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A NEW METHOD OF THE NOISE EMISSION DECLARATION BASED ON SOUND INTENSITY MEASUREMENT

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Miomir Praščević[1], Dragan Cvetković[2], Darko Mihajlov[3]

Department of Noise and Vibration, Faculty of Occupational Safety, University of Niš,
Čarnojevića 10a, 18000 Niš, Serbia and Montenegro
[1]momir@znrfak.znrfak.ni.ac.yu; momirdb@ptt.yu
[2]draganc@znrfak.znrfak.ni.ac.yu; dbest@ptt.yu
[3]darko@znrfak.znrfak.ni.ac.yu; dmihajlov@bankerinter.net

Abstract. *According to the European directives and international standards, the noise emission of noise sources may be declared. The prime descriptor is an A-weighted emission sound pressure level and its value determines the following step in the noise emission declaration. If an A-weighted emission sound pressure level value is greater than 85dB (A), then the sound power level may be declared. Today measurements of noise emission levels are carried out according to the ISO 11200-series in either specially defined test rooms or in ordinary environmental one, where the sound pressure levels must be correct. In this paper, the results of the investigation of a new method approximating the noise emission level by the sound intensity level have been presented. Because of the sound field reactivity, sound field diffusivity, noise source directivity and measurement probe directivity's influence on the measurement results, the results of investigation of the mentioned factors will be also presented.*

Key Words: *Noise emission, noise source, sound intensity, measurement*

1. INTRODUCTION

The noise problem actualization introduces a new interest in the field - fighting against noise. All segments of society from the producer to the user of a noise source are interesting in fighting the result. First of all, a successful fight against noise requires noise control of the source alone, and that requires the existence of relevant information about the acoustical emission of noise source.

The primary parameter used to describe and declare the noise source emission – the emission sound pressure level is defined as a sound pressure level under free field conditions at the specified positions that depends on the type and character of the noise source. In accordance with European directives [1,2] and international standards [3] related to

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noise sources, each producer of machines, devices and equipment has to declare the sound power level of his products, if the emission sound pressure level exceeds 85dB(A). Therefore, the emission sound pressure level becomes a parameter, which must be determined and whose value assigns the necessity for the determination of other acoustical quantities aimed at defining the noise source emission.

On the other hand, handling information about the emission sound pressure level enables the creation of a simple model of the noise source aimed at characterizing the noise source and the noise prediction in different environments.

The limitations and disadvantages of the standardized methods [3,4] for the determination of the emission sound pressure level of the noise source had determined the scope, subject and aim of the investigation presented in this paper, through definition and experimental verification of an alternative method for the emission sound pressure level determination.

The alternative method is based on the approximation of the emission sound pressure level by a sound intensity component in the direction of a two-microphone measurement probe axis in situ. The assumed approximation is based on the fact that the measurement of the sound intensity probe, located in the vicinity of noise source, will detect the sound intensity that equals the sum of the direct wave intensity of the sound source alone and the intensity of the reflected waves. By creating the conditions where in an ordinary room the hypotheses of the diffuse character of a sound field, deduced on the basis of a multi-reflection existence, and a long duration of the sound waves are valid, the vector sum of the sound intensity component of the reflected waves is very close to zero value at any position in a given room. Under these conditions, when the intensity of the reflected waves is negligible in comparison with the intensity of the direct wave, the sound intensity probe detects only a direct wave.

In this way, the sound pressure level under free field conditions corresponding to the emission sound pressure level can be measured, principally, by the approximation of the sound intensity detected by the measurement probe [5].

2. Method Definition

The sound pressure level detected by the measurement microphone or human ear corresponds to the emission sound pressure level when the noise source is placed in free-field conditions. In those conditions, the emission sound pressure level is equal to the sound intensity level:

$$L_p^{'} = L_I \tag{1}$$

where: $L_p^{'}$ - is the emission sound pressure level and L_I - is the sound intensity level.

When the noise source is placed in a large room with an equivalent absorption area A, the sound pressure level at the specified position in the room is determined by the emission sound pressure level and the sound power level [7]:

$$L_p = 10\log(10^{0.1L_p^{'}} + \frac{4}{A}10^{0.1L_W}) \tag{2}$$

where: L_p – is the sound pressure level in the room and L_W – is the sound power level.

The expression (2) is a mathematical formulation of the fact that two partial levels contribute to the total sound pressure level in the room and are therefore added energetically - the first one is produced by the direct radiation of the noise source and is, therefore, identical with the emission sound pressure level, and the second one is the level produced by the room reflections that depends on the sound power level and the room absorption characteristics.

The measurement of the sound intensity probe located in the vicinity of the noise source detects the sound intensity that equals the sum of the direct wave intensity of the sound source alone and the intensity of the reflected waves (Fig. 1):

$$\vec{I} = \vec{I}_d + \sum_i \vec{I}_{ri} \tag{3}$$

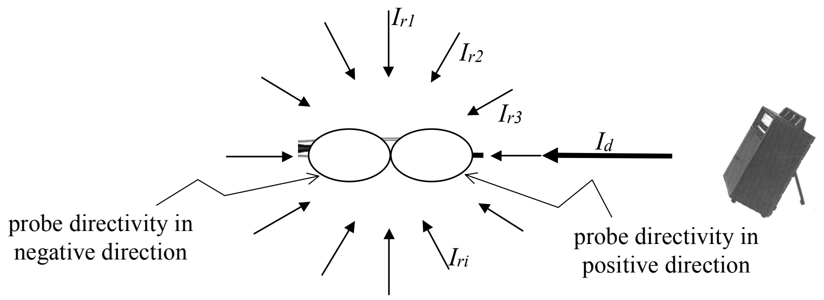

Fig. 1. Illustration of the total sound intensity detected by the measurement probe located in the vicinity of the noise source

The multi-reflection existence and long duration of the sound waves in the room enables the introduction of the following hypothesis:

H1: A large number of waves cover different paths so that they have different amplitudes and the phases come simultaneously into every room position.

H2: All propagation directions are equally probable, which means that sound propagates with equal probability in all directions.

H3: Every wave in his own movement throughout the room passes near enough to all the points in the room.

By creating the conditions where in an ordinary room the abovementioned hypotheses are valid, the vector sum of the sound intensity component of the reflected waves is very close to zero value at any position in a given room:

$$\sum_i \vec{I}_{ri} \approx 0 \tag{4}$$

Under these conditions, when the intensity of the reflected waves is negligible compared to the intensity of a direct wave, the sound intensity probe detects only the direct wave:

$$\vec{I} \approx \vec{I}_d \tag{5}$$

In this way, the sound pressure level under free field conditions corresponding to the emission sound pressure level can be measured, principally, by the approximation of the sound intensity detected by the measurement probe. Consequently, the relation (1) carried out under free field conditions will also be valid in an enclosed space if the above-mentioned hypotheses are satisfied.

3. Experimental Verification of Method

The experimental investigations that were carried out aimed to confirm the assumed approximation and determine the precision of the defined measurement method by a comparison with the results obtained using the standardized methods for the determination of the emission sound pressure level.

The measurement procedure for different locations of the sound source and measurement points, as well as different sound source orientation relative to the measurement transducers, was carried out in free-field conditions above the reflective plane, as well as in ordinary room with approximately diffuse sound field.

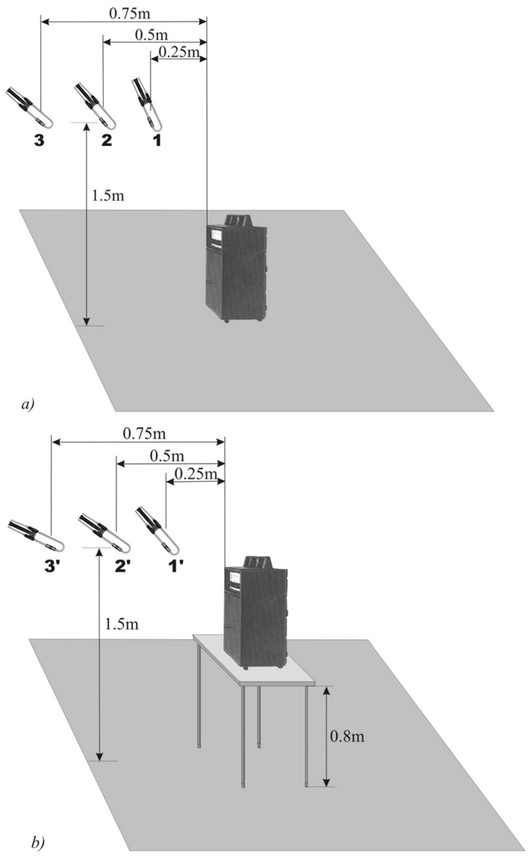

Fig. 2. Test set-up used in the experiment; the sound source location:
a) on the floor b) 0.8m above the floor

The emission sound pressure level was measured using one-third octave band filters with center frequencies ranging from 50Hz to10 kHz and by applying the following methods:

- sound pressure measurement in free-field conditions above the reflective plane (ISO 11201),
- sound pressure measurement in an approximately diffuse sound field above the reflective plane (ISO 11202), and
- sound intensity measurement in both environments in accordance with the described method.

The condenser microphone (CM) and the sound intensity measurement probe (SI) are alternately used as the transducers for the measurement of sound pressure level. The sound pressure level values were used to determine the emission sound pressure level according to the ISO 11201 and ISO 11202. The measured values were corrected for the influence of reflected sound on the emission sound pressure level. Regarding the preciseness of the standardized methods as the referential measurement, the measurement of the emission sound pressure level was made according to the ISO 11201 with the sound intensity probe as the transducer for the measurement of the sound pressure level.

The measurements according to the ISO 11202 and the sound intensity method (SI) were compared to the referential measurement. The deviations in the emission of the sound pressure level results obtained in free-field conditions under reflective plane using the sound intensity method (alternative method) and the sound pressure method (ISO 11201) are shown in Figure 3. The upper graph shows the deviations of the results obtained with a condenser microphone as the transducer for the sound pressure measurement and the lower one shows the sound intensity probe as the transducer.

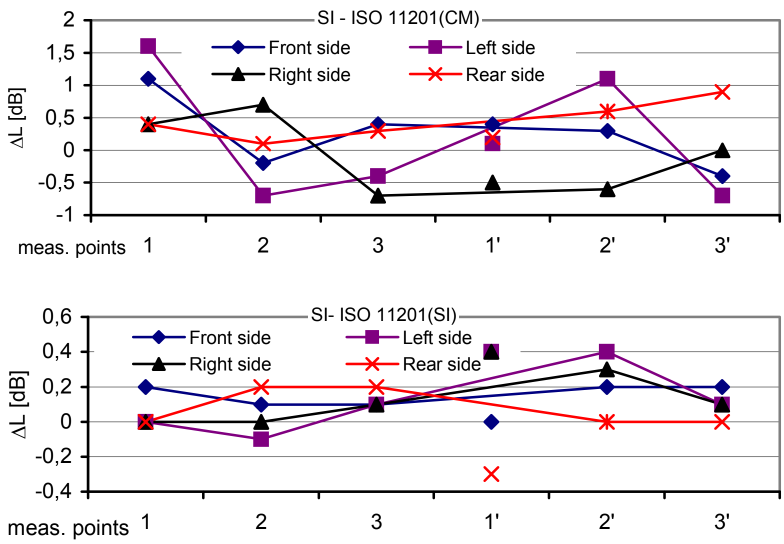

Fig. 3. Method comparison in free-field conditions above a reflective plane

When the measurements were carried out in free-field conditions, the obtained results pointed to fact that the intensity method will give values within ±0.5dB of the referential values with a standard deviation which is about 0.3 dB. The intensity method has lower result deviations when the same transducer for both methods was used. In this case, both sound intensity and the sound pressure were measured in the same point, the center of microphones spacer so that the transducer positioning error was minimized.

The result deviations, obtained using different methods in a regularly shaped room with an approximately diffuse field relative to the referential measurement (ISO 11201(CM)), are shown in Figure 4. The upper graph shows the deviations of the results obtained when the sound source was located on the floor, and the lower one when the sound source was located 0.8m above the floor.

In a regularly shaped room, the intensity method will give values within ±1dB of the referential values with a standard deviation which is about 1dB. The least result deviations were obtained for the measurement point located 0.5m from the source because the point is located in the direct field radiation where the influence of the reverberation field is the smallest.

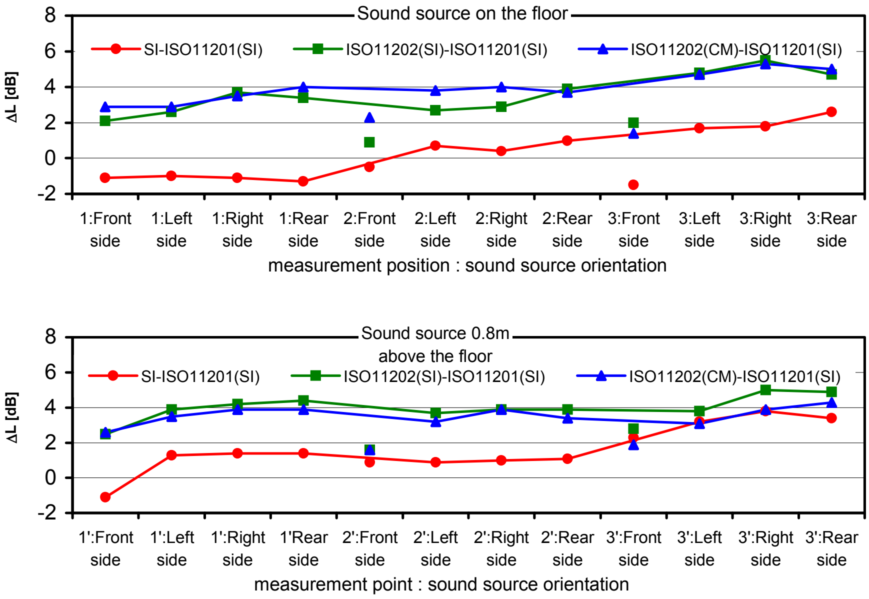

Fig. 4. Method comparison in approximately diffuse condition

4. Factors Influencing the Method

Based on the defined aim, the investigations that had been carried out were directed towards the search for answers to the questions related to the influence of the following factors on the precision and reliability of the suggested method:

- noise source directivity,
- sound intensity probe directivity,
- diffusivity of the sound filed in the environment, and
- reactivity of the sound field in the environment.

4.1 Noise source directivity

The degree of the noise source directivity is defined using the directivity index determined as the difference between the measured sound intensity level for the specified measurement position and the noise source orientation and mean value of the sound intensity level determined based on the measured sound intensity level for all the noise source orientations relative to the specified measurement position.

The directivity index of the test noise source for all the measurement positions is shown in Figure 5. The directivity index was compared to the deviation of the emission sound pressure level values obtained by the sound intensity method from the referential values.

The larger values of the directivity index cause more precise values of the emission sound pressure level determined by the sound intensity method. The most precise values were obtained when the test noise source was frontal, directed to the measurement point corresponding to the maximal value of the directivity index. Therefore, the test noise source should be directed in a way that his main radiation lobe is directed relative to the measurement point.

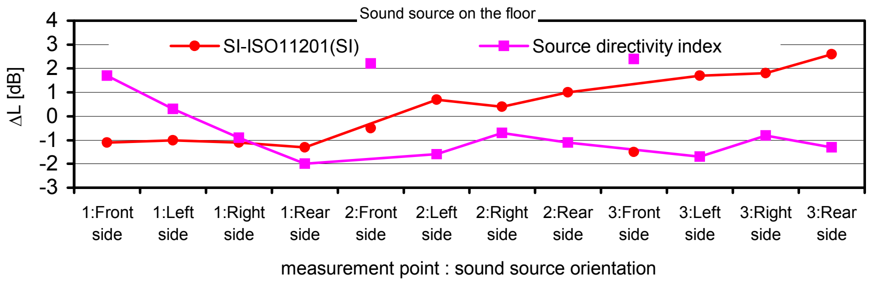

Fig. 5. Influence of the directivity index of the test noise source

4.2 The directivity index of the sound intensity probe

The influence of the directivity index of the sound intensity probe on the reliability of the measurement results has been investigated by different SI probe orientations relative to the tested noise source. The measurements of the sound intensity level with five different orientations of the SI probe relative to the tested noise source have been carried out in the measurement point whose location is shown in Figure 6 (left). The measurement results for different probe orientations are shown in Figure 6 (right) and are compared with the referential spectrum. Depending on the probe orientation the A-weighted emission

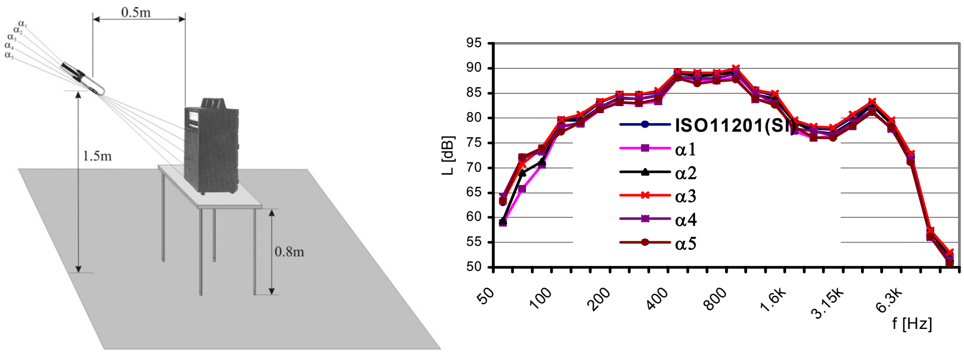

Fig. 6. Influence of the SI probe directivity – the test set-up (left) and measurement results (right)

sound pressure levels vary from 93.8dB (A) to 95.7dB (A). The referential value for this measurement point was 95.4dB (A).

The shown results point to the fact that it is obviously important to orientate the probe to detect the maximum intensity levels when the least deviations from the referential values are obtained.

4.3 Sound field diffusivity

The degree of the sound field diffusivity is defined using the diffusivity index determined as the difference of the sound pressure level measured in a specified measurement position and the noise source orientation and mean value of the sound pressure level determined based on the sound pressure level for all the noise source orientations relative to the specified measurement position. In this case, the sound pressure level was measured by the sound intensity probe.

The sound field diffusivity index for all the measurement positions is shown in Figure 7. The sound field diffusivity index has been compared to the deviation of the emission sound pressure level values obtained by the sound intensity method from the referential values.

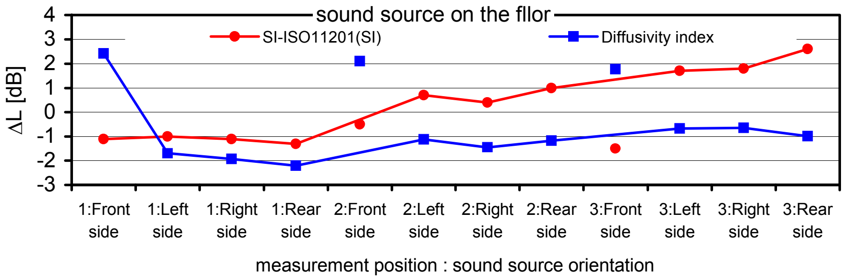

Fig. 7. Influence of the sound field diffusivity index

Comparing the sound field diffusivity index with the deviations of the emission sound pressure level obtained by the sound intensity levels from the referential value, we obtained confusing results. There is no good correlation between the diffusivity index and the obtained deviations.

4.4 Sound field reactivity

The sound field deviation of measurement environment under free-field conditions is defined by the reactivity index determined as the difference between the sound pressure level and the sound intensity level in the specified measurement position. Both values were measured by a sound intensity probe in the same measurement point.

The sound field reactivity index for all the measurement positions is shown in Figure 8. The sound field reactivity index has been compared to the deviation of emission sound pressure level values obtained by sound intensity method from the referential values.

Sound field reactivity had the least values for the measurement points located in direct field of noise source radiation, and a little greater values in the near field and the largest values in the reverberation field. Also, sound field reactivity had the least values in the case of the frontal orientation of the noise source relative to the measurement point and the larger values when the sound source is in the rear and directed toward the measurement point.

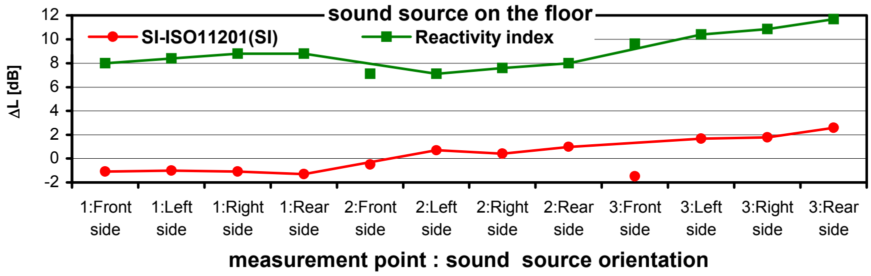

Fig. 8. Influence of the sound field reactivity index

The increasing sound field reactivity causes an increasing sound intensity measurement error. For sound field reactivity values ranging below 8dB, the measurement error will be ±1dB. For sound field reactivity values ranging from 8dB to 10dB, the measurement error will be ±2dB. And for sound field reactivity values ranging under 10dB, the measurement error will be greater than ±2dB.

5. Concluision

The procedures of the investigation process described in this paper have defined the method based on the physical laws of sound energy generation and propagation, which enable a fast, accurate and reliable determination of the emission sound pressure level generated in the exploitation process of a noise source during operational conditions and in the environment where noise source is located.

The alternative method for the determination of the emission sound pressure level is based on the approximation by a sound intensity component in the direction of two-microphone measurement probe axis in situ.

The defined measurement procedure can be applied in situ, in rooms with acoustic characteristics that do not satisfy the necessary conditions for the application of the standardized method for the measurement of the mission sound pressure level.

When the measurements are carried out in free-field conditions the shown results point to fact that the intensity method will give values within ±0.5dB of the referential values with a standard deviation which is about 0.3 dB.

In a regularly shaped room the intensity method will give values within ±1dB of the referential values (ISO 11201), with a standard deviation which is about 1dB. The least result deviations were obtained for:

- the measurement point located in direct field radiation of the noise source where the influence of the reverberation field is the least,
- the noise source placed on the floor,
- the measurement sound intensity probe directed relative to the noise source in such a way that detects the maximum intensity levels,

- the noise source directed relative to the measurement point in such way that his main radiation lobe is directed relative to the measurement point,
- the sound field reactivity index of the environment ranging below 8dB,
- the environmental indicator ranging above 2dB.

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NOVI METOD ZA DEKLARISANJE EMISIJE BUKE ZASNOVAN NA MERENJU INTENZITETA ZVUKA

Miomir Praščević, Dragan Cvetković, Darko Mihajlov

Emisija izvora buke mora se deklarisati u skladu sa zahtevima evropskih direktiva i međunarodnim standardima. Primarni parametar koji je potrebno odrediti je A-ponderisani nivo buke a njegova vrednosti određuje sledeći korak u proceduri deklarisanja emisije buke. Ako je A-ponderisani nivo emisije buke veći od 85dB(A) neophodno je deklarisati i nivo zvučne snage izvora buke. Nivo emisije buke određuje se u skladu sa serijom međunarodnih standarda ISO 11200 u ijalno definisanim mernim prostorijama ili u običnom okruženju kada se izmereni nivo zvučnog pritiska mora korigovati. U radu su prikazani rezultati istraživanja nove metode kojom se aproksimira nivo emisije buke izvora nivoom intenziteta zvuka. Prikazan je i uticaj različitih faktora na preciznost mernih rezultatata kao što su: difuznost zvučnog polja, reaktivnost zvučnog polja, direktivnost izvora buke i direktivnost merne sonde za intenzitet zvuka.

Ključne reči: *Emisija buke, izvor buke, intenzitet zvuka, merenje.*