

METHODOLOGY FOR EVALUATION OF SOUND POWER LEVELS IN WOODWORKING MILLING MACHINES

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ABSTRACT

Woodworking machines belong to the noisiest working machinery that requires study and analysis of noise characteristics in order to reduce the levels of noise emissions.

Noise generation is a complex process that depends on the design features and technical characteristics of the machine and its cutting tools, on one hand and the cutting process and the type of material to cut, on the other.

Generated noise can be categorized as idling noise and cutting noise, depending on the working process and each one of them has to be assessed and analyzed independently.

The objective of the current study is to present a methodology for evaluation of sound power levels, generated by woodworking milling machines, assessed by measuring the sound pressure levels.

Key words: sound power, sound pressure level, milling machines

INTRODUCTION

Woodworking machines are among of the noisiest working machines due mostly to the high rotating speed of their cutting tools. The quality of the modern woodworking machineries is assessed not only by their technological performance but also by the level of emitted noise. The noise, as a criterion, is crucial to ensure normal working conditions on one hand, and it is an indicator of their technical condition, on the other. The magnitude of the noise emission depends on a number of factors, such as power and speed of the drive motor, the output shaft speed, belt drive, condition of the bearings etc. (Filipov, 1979).

Milling machines are used both in furniture and joiner manufacturing and production of construction details and many more. Thanks to their various applications they are one of the most widespread machines in woodworking and furniture industries, while also belong to the loudest woodworking machinery with sound power levels L_w be-

tween 95-108 dB(A). According to the current European standards, in the technical characteristics of each machine, information about the radiant noise measured during its various working conditions, must be given (HSE, 1998).

In order to give an objective evaluation and a comparison between different in their design and technical parameters milling machines, an assessment based on a common methodology should be performed. Regarding the latest European standards the noise of one source is the best characterized by the emitted sound power L_w .

The following work presents a methodology for evaluation of the sound power levels, L_w , generated by the milling woodworking machines during idling, calculated on the basis of the sound pressure levels, L_p , measured in a certain number of points.

1. METHODOLOGY

According to the BDS EN ISO 3740:2003 for evaluation of the sound pow-

er levels from noise sources, the following methods can be used:

- Measurement of acoustic free field;
- Measurement of diffuse acoustic field;
- Measurement using reference sound source.

Taking into account the structural features of woodworking milling machines and the nature of the noise emissions, on one hand, and on the other, the mere fact that in practice the conditions of the free acoustic field are much easier to be found, the current study deals with the sound power evaluation of a milling machine, situated in a free acoustic field. The latter is a field in which the influence of reflections at the boundaries or other disturbing objects is negligible over the frequency range of interest.

1.1. Determination of reference box

The reference box is a hypothetical surface defined by the smallest right parallelepiped that just encloses the source under test. The delineation of the reference box is essential in order to facilitate the selection of the shape and dimensions of the measurement surface. When defining the dimensions of the reference box, elements protruding from the source which are known not to be significant radiators of sound may be designated.

1.2. Determination of the shape and area of the measurement surface

The measurement surface is defined as hypothetical surface of area S which envelops the reference box and terminates on the reflecting plane. The microphone positions at which the sound pressure levels are measured lie on the measurement surface. Under BDS EN ISO 3740:2003 the measurement surface should be of one of the following four shapes:

- a hemisphere, $\frac{1}{2}$ hemisphere, $\frac{1}{4}$ hemisphere with a measurement radius r ;
- a right parallelepiped with sides parallel to those of the reference surface, each side being spaced a distance d (the measurement distance) from the corresponding side of the reference box.
- a cylinder, $\frac{1}{2}$ cylinder or $\frac{1}{4}$ cylinder, with a diameter $2R$ and height h ;
- a combination of the two segments, each being hemispherical, rectangular or cylindrical in shape.

The shape of the measurement surface is determined based on shape and size of the noise source tested, with a goal of having the distance from each microphone to the noise source be roughly equivalent.

Different measurement surfaces have different requirements for the minimal distance between the microphones and the source. For measurement of the pressure on similar noise sources, e.g. machines of the same type, the same shape of measurement surface shall be used (БДС EN ISO 3744:2010).

Taking into account the shape and size of the woodworking milling machines, the right parallelepiped measurement surface with sides: a , b and c , with only one reflecting plane is considered most suitable. The area of the measurement surface S is given by the following equation:

$$S = 4(ab + bc + ca), \text{ m}^2 \quad (1)$$

where

$$a = 0,5l_1 + d;$$

$$b = 0,5l_2 + d;$$

$$c = l_3 + d;$$

l_1 , l_2 , l_3 are the length, width and height, respectively, of the reference box;

d – measurement distance (the distance from the reference box to the sites of the measurement surface – parallelepiped)

which depends on the size of the noise source under test, and $d \geq 1$ m.

1.3 Microphone position on the measurement surface

In the case of the measurement surface with a shape of right parallelepiped with

only one reflecting plane, each one of the fifth areas is regarded per se and each area has to be divided in a way that all of them should be consisted of segment areas with equal dimensions and a maximum length of the long side of $3d$ (fig. 1).

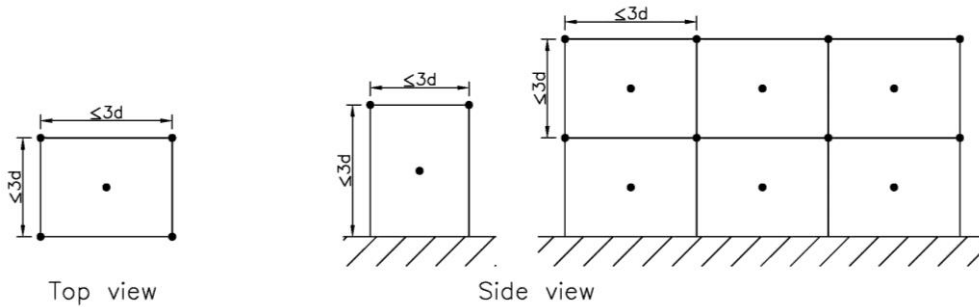


Figure 1: Microphone positions in the case of measurement surface in the shape of right parallelepiped with rectangular segmental areas

• – microphone positions, d – measurement distance

The microphone positions should be located at the center and the corners of each segment area, a part of the corners that intersect with the reflecting surface.

The microphone positions for the measurement of the sound pressure of a sound source with dimensions of the reference box: $l_1 \leq d$, $l_2 \leq d$, $l_3 \leq 2d$ are shown in fig. 2

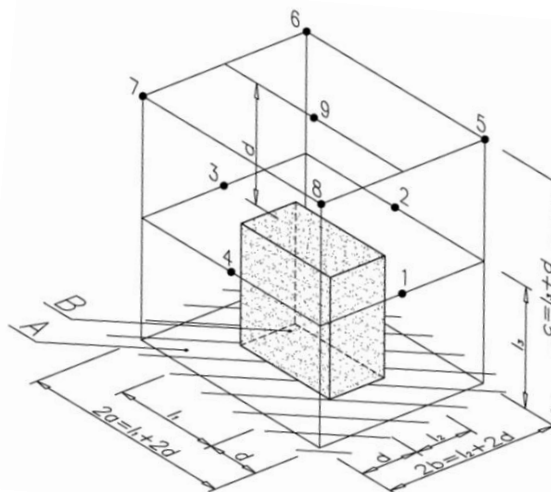


Figure 2: Microphone positions in the case of measurement surface in the shape of right parallelepiped and noise source with dimensions of the reference box:

$$l_1 \leq d, l_2 \leq d, l_3 \leq 2d$$

• – microphone positions; A – reflecting area; B – reference box; $2a$ – length of the measurement surface; $2b$ – width of the measurement surface; c – height of the measurement surface; d – measurement distance; l_1 – length of the reference box; l_2 – width of the reference box; l_3 – length of the reference box.

For calculating the sound power of a noise source according to the BDS EN ISO 3744:2010, the minimal number of measurement points is nine.

1.4. Measured values

Time-average sound pressure levels, $\overline{L_{pi(ST)}}$ in 1/1 octave bands in dB and sound level, corrected by A-weighted in dB(A) are to be obtained at each microphone position for the noise source under test using a specialized equipment. The mean time-average sound pressure level, $\overline{L_{p(ST)}}$, from the array of microphone positions over the measurement surface for the chosen mode of operation of the noise source under test, is calculated using equation (2):

$$\overline{L_{p(ST)}} = 10 \lg \left[\frac{1}{N_M} \sum_{i=1}^{N_M} 10^{0,1L_{pi(ST)}} \right] \quad (2)$$

where

$L_{pi(ST)}$ is the octave band in dB or A-weighted in dB(A) time average sound pressure level

measured at the i^{th} microphone position with the noise source under test (ST) in operation;

N_M – the number of microphone positions.

Moreover, immediately before or after the measurement of the sound pressure levels of the noise source under test, $\overline{L_{p(ST)}}$, the sound pressure levels of the background noise, measured at each microphone positions, should also be determined. Time-average sound pressure level of the background noise, $\overline{L_{p(B)}}$, is calculating using equation:

$$\overline{L_{p(B)}} = 10 \lg \left[\frac{1}{N_M} \sum_{i=1}^{N_M} 10^{0,1L_{pi(B)}} \right] \quad (3)$$

where

$L_{pi(B)}$ is the mean octave band, in dB time-average sound pressure level of the background noise or the time-average sound pressure level of the background noise, corrected by A-weighted, in dB(A) measured at the i^{th} microphone position.

The background noise correction, K_1 , is calculating according the equation:

$$K_1 = -10 \lg(1 - 10^{-0,1\Delta L_p}), \text{ dB} \quad (4)$$

where

$$\Delta L_p = \overline{L_{p(ST)}} - \overline{L_{p(B)}}$$

$\overline{L_{p(ST)}}$ is the mean octave band, in dB time-average sound pressure level or the time-average sound pressure corrected by A-weighted, in dB(A);

$\overline{L_{p(B)}}$ – the mean octave band, in dB time-average sound pressure level of the background noise or the time-average sound pressure level of the background noise, corrected by A-weighted, in dB(A).

If $\Delta L_p > 15$ dB, the background noise does not exert any influence on the measurement and therefore no correction for shall be applied, i.e $K_1 = 0$.

If $6 \text{ dB} \leq \Delta L_p \leq 15 \text{ dB}$, the noise correction K_1 shall be calculated using equation (4) and applied:

If $\Delta L_p < 6$ dB the accuracy of the results is reduced. In this case, it shall be clearly stated in the text of the report that the data in such bands represent the upper bound to the sound power level of the noise source under test.

Since in practice the characteristics of the free acoustic field are difficult to be achieved, the environmental correction coefficient – K_2 should be also estimated. The environmental correction accounts for the influence of reflected or absorbed sound, and is calculated using equation:

$$K_2 = 10 \lg \left[1 + 4 \frac{S}{A} \right], \quad dB \quad (5)$$

$$A = \alpha \cdot S_v, \quad m^2 \quad (6)$$

where
 A is equivalent area of sound absorption of the test room, m^2 ;
 S – total area of the measurement surface, m^2 .
 The equivalent area of absorption of the test room, A , is calculated using equation:

where
 α – is coefficient of sound absorption;
 S_v – total area of the boundaries of the test room, m^2 .
 The values of the mean sound absorption coefficient, α , depending on the room absorption are presented in Table 1.

Table 1: Values of the mean sound absorption coefficient depending on the room absorption

Mean sound absorption coefficient, α	Room description
0,05	Nearly empty room with smooth, hard walls, made of concrete, brick, plaster or tile
0,10	Partly empty room; room with smooth walls
0,15	Right cuboid room with furniture; right cuboid machinery room or industrial room
0,20	Irregularly shaped room with furniture; irregularly shaped machinery room or industrial room
0,25	Room with upholstered furniture; machinery or industrial room with sound-absorbing material on part of ceiling or walls
0,30	Room with sound-absorbing ceiling, but not sound-absorbing materials on walls
0,35	Room with sound-absorbing materials on both ceiling and walls
0,50	Room with large amount of sound-absorbing materials on ceiling or walls

The real time average sound pressure level of the noise source under test, \overline{L}_p is calculated using the equation (7):

$$\overline{L}_p = \overline{L}_{p(ST)} - K_1 - K_2 \quad (7)$$

where
 K_1 – is correction coefficient for the background noise, dB;
 K_2 – correction coefficient for the test environment, dB.

Sound power level of the noise source under test, L_w is calculated using the equation (8):

$$L_w = \overline{L}_p + 10 \lg \frac{S}{S_0}, \quad dB \quad (8)$$

where
 \overline{L}_p is time average sound pressure level, dB;
 S – total area of the measurement surface, m^2 ;
 $S_0 = 1 \text{ m}^2$.

2. MEASUREMENT EQUIPMENT

To measure the sound pressure levels of a noise source, precision measurement equipment should be used. Currently, in Bulgaria the most used are the sound level meters offered by “Bruel & Kjaer”, Denmark and “RFT”, Germany. They work with a frequency range from 20 to 20 000 Hz. These devices provide an opportunity for measurements according to time constants “fast” (F) and “slow” (S) and they measure both linear sound pressure levels and sound levels, corrected according to the standard frequency characteristics A, B, C and D. For conducting of an octave frequency analysis of noise, the sound level meters should be equipped with 1/1 octave frequency filters with mean geometric frequency, as follows: 31, 5, 63, 125, 250, 500, 1000, 2000, 4000, 8000, 16000, 31500 Hz.

Essential for the accurate measurement of the device is its calibration. For the calibration, it is recommended to be performed using a standard sound signal, emitted by electric generators, called pistonphones. The corrections for the changes in atmospheric pressure are carried out according to the barometer readings, accompanying the pistonphone.

CONCLUSIONS

The presented methodology is applicable for evaluation of the sound power levels, generated during idling, with or without cutting tools by milling woodworking machines and all types of machineries used in woodworking industry, alike.

In order a full characteristic of the sound power levels emitted from a woodworking machine to be obtained, the meas-

urements should be performed at all rotating speeds of the shaft.

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