influence of sound intensity directivity

Intensity probes are not unidirectional so to some extent they also register sound intensity coming form other directions (Fig. 2). The shape of directional characteristics implies that sound sources located outside the main axis of sensitivity also contribute to the overall intensity measured by the probe. Also, noise reflections from all sources that reach the probe from its rear side may influence the results. However, as the contribution of any source located at the side is roughly proportional to the cosine of the angle between this source and the probe axis the contribution of investigated source located in front of the probe is dominant.

When determining sound power of noise source the background noise will be eliminated because the net flow through the surface enclosing investigated source from sound sources placed outside the enclosing surface is zero (Gauss' theorem) [9].

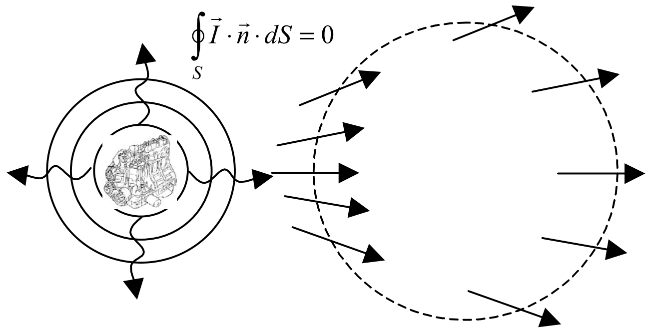

Fig. 3. Gauss's theorem

4. LOCALIZATION OF DOMINANT TIRE NOISE MECHANISMS USING SOUND INTENSITY MEASUREMENTS

Sound intensity measurements offer several ways of localization and identification of parts of the tire radiating the most acoustic energy [10]. In that way, it is possible identify dominant source and noise generation mechanism, which significantly influence to the noise emitted to tire and road interaction.

Sound intensity measurements may be used to localize noise sources and to construct intensity maps showing regions of high and low noise radiation and also in which direction the energy flux.

The null search method uses the probe's directional characteristics. Therefore, there is a change in direction for only a small change in sound incident angle. The position of measurement probe where the sound intensity direction alternates rapidly between positive- and negative-going intensity defines point where the sound source must be incident on the probe at 90° to its axis. In that way the sound source can be located by sweeping the probe so that its axis makes a line parallel to the plane on which we think the source is located.

Contour and 3-D plots give a more detailed picture of the sound field generated by a source. The structure parts radiating most acoustic energy can then be identified with accuracy. Based upon sound intensity measurement directly above the plane on which we think the source is located the level matrix is created. Lines of equal intensity can be drawn by interpolating and joining up point of equal intensity. These are sometimes called iso-intensity lines and they can be drawn either at single frequencies or for overall level. The same data can be used to generate 3-D plots, which provide easy visualization of the sound field generated, by a source.

already in 1980 the sound intensity technique for sound source localization on tires is used [1]. Using a test tire on a trailer along which the intensity probe is moved the research team was able to map the major sound sources (Fig. 4). The dominant source close to the leading edge is evident in the 500-1000Hz range and it is likely to be the tread impact mechanism.

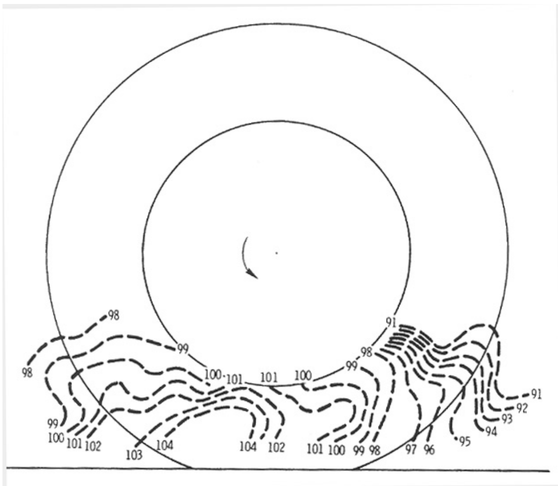

Fig. 4. Map of major sound sources of tire in 500-1000Hz range [1]

The Japanese authors [11] used a car with tire rolling on a drum with the smooth surface and they identified four areas of major acoustical emission (Fig. 5):

- leading edge: 500-2000Hz
- trailing edge: 500-2000Hz
- sidewall: 400-600Hz
- wheel housing: 500-600Hz

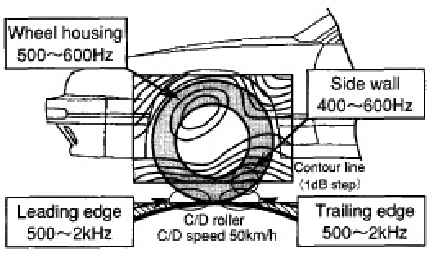

Fig. 5. Contour map of sound intensity level [11]

The contour map indicated major acoustical emission contributions from the trailing and leading edges, especially at the pronounced spectral peak. The similar trend can be seen from the investigations at the Technical University of Gdansk [1]. The different tires have been investigated using the sound intensity technique and some of the sound intensity contour maps are presented in Fig. 6.

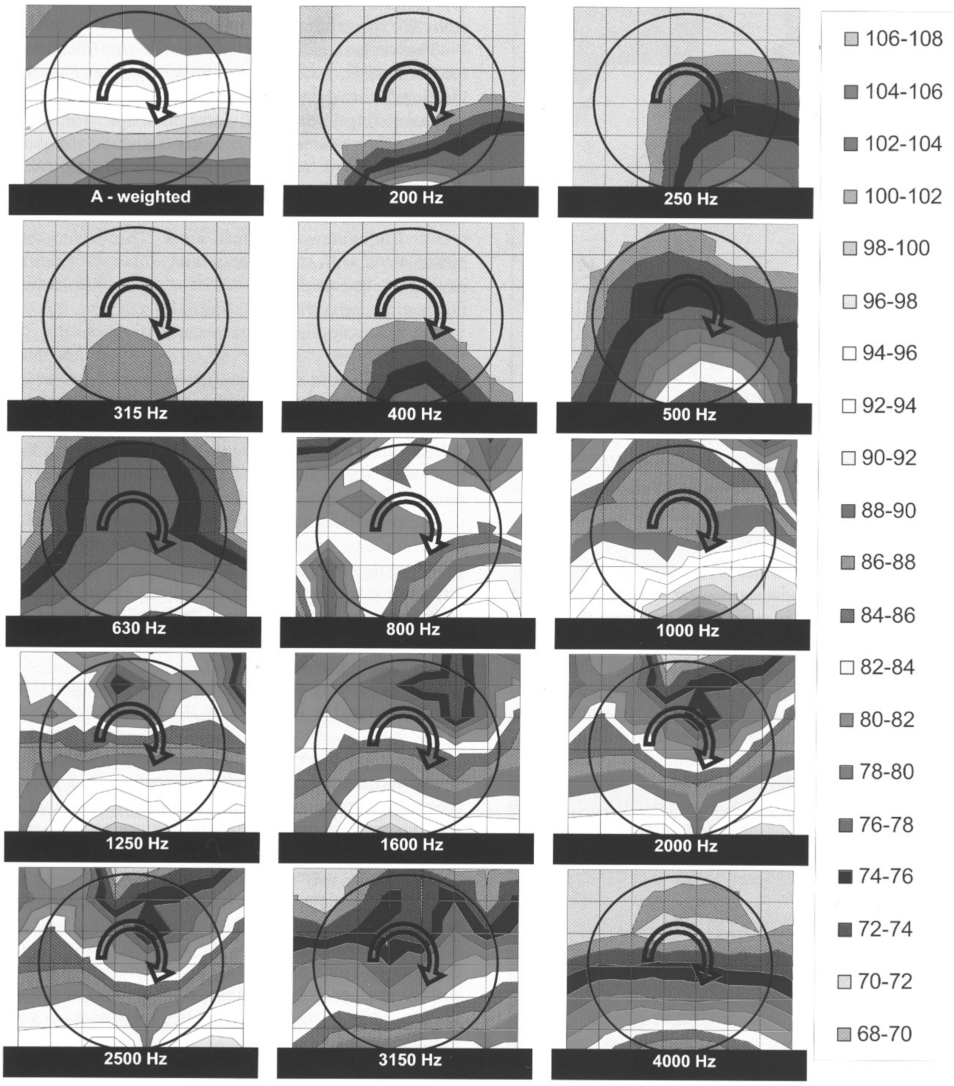

Fig. 6. Sound intensity maps for a summer tire [1]

The sound intensity maps indicate that the location of high acoustical emission vary with frequency. Regions of high acoustical emission can be related with source and tire noise generation mechanisms.

5. CONCLUSION

The sound intensity as a vector quantity offer the possibility of valorization of acoustical emission of noise source in situ, with much more flexibility in choice of measurement environment and size of noise source. Sound intensity measurements may be used to localize noise sources and to construct intensity maps showing regions of high and low noise radiation and also in which direction the energy flux. The shown examples of mapping sound intensity indicate that the sound intensity technique is very reliable tool for identification and valorization of source and tire noise generation mechanisms.

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VALORIZACIJA AKUSTIČKE EMISIJE PNEUMATIKA METODOM INTENZITETA ZVUKA

Momir Praščević

Kvalitet pneumatika je opredeljujući faktor za proizvođača u cilju zadovoljenja poverenja partnera i uspeha na svetskom tržisštu pneumatika. Značajan doprinos mehanizama generisanja buke pneumatika ukupnom nivou buke motornog vozila čini da je nivo buke značajan indikator kvaliteta i tehnološkog nivoa kako pneumatika tako i procesa proizvodnje pneumatika. Akustičke informacije o izvoru buke dobijaju se merenjima koja su valjana samo uz korišćenje standardizovane opreme pri unapred definisanim uslovima i ako rezultati predstavljaju definisanu akustičku veličinu. U radu je dat pregled međunarodnih standarda za određivanje akustičke aktivnosti izvora buke koji su zasnovani na merenju zvučnog pritiska pod unapred definisanim uslovima i u definisanom akustičkom okruženju. Takođe predložen je dvo-mikrofonski metod meranja intenziteta zvuka za valorizaciju akustičke emisije izovra buke. Prikazani primeri mapiranja intenziteta zvuka pokazuju da je intenzitet zvuka veoma pouzdan alat za identifikaciju i valorizaciju izvora i mehanizama generisnja buke pneumatika.

Ključne reči: *akustička emisija, buka pneumatika, intenzitet zvuka, mehanizmi generisanja*