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An Objective and Subjective Study of Noise Exposure within the Frequency Range from 10 kHz to 40 kHz

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The paper consists of study results of exposure to high frequency noise at metalworking workplaces. The study was carried out using objective methods (measurements of parameters characterizing the noise) and subjective studies (questionnaire survey). Metalworking workplaces were located in a steel structure (e.g. deck gratings) of the manufacturing plant. The results are equivalent sound pressure levels in the 1/3 octave frequency bands with center frequencies from 10 kHz to 40 kHz in reference to an 8-hour workday equal to approximately 81–105 dB at most of the tested workplaces and exceed permissible values. The questionnaire survey of annoyance high frequency noise (i.e. in the audible frequency and low ultrasound range) was conducted among 52 operators of machines. Most of the workers describe the noise as: buzzing, insistent, whistling and high-pitched squeaky. Respondents specify the noise levels occurring at workplaces as: loud, impeding communication, highly strenuous and tiring.

Keywords: ultrasonic noise exposure, metalworking workplaces.

1. Introduction

The broadband noise containing high audible frequencies (10–16 kHz) and low ultrasonic frequencies (20–40 kHz) at workstations is in Poland defined as ultrasonic noise. The assessment of ultrasonic noise exposure is based on (equivalent and maximum) sound pressure levels in the 1/3 octave band (the central frequencies are in the range from 10 kHz to 40 kHz) (Regulation of the Minister of Labour and Social Policy of 29 November 2002). The main sources of ultrasonic noise in the working environment are the so-called low frequency ultrasonic technological devices, including washers, welders, drills, soldering tools and galvanizing pots (Smagowska, 2013). Apart from the above-mentioned technological devices, in which the ultrasonic vibrations constitute the working factor, ultrasonic noise arises also as an unintentional result of the work of many machines and devices. The existence of ultrasonic components of significant sound pressure levels has been found in the work of devices where phenomena of aerodynamic (flow or outflow of compressed gas) or mechanical character (big rotational speed of machine elements) occur (Smagowska, 2010; 2012). This refers to compressors, blowpipes, valves, pneumatic tools and high-speed machinery (planers, millers, circular saws and some textile machinery).

The results of exposure to ultrasonic noise may affect the workers hearing organ (hearing losses) and the non-hearing parts of the body (Pawlaczyk-Łuszczyńska *et al.*, 2007; Smagowska, Mikulski, 2012). For the prevention of adverse effects of ultrasonic noise exposure and related hearing losses, Maximum Admissible Intensities[1] (MAI) have been determined (Regulation of the Minister of Labour and Social Policy of 29 November 2002).

This paper contains measurement and assessment results of exposure to ultrasonic noise from the so-called non-technological noise sources at metal workplaces. The assessment was carried out using objective methods (measurements of parameters characterizing noise within the frequency range covering sounds and ultrasonics of frequencies from 10 kHz to 40 kHz) and subjective studies (questionnaire survey). The test results are presented below.

[1] MAI – admissible exposure limits of a health-damaging factor are established as exposure levels adjusted to the properties of respective factors, so that the impact of the factor on an employee during his work activity shoud not bring about adverse consequences on the state of his health or on that of future generations.

2. Admissible values of ultrasonic noise in Poland

The admissible values of ultrasonic noise in respect of health protection of workers, valid in Poland, are specified in the Regulation of the Minister of Labour and Social Policy of 29 November 2002 (Regulation of the Minister of Labour and Social Policy of 29 November 2002). On the basis of measurements, the physical parameters characterizing ultrasonic noise are identified as follows:

- the equivalent sound pressure level in the 1/3 octave band with central frequency, f, from 10 kHz to 40 kHz, referred to an 8-hour working day, $L_{feq,8\,\mathrm{h}}$, or to the working week, $L_{feq,w}$, both in dB; the reference to a working week is exceptionally used in case of the irregular ultrasonic noise influence on the human organism in certain days of the week or when an employee works in a number of days a week different from 5),
- maximum sound pressure levels in 1/3 octave band with the central frequency, f, from 10 kHz to 40 kHz, $L_{f\,\max}$ in dB.

Admissible equivalent sound pressure levels at workstation referred to 8-hour working day and maximum sound pressure levels in 1/3 octave bands consists Table 1.

Table 1. Admissible equivalent sound pressure levels at a workstation referred to 8-hour working days and maximum sound pressure levels in 1/3 octave bands.

Central frequency of 1/3 octave bands f [kHz]	Admissible equivalent sound pressure levels $L_{feq,8\,\mathrm{h,dop}}$ [dB]	Maximum admissible sound pressure levels $L_{f\,\max,\mathrm{dop}}$ [dB]
10; 12.5; 16	80 (77[1])(75[2])	100
20	90 (87[1])(85[2])	110
25	105 (102[1]) (100[2])	125
31.5; 40;	110 (107[1])(105[2])	130

[1] Admissible values of equivalent ultrasonic noise sound pressure levels for pregnant women (Regulation of the Council of Ministers of 10 September 1996).

[2] Admissible values of equivalent ultrasonic noise sound pressure levels for juveniles (Regulation of the Council of Ministers of 24 August 2004).

3. Results of measurements and assessment of ultrasonic noise at selected metalworking workplaces

The equivalent sound pressure levels in 1/3 octave bands with the central frequency, f, from 10 kHz to 40 kHz, $L_{feq,8\,\mathrm{h}}$ and maximum sound pressure levels in 1/3 octave bands with the central frequency, f,

Table 2. Values of equivalent sound pressure levels at workplaces.

No.	Machine	Activity	The equivalent sound pressure level $L_{feq,8\,\mathrm{h}}$ in 1/3 octave bands in reference to an 8-hour workday, in dB						
			10	12.5	16	20	25	31.5	40
1.	Plate saw – Tyro	cutting of deck gratings	96.6	86.7	81.5	88.3	80.4	79.5	74.1
2.	Plate saw – automatic drive	cutting of deck gratings	89.0	100.2	96.0	86.2	89.4	86.0	87.2
3.	Plate saw – hand drive	cutting of deck gratings	84.7	75.2	75.2	82.7	73.2	76.3	67.4
4.	Plate saw – Trennjaeger	cutting of deck gratings	94.1	104.8	93.8	91.9	94.1	87.2	86.6
5.	grinder for sharpening	sharpening of circular saw's teeth	81.1	79.4	80.6	48.5	74.9	73.0	70.2
6.	welding machine – ESAB	burning out a shape on the grating with oxygen-acetylene mixture	81.1	78.1	79.2	80.7	82.4	84.2	85.8
7.	welder SCI 1500	submerged arc	74.5	72.4	70.9	67.8	65.6	65.0	62.8
8.	Johnson' rotary cutter	cutting of iron plate (m. – platform 1)	91.0	76.3	81.5	80.9	70.9	67.7	61.3
9.	Johnson' rotary cutter	cutting of iron plate (m. control pulpit)	82.5	68.5	75.5	76.0	64.3	61.4	56.9
10.	Johnson' rotary cutter	cutting of iron plate (m. – platform 2)	86.1	75.2	82.7	84.4	82.8	67.4	67.9
11.	arc welder	carbon-arc air gouging	102.8	102.1	100.1	98.9	98.2	98.0	96.9
12.	machine for plasma cutting – Plasmatome 20HPO	cutting of deck gratings of plasma burner	78.5	93.7	83.8	86.2	91.5	92.7	96.2
13.	welding line EVGZ	termal welding of deck grating	82.7	84.7	85.5	84.4	84.2	85.0	84.3

Table 3. The values of maximum sound pressure levels at workplaces.

No.	Machine	Activity	The maximum sound pressure level $L_{f\,\max}$, in 1/3 octave bands , in dB						
			10	12.5	16	20	25	31.5	40
1.	Plate saw – Tyro	cutting of deck gratings	108.2	97.2	94.4	102.8	92.6	91.8	89.0
2.	Plate saw – automatic drive	cutting of deck gratings	99.6	114.1	109.9	94.7	103.3	100.0	101.4
3.	Plate saw – hand drive	cutting of deck gratings	108.0	99.4	97.6	104.4	94.4	94.5	88.5
4.	Plate saw – Trennjaeger	cutting of deck gratings	106.5	120.3	105.9	104.1	107.1	100.0	99.6
5.	grinder for sharpening	sharpening of circular saw's teeth	85.3	83.1	84.0	81.3	77.9	76.1	73.3
6.	welding machine – ESAB	burning out a shape on the grating with oxygen-acetylene mixture	88.4	85.9	85.7	86.5	88.7	91.1	93.5
7.	welder SCI 1500	submerged arc	72.7	76.3	73.3	70.5	69.8	68.5	67.2
8.	Johnson' rotary cutter	cutting of iron plate (m. – platform 1)	101.4	83.8	90.5	88.3	86.2	75.2	66.1
9.	Johnson' rotary cutter	cutting of iron plate (m. control pulpit)	85.8	73.0	79.4	86.0	75.1	63.7	65.1
10.	Johnson' rotary cutter	cutting of iron plate (m. – platform 2)	94.1	85.7	87.6	91.8	90.4	72.2	75.0
11.	arc welder	carbon-arc air gouging	121.8	121.2	120.4	119.8	118.4	117.3	116.3
12.	machine for plasma cutting – Plasmatome 20HPO	cutting of deck gratings of plasma burner	84.2	103.0	92.4	96.0	102.2	104.3	107.1
13.	welding line EVGZ	termal welding of deck grating	90.3	91.9	93.1	92.6	92.4	94.2	94.3

from 10 kHz to 40 kHz $L_{f\,\max}$ have been measured at selected metalworking workplaces. The measurements of the noise parameters were taken in places where the employee's stay during work (i.e. at a distance between 0.5 m and 1.5 m from the noise source, depending on the workplace type). The studies were carried out during the following operations: cutting of deck gratings, sharpening of circular saw's teeth, burning out a shape on the grating with an oxygen-acetylene mixture, submerged arc and plasma arc welding, cutting of a metal sheet with rotary shears, carbon-arc air gouging of joints, and pressure welding of deck grating. The results of measurements of the noise parameters are presented in Tables 2 and 3.

The values of equivalent sound pressure levels in 1/3 octave frequency band with the central frequency, f, from 10 kHz to 40 kHz, in reference to an 8-hour workday are within the range of 81–105 dB at most of the tested workplaces. In most cases, the excess of MAI values for ultrasonic noise occurs for this parameters. The operation of submerged arc welding is the only exception (measured levels are within the 63–75 dB range during operating the welder SCI 1500). The highest equivalent sound pressure levels are measured during the carbon-arc air gouging of joints; they are equal to 97–103 dB. The measured maximum sound pressure levels in 1/3 octave bands of frequencies from 10 kHz to 40 kHz vary between 64 and 122 dB. Allowable values of this parameter are exceeded in 1/3 octave bands of 10 kHz, 12.5 kHz and 16 kHz during the following activities: cutting of deck gratings, cutting of metal sheets and carbon-arc air gouging of joints. The highest equivalent sound pressure levels occur during carbon-arc air gouging of joints and vary in this case within the range of 116–122 dB.

4. Questionnaire survey results

The questionnaire survey was conducted for 52 operators of machines used in the manufacturing of the aforementioned deck gratings. This was performed in order to carry out the subjective assessment of noise exposure at workplaces. The tested group consisted of men; the group's average period of working was approximately 11 years. The average age experience within the surveyed group equalled to 40 years. About 95% of the surveyed workers were employed on a full-time basis.

92% of the respondents stated that they are exposed to noise constantly. The noise was characterized by the majority of workers as: droning, insistent, creaking, whistling and squeaky, whereas slightly fewer people described it as roaring and wheezing. Male respondents unequivocally considered the Sound Pressure Level (SPL – in the survey "noise level") at their

workplaces as: not nuisance, tolerable, loud, impeding communication, high bothersome and tiring. Figure 1 shows survey results for the workers subjective assessment of the 'noise level" at their workplaces. About 50% of responses confirmed that the "noise level" is: loud, impeding communication, high bothersome and tiring.

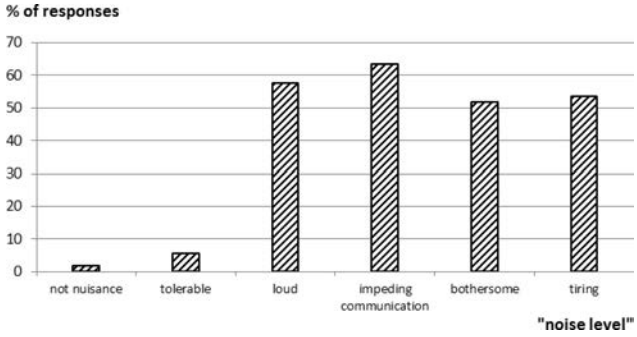

Fig. 1. Employees subjective assessment of the "noise level" at workplaces for the production of deck grating.

Figure 2 presents survey results for the employees' subjective assessment of the degree of annoyance of the level of noise at workplaces for the production of deck grating The following terms received the largest number of points on the scale representing the degree of annoyance of noise: horrible, enormous, persistent, and intense.

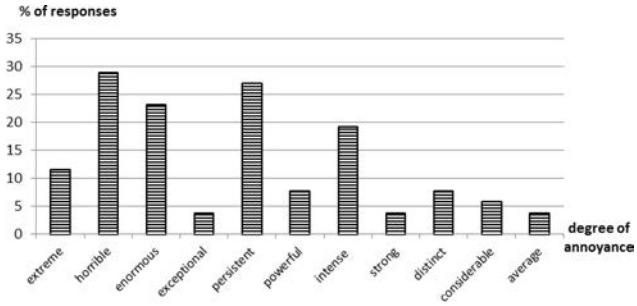

Fig. 2. Employees' subjective assessment of the degree of annoyance of the level of noise at workplaces for the production of deck grating.

Audiometric tests are performed at least once every two years, what was confirmed by the respondents, in their subjective appraisal. 17% of the interviewee considered the state of their hearing as defective. 21.2% of the employees have a nuisance in hearing normal speech, whereas in case of a whispering voice these difficulties were noticed by 50% of respondents. 26.9% of the questionnaire people suffer tinnitus, 19.2% claim to understand very loud speech. All interviewed people have and wear hearing protector devices (alternatively): earmuffs (9.6%). earplugs (61.5%) and custom-made earplugs (96.2%). The most often enumerated machines and devices used at their workplace are: acetylene-oxygen torch, pneumatic tool, grinder, plasma cutting processes, cutting with acetylene-oxygen torches and gas metal arc welding.

5. Summary

The results of measurements and the assessment of high frequency noise at selected metalworking workplaces confirmed that during operating these devices and machines the workers are exposed to an occupational risk of ultrasonic noise. The results have proved a large diversity of risk at workplaces of different types of machines The highest values characterizing this hazard factor occur most often within the operating frequency of the equipment. In case of non-technology ultrasonic noise sources, they exceed the ultrasonic noise MAI values in three primary 1/3 octave bands of central frequencies: 10 kHz; 12.5 kHz and 16 kHz. Due to the fact that these frequency bands overlap clearly with the upper range of audible sound frequencies, the risk of the occurrence of hearing damage is assessed as high.

The results of the subjective test confirmed the annoyance of exposure to this type of noise in the environment. In the relation between objective and subjective results of exposure to this hazard factor in the work environment, it is necessary to take appropriate preventive actions (technical organizational and medical actions) (Regulation of the Minister of Health and Social Policy of 30 May 1996 Regulation of the Minister of Economy and Labour of August 5, 2005). Devices emitting high frequency noise should be equipped by the manufacturers with means of technical protections against noise (soundproof and isolation casings shields or silencers) (Dobrucki *et al.*, 2010) In the case when those ways of noise limitations at workplaces are impossible, the employer should fit the workers with hearing protections or plugs. When the measurements of noise parameters in reference to an 8-hour workday the MAI values are exceeded, a properly time of work or even a full stop of activity should be implemented as well as employees' rotation. Technical and organizational activities have to been used at the same time with medicine prevention. A preliminary and periodic medical care should be provided.

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