JEE Journal of Ecological Engineering

Volume 19, Issue 1, January 2018, pages 83–93

https://doi.org/10.12911/22998993/79447

Received: 2017.10.12
Accepted: 2017.10.30
Published: 2018.01.01

Monitoring of the Noise Emitted by Machine Tools in Industrial Conditions

Jerzy Józwik[1*], Andrzej Wac-Włodarczyk[2], Joanna Michałowska[3], Monika Kłoczko[4]

[1] Mechanical Engineering Faculty, Department of Production Engineering, Lublin University of Technology, Nadbystrzycka 36 Str., 20-618 Lublin, Poland

[2] Electrical Engineering and Computer Science Faculty, Institute of Electrical Engineering and Electrotechnologies, Lublin University of Technology, Nadbystrzycka 38a Str., 20-618 Lublin, Poland

[3] The State School of Higher Education, The Institute of Technical Sciences and Aviation, Pocztowa 54 Str., 22-100 Chełm, Poland

[4] Aesculap-Chifa Sp.z o.o. Radzyń Podlaski, Budowlanych 3 Str., 21-300 Radzyń Podlaski, Poland

* Corresponding author's e-mail: j.jozwik@pollub.pl

ABSTRACT

The paper presents an analysis of noise emitted by selected machine tools in a production hall (under industrial conditions). Noise monitoring is a fundamental task for maintaining workplaces which are safe and healthy. This paper presents the noise measurements obtained for several machine tools, performed in accordance with the PN ISO 230–5:2002 standard. The identification of noise sources and levels was conducted by means of the UNIT 352 measurement system for DMU 50, BGO-CNC/RV/R, FU 251, FW 801, FWC 25/H. Detection of noise sources in the tested machine tools allows to maintain safety of workers and effective means of noise reduction, which are highly significant from the perspective of minimising noise at various workstations. The method of performing noise measurements at workstations using specific machines is normalised, so that the results of such measurements for different machines could be compared. The test results were presented in the form of diagrams and tables. The results of the tests are concluded by a detailed recommendation for the CNC machine tool operators to use hearing protection when at work. The results showed that the level of noise at the operator's workstation significantly exceeds the standard at certain machining parameters.

Keywords: noise monitoring, measurement, sound pressure, CNC machine tools

INTRODUCTION

Metal processing with CNC machine tools (lathes, milling machines, grinders and others) always creates certain risks, despite the use of protective equipment. The majority of such factors come with time (operation) and it is impossible to avoid them. This can be attributed, inter alia, to changes in the work environment, machine wear, failures, and non-compliance with health and safety rules. One of these risks is noise. Noise is defined as any unwanted, unpleasant or injurious mechanical vibration traveling through an elastic medium which negatively affects the organ of hearing and other elements of the human body. Energy in an acoustic field is determined by the following quantities: sound power L_N, noise level L_I or sound pressure L_p. Noise is frequently defined as any sound which, in given conditions, is undesirable, tiring or harmful to human health [2]. Noise-induced hearing loss is one of the most common occupational illnesses in Europe and it is present in about one third of all work-related diseases [16]. Safety is a wide subject of interest and its proper application allows to obtain a safe product and safe working environment [6–7, 14–15, 17]. Noise minimisation is exceptionally important in machinery industry, where constant operation of machinery and devices entails exposition to high levels of noise. Examples of this include production halls with CNC machines [4–5, 8–13]. Evaluation of that kind of noise constitutes the basis for using different methods of noise reduction and personal hearing protection when operating CNC machines [18–19]. According to data provided by the Central Statistical Office (GUS), 34% of plants out of 3236 noise emitting objects exceeded the allowable noise level in years 2012–2015. Nearly 40% of Polish employees employed under harmful and hazardous conditions (GUS) work in noise exposure levels of over 85 dbA (the data collected by the Central Statistical Office are incomplete because they cover only the companies that employ more than 9 people). Reliable measurement of noise created a need to prepare a procedure for measuring the noise emission at CNC workstations. A comprehensive procedure of measuring the acoustic energy emitted by CNC machines is presented in the Polish standard PN-ISO 230–5:2002. The standard contains the information on basic conditions for carrying out tests of emission and sound power, test methods, necessary measuring equipment and the procedure for analysing the results. Noise is one of the most tiring factors in working environments. Its impact on the human organism is difficult to assess [2–3, 20]. Every person working under industrial conditions is exposed to the noise levels that very often exceed the allowable values. The harmful and tiring effects of noise depend on its intensity, frequency and changes in time, long-lasting effects and the contents of inaudible components, as well as certain characteristics of the operators such as age, mental condition, health and individual sensitivity to sounds. Prolonged exposure to high levels of noise has negative effects on a person's health. High levels of noise have a negative effect on well-being, and – in extreme cases – may lead to hearing impairment. Hearing protection must be worn if the level of noise is 85 dB or higher [2, 4, 18–20]. Machine tools for cutting metal are a source of noise. For example lathes, milling and drilling machines produce noise up to 104 dB, metal cutting saws – up to 115 dB, and grinders – up to 134 dB. There are a couple of standards that substantially limit the permissible values of the noise emitted by machine tools. The permissible noise levels in work environments (NDN values), established for hearing protection, are specified by the Ordinance of the Minister of Labour and Social Policy. These levels are, respectively: noise exposure level applicable to an 8-hour working day (LEX,8h) should not exceed 85 dB and the corresponding daily exposure should not exceed $3.64 \cdot 103$ $Pa^2 \cdot s$; in exceptional cases, when the noise exposure level varies from one working day to another, the noise exposure level in relation to the average weekly working time (LEX, W) should not exceed 85 dB and the corresponding weekly exposure should not exceed $18.2 \cdot 103$ $Pa^2 \cdot s$; the maximum A weighted sound level (LAmax) should not exceed 115 dB; the peak C-weighted sound level (LCpeak) should not exceed 135 dB. The exposure action values are set out in the Regulation of the Minister of Economy and Labour on Occupational Safety and Health for Works Related with Exposure to Noise or Mechanical Vibrations. These values are as follows: noise exposure level applicable to an 8-hour working day or weekly noise exposure level – 80 dB; the peak C-weighted sound level – 135 dB. The above-mentioned normative values apply if other provisions do not specify the lower exposure action values (e.g. in the workstations occupied by young people – LEX,8 h = 80 dB, and in the workstations occupied by pregnant women – LEX,8 h = 65 dB). However, as it turns out, the noise emission in industrial plants is slightly decreasing, compared to the previous research periods. Increasingly, the stringent rules for the protection of health require to reduce the airborne noise emissions from industrial plants. This is facilitated by a change of mentality and approach to the protection of workers' health as well as the introduction of new "low-noise" and more "environmentally friendly" means of production, i.e machine tools.

RESEARCH METHODOLOGY

The principal objective of the work was to assess and analyse the noise emitted by machine tools in a production hall, underindustrial conditions. The research was carried out in Aesculap-Chifa Sp.z o.o. in Radzyn Podlaski, a company that manufactures surgical instruments, such as: tissue grasping forceps, scrapers, scissors, dental forceps, etc. The noise in the analysed company is a result of mechanical vibrations, which are caused by the loss of machine's basic properties as well as increasing wear of particular kinematic pairs, formation of backlash and improper exploitation, machining conditions as well as inadequate assembly of basic and auxiliary equipment.

All these factors contribute to the increased noise levels generated by machine tools. Numerically controlled CNC machines and conventional NC machines were monitored. A group of milling machines marked with the following trade symbols: DMU 50, BGO-CNC/RV/R, FU 251, FW 801, FWC 25/H (Figure 1), were placed in the production hall (Figure 2).

The noise monitoring process was carried out in accordance with the strictly defined rules and regulations contained in the PN-ISO 230–5:2002 standard ”Test code for machine tools – Part 5: Determination of the noise emission”. This standard specifies the procedure for testing the noise of stationary machine tools and associated auxiliary equipment located in a production hall. Auxiliary equipment used in the analysed company includes: heat exchangers, freezer units, hydraulic power packs, extraction equipment and chip conveyors. UT352 sound-level meters (30–80 dB, 50–100 dB, 60–110 dB, 80–130 dB) were used for the laboratory and industrial measurements. According to technical specifications of the device, it is characterised by a high accuracy of +/- 1.5dB. The measurement channel structure is shown in Figure 3. The measurements were made for different spindle speeds n: maximum value n_{max}, average value n_{avg} and minimum value n_{min}.

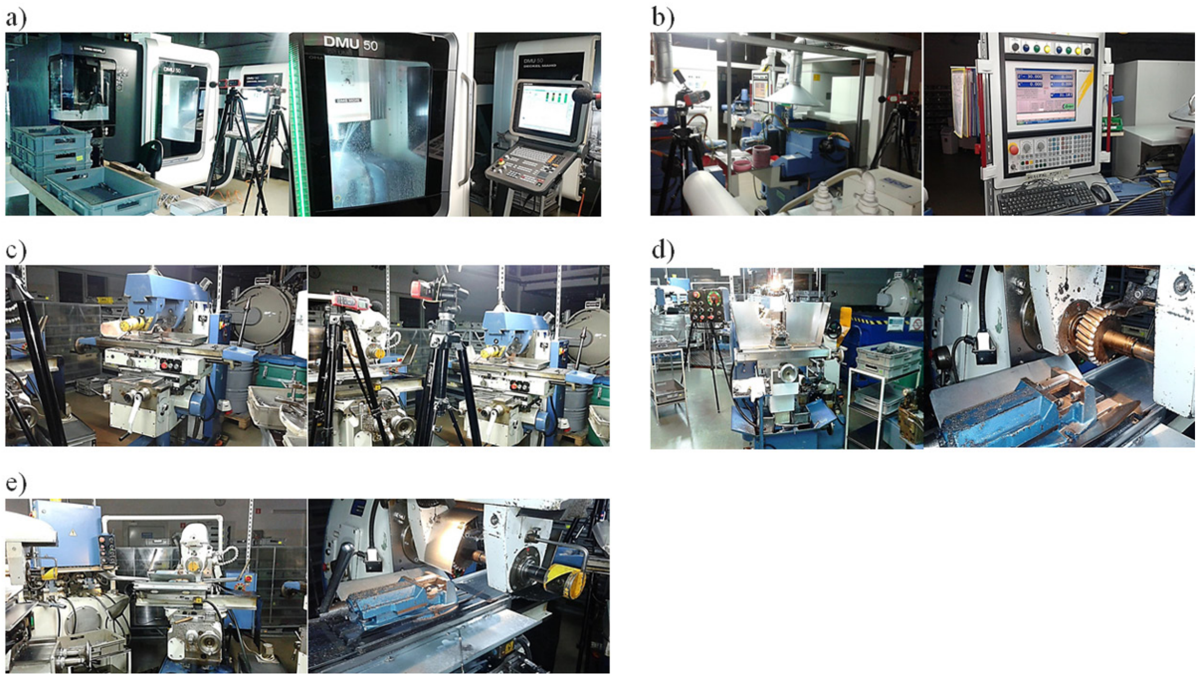

Fig. 1. Test stands: a) milling machine DMU 50, b) Berger BGO-CNC/RV/R, c) FU 251, d) FV 801, e) FWC 25/H

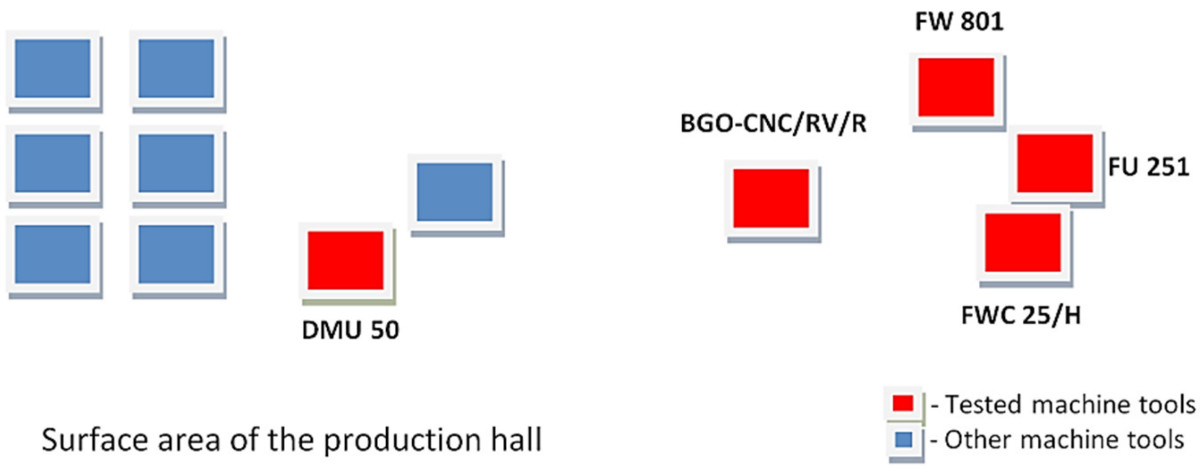

Fig. 2. Arrangement of machine tools in the production hall

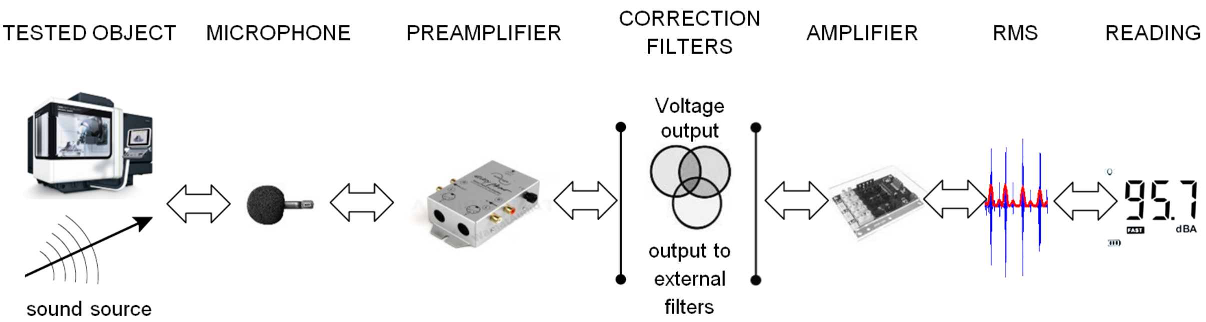

Fig. 3. Measurement channel structure

A correction filter A was used to measure the maximum sound level. This filter represents noise frequency components in the best possible way. The filters were also used to adjust the readings of the meter to various characteristics of the human ear, i.e. so they could represent the actual acoustic effects. Equally loud sounds with different frequencies are perceived by the human ear as sounds of varying intensity levels. When it comes to metal cutting machines, as well as most machines, it is recommended to make measurements with a correction filter A.

In order to determine the effective value, the signal passes through the RMS converter that allows integration:

$$U_{RMS} = \sqrt{\frac{1}{T}\int_0^T u^2(t)dt} \qquad (1)$$

The processed signal can be oriented along the direction of the indicator, enabling to read the noise level in dB.

The scope of research includes the measurements of noise emitted by 5 metal cutting machines with similar kinematics and geometrical characteristics, equipped with computer numerical control systems CNC and located in the production hall, as shown in Figure 2.

Diagnostic evaluation

The process of diagnostic evaluation was carried out in accordance with the scheme covering:

- preparatory work (determining the amount of measurement points and their locations, starting the machines, defining machine parameters – idling operation and work tests),
- diagnostic evaluation (measurements and analysis of research results),
- drawing conclusions (comparison and evaluation of the results as compared to the permissible value, permissible noise exposure levels applicable to an 8-hour working day (LEX, 8 h < 85 dB).

The noise measurements were conducted in one plane at 8 measurement points during idling operation and work tests, as shown in Figure 4.

Experimental tests and their results

Noise level monitoring was performed for five milling machines, two of which were numerically controlled machine tools, and the other three included conventional machine tools. The research area is presented in Figure 2. On the other hand, Figure 4 shows the location, arrangement and distance between different meters in relation to the machine tool and the operator marked with X. The meters were located at a distance of 1 m from

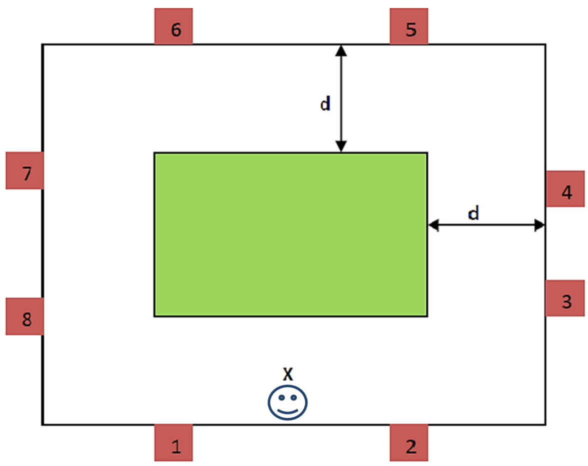

Fig. 4. Location of measuring instruments in relation to the machine tool and the operator, X – location of the operator, d – measurement distance of meters in relation to the machine tool, 1, 2, .., 8 – measurer position

the machine tool and at a height of 1.6 m. Measurement microphones were situated horizontally, along the direction of a given machine tool. These rules were applied to each tested machine. The volume of the research area was determined according to the following formula (2):

$$V = a \cdot b \cdot h \qquad (2)$$

where: a – length,
b – width,
h – height
$V = 40 \text{ m} \cdot 20 \text{ m} \cdot 6 \text{ m} = 4800 \text{ m}^3$

Background measurements were carried out for the purpose of making an accurate calculation. Their value was $L'_{pA} = 55.98$ dB. The equivalent acoustic absorption was determined according to the following formula (3):

$$A = 0.16 \cdot (\frac{V}{T}) \qquad (3)$$

where: V – volume of the research area,
T – reverberation time,
A – equivalent acoustic absorption.

The equivalent acoustic absorption was 419.7 m^2 for the characteristic data contained in the (3) formula, i.e. $v = 4800$ m^3 and $T = 1.83$ s

The local environmental correction, at a distance from a given place to the nearest major sound source from the tested machine $a = 1$ m, was determined from the following formula (4):

$$K_3 = 10\lg[1 + 4\left(\frac{2\pi a^2}{A}\right)] \qquad (4)$$

After adding the distance value $a = 1$, and the equivalent acoustic absorbance $A = 419.7$ m^2 to the formula (8), the correction value was $K_3 = 0.25$ dB.

The local environmental correction K_3 (correcting element) is expressed in decibels. It depends on the frequency and location, and takes into account the impact of the reflected sound on the emission sound pressure level at a specific location of the tested machine tool, e.g. at the workstation. The A-weighted frequency correction is marked by K_{3A}. In order to determine the A-frequency weighted surface sound pressure levels, one must calculate the average of the measured A-frequency weighted sound pressure levels. The following sections of this paper contain corresponding formulas used to calculate the A-frequency weighted surface sound pressure level. For this purpose, frequency-weighted environmental corrections K_2 were also determined. The K_2 correction is expressed in decibels. It takes into account the impact of the reflected or absorbed sound on the surface sound pressure level. As in the case of the K_3 correction, the A-frequency weighted correction is marked by K_{2A} (5). The dependence of the correction takes into consideration the unwanted sound that is reflected at the objects and walls surrounding the tested machine. The value of the environmental correction depends on the target area S and the equivalent acoustic absorption A.

$$K_{2A} = 10\lg[1 + 4\left(\frac{S}{A}\right)] \qquad (5)$$

The average of the A-frequency weighted acoustic pressure levels measured by the measuring instrument are used to calculate the sound pressure level, taking into account the previously calculated local environmental correction. The emission sound pressure level is calculated from the formula (6). It depends on the size of the local environmental correction and the average of the A-frequency weighted acoustic pressure levels contained in table 8.

$$\mathrm{L_{pA}} = \mathrm{L'_{pA}} - \mathrm{K_{3A}} \qquad (6)$$

The A-frequency weighted surface sound pressure level is calculated from the formula (7). In order to determine L_{pfA} it is necessary to obtain the A-frequency weighted average of the measurements calculated for the tested machine tool.

$$\bar{L}_{pfA} = 10\log[\frac{1}{N}\sum_{i=1}^{N} 10^{0,1L'_{pAi}}] - K_{2A} \qquad (7)$$

where: L'_{pAi} – the frequency weighted sound pressure level measured during operation of the machine, in the i-th position of the microphone,
N – the number of microphone positions

The weighted sound power level is calculated from the (8) formula. The value of the sound power level depends on the size of L_{pfA} and target area.

$$L_{wA} = \bar{L}_{pfA} + 10\log(\frac{S}{S_0}) \qquad (8)$$

The exemplary results of the tested machines' acoustic evaluation, including the results of the calculations obtained for the tested machine tools, are presented in Tables 1 to 6. Table 1 presents the results of noise level measurements made using DMU 50. Table 2 presents the results of measurements and calculations of the acoustic parameters of Berger BGO-CNC/RV/R. Table 3 presents the acoustic evaluation carried out for the FU 251 milling machine. Table 4 shows the results of acoustic tests performed for the FW 801 milling machine. Table 5 presents the results of acoustic tests performed for the FWC 25/H milling machine.

Figure 5 shows the course of changes in sound pressure for the tested machine tools (for the DMU 50 machine (Figure 5a), for the BGO-CNC/RV/R machine (Figure 5b), for the FU 251 machine (Figure 5c), for the FV 801 machine (Figure 5d) and for the FWC 25/H machine (Figure 5e)).

The results of the minimum, maximum and average value measurements of A-frequency weighted sound power levels – are presented in Table 6 and the comparison of the five machine tools is presented in the bar chart (Figure 6).

The conclusions were drawn upon the context of the efficiency and safety of the operators and their surroundings. While performing the comparative analysis and drawing conclusions, one should take into account the noise exposure level applicable to an 8-hour work day or weekly noise exposure level and the peak sound level. The conducted research permits a more precise control of the exposure of workers to noise and enables to improve the machine operating conditions as well as minimize the negative impact of noise on the human organism and environment.

CONCLUSIONS

The expansion of the machine park installed in the company increases the exposure to noise in the work environment. The machine park of the company which was the subject of the noise exposure assessment continues to grow and develop, while the space in which the machines are located remains unchanged. The noise in the analysed production plant is not only the result of a large group of machines and equipment, but also their parallel operation. The noise generated by machines increases as they wear out. The conducted research clearly shows that none of the tested machines exceeded the limit values permitted by the relevant standard (85 dB). Nevertheless, it should be noted that the noise levels (78–78.9 dB) determined by means of experimental and computational methods are close to the limit value permitted by the standard. Noise is not only dangerous for employees in a purely physical, but also

Table 1. Results of noise level measurements and calculations for DMU 50 machine tool

A-frequency weighted sound power levels. L_{wA}		90.8 W							
Emission sound pressure level L_{pA}		73.15 dB							
Linear dimensions of the target area (reference cuboid)		l_1 + 2 = 4.5 + 2 = 6.5 m l_2 + 2= 4 + 2 = 6 m l_3 + 1 = 2.5 + 1 = 3.5 m							
Target area S		117.6 m^2							
Measurement distance d		1 m							
K_{2A}. K_{3A}		3.3 dB; 0.25 dB							
A-frequency weighted background noise		55.9 dB							
		1	2	3	4	5	6	7	8
A-frequency weighted sound power levels at each measurement point	1.	71.5	68.4	68.9	71.2	67.5	66.2	65.5	69.3
	2.	67.2	66.1	66.7	71.8	65.4	66.6	64.9	67.0
	3.	77.8	64.5	86.1	82.7	64.9	68.7	64.8	67.2
	4.	80.6	72.8	83.3	82.5	80.5	76.3	67.0	73.9
	5.	78.6	81.3	75.1	74.7	79.4	69.7	77.5	82.1
	6.	72.4	77.9	71.5	71.3	79.8	79.1	68.5	81.2
	7.	69.8	77.2	88.4	83.5	68.5	71.2	70.3	72.6
	8.	81.7	68.2	68.3	70.5	67.5	70.4	79.8	79.8
	9.	67.2	86.2	68.1	70.4	79.8	85.1	66.9	78.2
	10.	76.9	65.2	87.4	69.8	65.6	66.9	73.6	74.6
A-frequency weighted surface sound pressure levels. $\bar{L}_{pfA}$		70.1 dB							

Table 2. Results of noise level measurements and calculations for Berger BGO-CNC/RV/R machine tool

A-frequency weighted sound power levels. L_{wA}	85.7 W								
Emission sound pressure level L_{pA}	68.35 dB								
Linear dimensions of the target area (reference cuboid)	l_1 + 2 = 5 + 2 = 7 m l_2 + 2= 3.5 + 2 = 5.5 m l_3 + 1 = 1.5 + 1 = 2.5 m								
Target area S	101 m^2								
Measurement distance d	1 m								
K_{2A}. K_{3A}	2.92 dB. 0.25 dB								
A-frequency weighted background noise	55.9 dB								
		1	2	3	4	5	6	7	8
A-frequency weighted sound power levels at each measurement point	1.	74.2	70.9	71.1	67.6	70.5	68.4	69.3	68.9
	2.	72.6	70.7	69.3	65.6	69.8	70.5	69.5	68.3
	3.	71.8	69.8	69.8	66.1	67.1	66.4	70.3	68.6
	4.	70.6	67.9	69.5	65.5	67.3	67.5	69.4	66.2
	5.	68.6	66.9	70.0	63.8	67.5	69.5	68.6	66.1
	6.	69.0	67.3	74.3	68.4	67.1	66.2	68.6	66.8
	7.	72.2	70.5	69.4	65.6	70.1	68.9	69.4	68.7
	8.	70.5	69.1	70.3	64.5	68.8	67.9	69.2	67.3
	9.	69.3	66.6	69.2	66.9	68.9	66.5	69.6	68.2
	10.	68.8	66.4	69.4	63.8	68.6	66.5	69.1	65.5
A-frequency weighted surface sound pressure levels. $\bar{L}_{pfA}$	65.7 dB								

Table 3. Results of noise level measurements and calculations for FU 251 machine tool

A-frequency weighted sound power levels. L_{wA}	90 W								
Emission sound pressure level L_{pA}	73.05 dB								
Linear dimensions of the target area (reference cuboid)	l_1 + 2 = 2 + 2 = 4 m l_2 + 2= 1.5 + 2 = 3.5 m l_3 + 1 = 1.7 + 1 = 2.7 m								
Target area S	54.5 m^2								
Measurement distance d	1 m								
K_{2A}. K_{3A}	1.82 dB. 0.25 dB								
A-frequency weighted background noise	55.9 dB								
		1	2	3	4	5	6	7	8
A-frequency weighted sound power levels at each measurement point	1.	70.4	70.5	72.2	72.1	74.0	69.6	73.4	74.6
	2.	70.5	69.8	73.7	73.1	73.8	69.5	75.3	77.2
	3.	70.2	70.2	73.5	74.1	75.2	71.2	75.6	74.4
	4.	69.9	70.3	73.5	74.0	75.2	70.0	76.0	77.7
	5.	70.6	71.0	73.4	74.2	75.4	71.8	73.1	75.4
	6.	71.0	71.0	73.6	73.7	75.2	71.7	76.1	78.3
	7.	70.1	70.3	73.0	74.6	74.7	70.8	76.1	78.7
	8.	70.5	70.7	72.5	74.9	75.0	70.6	76.7	78.3
	9.	69.4	70.2	72.6	73.8	75.4	71.6	76.0	78.9
	10.	70.4	71.4	73.4	74.4	75.1	71.2	76.8	78.5
A-frequency weighted surface sound pressure levels. $\bar{L}_{pfA}$	73.5 dB								

economical way. For the analysed company, it is recommended to periodically control the highest permissible concentration (NDS) and the highest permissible intensity (NDN). In addition, it is recommended to reorganize all workstations and conduct frequent surveys among employees. What is more, it is recommended for the crossings between the machines to be at least 0.75 m wide, and for each employee to occupy at least 2 m^2 of floor space. There should be adequate lighting and ventilation in the room. All other noise sources should be eliminated to ensure that the noise levels are not exceeded. The noise in the analysed company is also emitted by fans, coolant pumps

Table 4. Results of noise level measurements and calculations for FW 801 machine tool

A-requency weighted sound power levels. L_{wA}	93.7 W								
Emission sound pressure level L_{pA}	77.65 dB								
Linear dimensions of the target area (reference cuboid)	l_1 + 2 = 2. + 2 = 4.2 m l_2 + 2= 1.6 + 2 = 3.6 m l_3 + 1 = 1.8 + 1 = 2.8 m								
Target area S	58.8 m^2								
Measurement distance d	1 m								
K_{2A}. K_{3A}	1.93 dB. 0.25 dB								
A-frequency weighted background noise	55.9 dB								
		1	2	3	4	5	6	7	8
A-frequency weighted sound power levels at each measurement point	1.	76.4	77.3	80.0	79.1	77.5	77.1	75.8	80.2
	2.	77.6	75.8	79.8	79.6	78.8	77.9	79.8	80.6
	3.	78.3	77.3	79.2	77.5	77.0	77.6	79.3	78.7
	4.	78.0	76.8	79.1	79.3	76.9	76.3	78.0	78.4
	5.	77.0	76.4	78.1	79.0	76.9	76.6	79.3	78.9
	6.	77.6	76.0	78.7	77.5	77.8	76.2	79.9	77.9
	7.	77.9	76.7	78.2	78.1	77.4	76.8	78.7	78.2
	8.	78.1	76.1	77.9	78.2	78.9	77.4	79.8	77.6
	9.	75.3	77.4	78.3	78.9	78.1	76.8	76.2	77.2
	10.	77.3	76.2	78.5	78.2	79.9	77.8	78.0	77.0
A-frequency weighted surface sound pressure levels. $\bar{L}_{pfA}$	75.97 dB								

Table 5. Results of noise level measurements and calculations for FWC 25/H machine tool

A-frequency weighted sound power levels. L_{wA}	89.1 W								
Emission sound pressure level L_{pA}	73.25 dB								
Linear dimensions of the target area (reference cuboid)	l_1 + 2 = 2. + 2 = 4.0 m l_2 + 2= 1.8 + 2 = 3.8 m l_3 + 1 = 1.6 + 1 = 2.6 m								
Target area S	55.8 m^2								
Measurement distance d	1 m								
K_{2A}. K_{3A}	1.85 dB. 0.25 dB								
A-frequency weighted background noise	55.9 dB								
		1	2	3	4	5	6	7	8
A-frequency weighted sound power levels at each measurement point	1.	69.5	71.3	74.1	76.4	73.2	73.6	73.1	74.5
	2.	69.9	71.9	73.9	75.1	74.2	76.1	74.9	73.5
	3.	69.8	71.9	74.0	75.8	74.2	76.4	74.8	73.8
	4.	69.8	71.9	73.9	75.8	74.1	76.3	74.6	73.3
	5.	68.4	70.6	73.8	75.5	74.3	76.0	75.3	74.2
	6.	69.1	71.3	74.0	76.4	73.2	75.6	74.6	73.7
	7.	69.7	71.5	63.9	75.6	74.0	76.4	75.0	73.9
	8.	69.8	71.7	74.1	75.6	74.0	76.2	75.0	74.1
	9.	69.1	71.2	74.2	75.8	73.4	75.9	74.9	74.2
	10.	68.9	71.1	74.0	76.0	73.6	76.2	74.8	74.8
A-frequency weighted surface sound pressure levels. $\bar{L}_{pfA}$	71.65 dB								

Table 6. Summary of minimum, maximum and average noise levels obtained for selected machine tools

Noise level	DMU 50	BGO-CNC/RV/R	FU 251	FW 801	FWC 25/H
min [dB]	64.50	63.80	69.40	75.30	63.80
avg [dB]	76.45	69.00	74.15	77.95	70.10
max [dB]	88.40	74.20	78.90	80.6	76.40

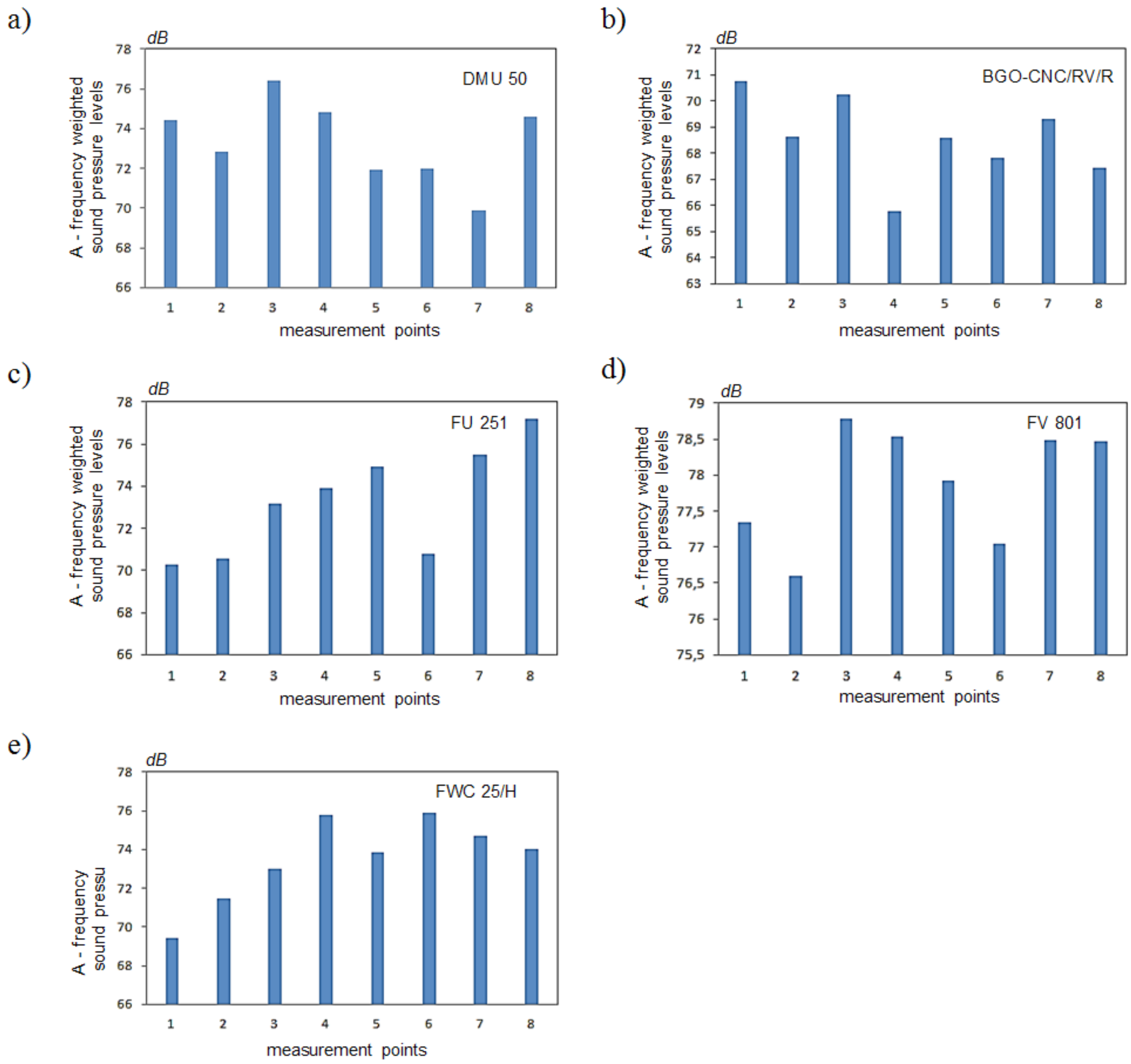

Fig. 5. The course of changes in sound pressure for the machine:
a) DMU 50, b) BGO-CNC/RV/R, c) FU 251, d) FV 801, e) FWC 25/H

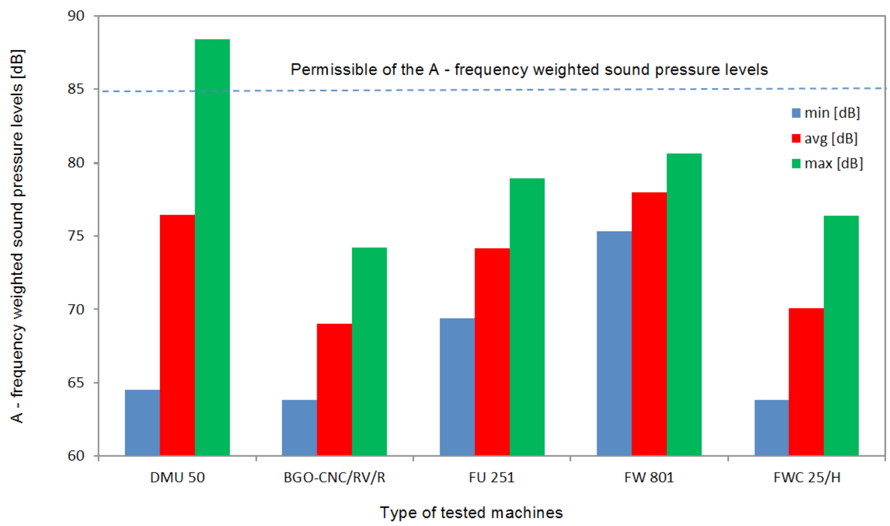

Fig. 6. Comparison of the noise levels obtained for selected machine tools machine tools

and oil pumps. Additionally, it is recommended to use hearing protectors. Limiting the noise emission within the production hall should be a priority, as it is one of the most effective measures to reduce the risk of exposure of workers to noise. A few cases identified within the analysed company showed that a long-term exposure to high levels of sound can pose serious risks to humans and their health. Ultrasounds, as well as infrasounds, have adverse effects on the human nervous system, organs, tissues and hearing. The harmful and tiring effects of noise depend on its intensity, frequency, changes in time, long-lasting effects and the contents of inaudible components, as well as certain characteristics of the operators such as: age, mental condition, health and individual sensitivity to sounds. High levels of noise have a negative effect on well-being, and – in extreme cases – may lead to hearing impairment. Hearing protection must be worn if the level of noise equals or exceeds 85 dB (A). While comparing the results of measurements of the emission sound pressure levels for different machine tools, it was found that the values for individual machines do not exceed the allowable limit values and, in exceptional cases, they are significantly lower (by approx. 1 to 30 dB) in relation to the scope of the conducted tests. The noise emitted by various machines is most often associated with rotary or reciprocating motions. In comparison with the data submitted by the Central Statistical Office, almost 40% of employees (in Poland) work under harmful and hazardous conditions. They are most often exposed to excessive noise, i.e. the noise exposure levels of over 85 dB_A. These data also indicate that the employees who work for the companies that manufacture products from metal and wood are most vulnerable. If the sound test procedure permits the use of several PN-EN ISO 11200 standards or if there is no sound test procedure, the choice of method depends on the required accuracy class, parameters of the available research environment, size of the machine, nature of the emitted noise and accuracy classes for measuring instruments. Limiting the noise emission within the production hall should be a priority, as it is one of the most effective measures to reduce the risk of exposure to noise. Consequently, one of the most important duties of the machine manufacturer and the user is to carry out the assessment of machinery noise emission and take all the necessary measures to limit this emission.

REFERENCES

1. Augustyńska D., Pleban D., Mikulski W. 2000. Hałas maszyn – znormalizowane metody wyznaczania poziomu mocy akustycznej. Bezpieczeństwo Pracy, 2–3.
2. Błasiak M., Mięsikowska M., Nowakowski Ł. 2015. Analiza zmian poziomu ciśnienia akustycznego wrzeciona obrabiarki w strefie pracy operatora. Mechanik, 8–9, 390–398.
3. Bryła R. 2007. Ocena ryzyka zawodowego na stanowisku obróbki skrawaniem metali. Stal – Metale i Nowe Technologie, 5–6.
4. Engel Z., Pleban D. 2001. Hałas Maszyn i Urządzeń – źródła, ocena. CIOP, Warszawa.
5. Girvin R. 2009. Aircraft Noise-Abatement and Mitigation Strategies. J. of Air Transport Management, 15, 14–22.
6. Glowacz A. 2014. Diagnostics of direct current machine based on analysis of acoustic signals with the use of symlet wavelet transform and modified classifier based on words, Maintenance and Reliability, 16 (4), 554–558.
7. Glowacz A., Glowacz A., Korohoda P. 2014. Recognition of monochrome thermal images of synchronous motor with the application of binarization and nearest mean classifier. Archives of Metallurgy and Materials, 59, 1, 31–34.
8. Jemielniak K., Kosmol J. 1995. Tool and Process Monitoring – State of Art and Future Prospects. Scientific Papers of the Inst. of Mech. Engng. and Automation of the Technical Univ. of Wroclaw, 61, 90–112.
9. Jemielniak K. 1994. Obróbka wysokoczęstotliwościowych sygnałów emisji akustycznej pochodzącej z procesu skrawania. Postępy Technologii Maszyn i Urządzeń, 18 (4), 21–29.
10. Józwik J., Czwarnowski M.: Angular positioning accuracy of rotary table and repeatability of five-axis machining centre dmu 65 MonoBlock. Advances in Science and Technology Research Journal, 9 (28), 2015, 89–95.
11. Józwik J., Mika D. 2015. Diagnostics of workpiece surface condition based on cutting tool vibrations during machining, Advances in Science and Technology Research Journal, 9 (26), 57–65.
12. Józwik J., Pietras P. 2013. Investigation and Assessment of Occupational Risk on the Metal Cutting Machine Tool Stand. Advances in Science and Technology Research Journal, 7 (20), 47–54.
13. Józwik J., Semotiuk L., Kuric I.: Diagnostic of CNC Lathe with QC 20 Ballbar system. Advances in Science and Technology Research Journal, 9 (28), 2015, 96–102.
14. Krolczyk G., Krolczyk J., Legutko S., Hunjet A.

2014. Effect of the disc processing technology on the vibration level of the chipper during operations process. Technical Gazette, 21 (2), 447–450.

15. Krolczyk G.M., Nieslony P., Krolczyk J.B., Samardzic I., Legutko S., Hloch S., Barrans S., Maruda R.W. 2015. Influence of argon pollution on the weld Surface Morphology. Measurement, 70, 203–213.
16. Marchuk V.I., Ravenets L.M., Marchuk S.V., Świć A. 2014. Mechanism of origin of structural vibrations in conical roller BEARINGS. Advances in Science and Technology Research Journal, 8 (23), 68–72.
17. Maruda R., Legutko S., Krolczyk G., Hloch S., Michalski M. 2015. An Influence of Active Additives on the Formation of Selected Indicators of the Condition of the Z10CrNi18–8 Stainless Steel Surface Layer in MQCL Conditions. International Journal of Surface Science and Engineering, 9 (5), 452–465.
18. Miko E., Nowakowski Ł. 2012. Vibrations In the Machining System of the Vertical Machining Center. XIIIth International Scientific And Engineering Conference Hermetic Sealing. Vibration Reliability And Ecological Safety Of Pump And Compressor Machinery–Hervicon, 39, 405–413.
19. Mikulski W., Augustyńska D., Pleban D. 1999. Opracowanie projektów PN-EN dotyczących określenia poziomu mocy akustycznej maszyn. Zadanie badawcze 02.4.6SPR-1, CIOP, Warszawa.
20. Sadowski J. 2011. Możliwości zmniejszenia hałasu technologicznego przecinarek tarczowych do drewna. Inż. Ap. Chem, 50 (3), 71–72.