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SPEECH INTELLIGIBILITY IN THE POSITION OF CNC MACHINE OPERATOR

Ł. Nowakowski[*], M. Mięsikowska[**], M. Blasiak[***]

Abstract: *This article presents the results of the intelligibility of speech in the position of CNC milling machine operator. The study was conducted in two stages in a laboratory of numerically controlled machine tools in Kielce University of Technology. The first stage involved the measurement and analysis of changes in the sound pressure level in the work zone of the operator, which is emitted by the spindle of milling machine AVIA VMC 800. The measurement was carried out using the analyzer's NOR140 of NORSONIC during the operation of machine spindle without load with different speeds in the range of 1000 ÷ 10000 rpm / min. The second step was to study the possibility of verbal communication in a room where there are the machines, on the basis of the measurement recorded files in the first stage. Speech intelligibility was determined according to ISO 9921 based on the parameter SIL (Speech Interference Level).*

Keywords: Speech Intelligibility, Sound Pressure Level, Communication Man - Machine, CNC Milling Machines.

1. Introduction

Sounds accompanying man can be divided into useful, used, for example, to communicate and burdensome and harmful occurring e.g. in the position of the operator of numerically controlled machine tools. The latter often exceed the permissible sound level indication in the workplace, and become noise, adversely affecting human health. Noise also negatively affects the concentration of the operator in the workplace, which poses a serious threat. The most common source of noise in the workplace of the numerically controlled machine tool operator is work of drives of machine tools and machining process during which there are generated machine, the workpiece and the tool vibration (Miko & Nowakowski, 2012a).

For the measurement of vibrations in the cutting process, the non-contact face seals (Blasiak, 2015a, 2015b) piezoelectric transducers are used (Blasiak & Kotowski, 2009). Piezoelectric transducers are also used to measure the vibration of flying objects (Krzysztofik & Koruba, 2012) and to build gyroscopes (Koruba et al., 2010). The vibrations in the cutting process are an important factor in the process of machining, surface roughness (Miko & Nowakowski, 2012b) and the level of sound emission, which also reduces the concentration of the operator, causes fatigue, has a negative effect on hearing and the human nervous system and affects speech intelligibility.

In the study (www.ecophon.com.pl), the authors describe the method of calculating the speech intelligibility as an acoustic signal by the difference between the level of speech sound (signal) and the level of sound interference (noise).

According to the authors of the study (https://hipokrates, 2012) constant noise on the level of 70 dB to 80 dB prevents speech intelligibility from a distance of 0.5 m.

[*] Łukasz Nowakowski, PhD.: Chair of Mechanical Engineering and Metrology, Kielce University of Technology; Aleja Tysiąclecia Państwa Polskiego 7; 25-314 Kielce; PL, lukasn@tu.kielce.pl

[**] Marzena Mięsikowska, PhD.: Department of Applied Computer Science and Armament Engineering, Kielce University of Technology; Aleja Tysiąclecia Państwa Polskiego 7; 25-314 Kielce; PL, marzena@tu.kielce.pl

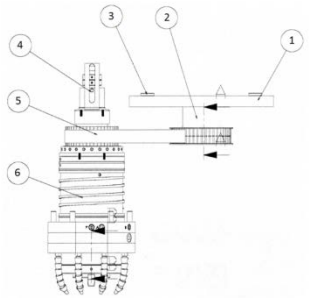
[***] Małgorzata Błasiak, PhD.: Department of Mechanics, Kielce University of Technology; Aleja Tysiąclecia Państwa Polskiego 7; 25-314 Kielce; PL, mdrab@tu.kielce.pl

The aim of the study is to calculate speech intelligibility according to ISO 9921 in the position of the operator of CNC milling machines working without a load of different speeds.

2. Methods

The study of speech intelligibility were carried out at the Laboratory of Numerically Controlled Machine Tools in Kielce University of Technology in the workplace of operator of CNC milling machine VMC 800 Series, production FOP "AVIA SA. A characteristic feature of the machine is the solution of spindle drive, which has been based on engine HEIDENHAIN that using a belt drive with a toothed belt (POWERGRIP GT2) drives precisely balanced spindle of "cartrige" type. View of the machine, the design of the main drive and the basic parameters of CNC machine AVIA VMC 800 is presented in Table 1 (Extract from the machine metrics, 2008, Manual Machine, 2008).

Table 1. View and basic parameters of vertical machining center AVIA VMC 800 (Extract from the machine metrics, 2008, Manual Machine, 2008).

General view of the machine	The design of the drive spindle	
		
Spindle		**Description of construction**
Type	cartridge	1 – spindle plate, 2 –pulley of spindle drive motor, 3 – washer, 4 – bracket of tools presence sensor 5 – toothed belt 920-8MGT-30, 6 – spindle unit [6]
tip of the spindle	ISO 40 according to PN-92/M55085/01	
Spindle speed	50 - 10000 rev/min	
main motor power	10 / 17 kW	

Manufacturer of milling machines give in the manual of machine tools only the maximum noise level of 79 dB for a closed cabin and the maximum speed of the spindle. There is a lack of data for the full range of rotation speed, that is why laboratory tests were divided into two stages. The first stage involved the measurement and analysis of changes in the sound pressure level in the operator's work zone, which is emitted by a spindle of the milling machine CNC AVIA VMC800.

Fig. 1: Measurement position in the operator's work zone of CNC milling machine (Błasiak, M. et al., 2015).

Measurement of the sound level was made by the analyzer NOR140, of Norsonic company, which microphone was in the operator's work zone at a height of 170 cm corresponding to the position of the human ear. The measurement was performed for 10 different rotation speeds of the milling machine spindle without load in the range from 1000 to 10000 rev/min at 1000 rpm.

The second stage of the study was to examine and determine the possibility of verbal communication human-human / human-machine (Mięsikowska, 2015) in a room where there are the machines. The study was conducted on the basis of measurement files obtained in the first stage using the meter Nor140and acoustic parameter of speech intelligibility. Speech intelligibility was determined

according to ISO 9921 based on the parameter SIL (Speech Interference Level).

3. Results

The results of the first phase of laboratory tests are shown in Figure 6, which shows the measured A sound level at the workstation of the operator of the CNC milling machine, which contains the sound emitted by the machine in the "standby" mode at a constant level equal to 67 dB (A), and in relation to the growing rotation speed of spindle. A level of A sound pressure for the milling machine spindle running without load in the speed range from 1000 to 5000 rev/min remains constant at the level of 71.4 ÷ 74 dB (A). For the speed 6000 rev/min, there is an increase of the sound level by 2.5 dB (A) to 76.5 dB (A) which progressively with increasing rotation of the spindle is increases to 80 dB (A) for a maximum spindle speed of 10000 r/min.

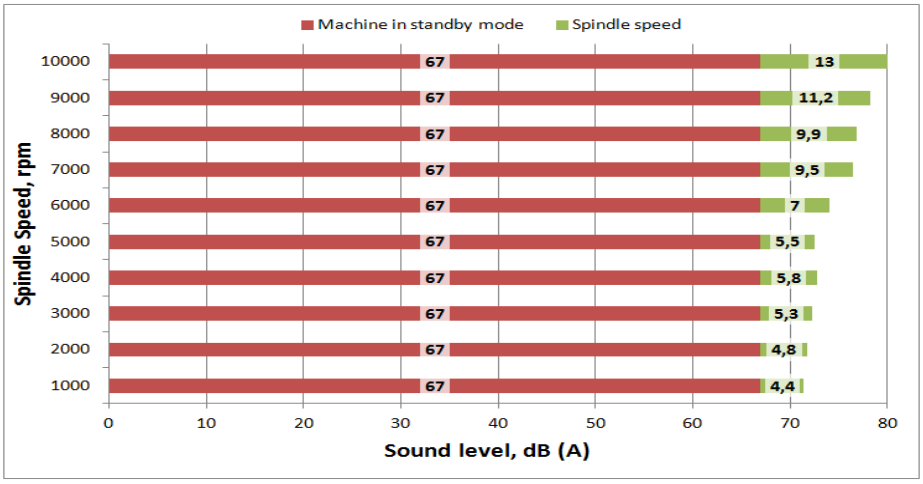


Fig. 6: level of A sound pressure measured at the workplace of the CNC milling machine operator

The second phase of the laboratory research, or the level of speech intelligibility determined according to ISO 9921 on the basis of the parameter SIL is presented in Table 2. Parameter SIL was determined as the difference between the $L_{S,A,L}$ parameter, - volume received by the listener (recorder) and a parameter L_{SIL} , which is an average sound level for the four octave band of frequency: 500Hz, 1000Hz, 2000Hz, 4000Hz. For the purpose of the study, there was estimated the value of the parameter $L_{S,A,L}$ equal to 72 dB, while the distance L = 1m. Thus, $L_{S, A, 1m}$ = 72 dB.

Table 1. Speech intelligibility at the workplace of the operator of numerically controlled machine tools

Spindle speed rev/min	Level of A sound pressure dB(A)	$L_{SIL,}$ dB	SIL, dB	Speech intelligibility
1000	71,4	58,1	14,0	Fair
2000	71,8	59,5	12,5	Fair
3000	72,3	58,2	13,8	Fair
4000	72,8	60,9	11,2	Fair
5000	72,5	61,8	10,2	Fair
6000	74	60,8	11,2	Fair
7000	76,5	61,9	10,1	Fair
8000	76,9	63,0	9,0	Poor
9000	78,2	64,6	7,4	Poor
10000	80	67,5	4,6	Poor

Analyzing the results of the tests of Table 2, it has been found that the intelligibility of speech for the spindle speed in the range from 1000 rev/min to 7000 rev/min is Fair, and for the speed from 8,000 rev/min to 10,000 rev/min is Poor. Corresponding to the speech intelligibility, fair values of SIL parameter are in the range of 10.1 to 14.0 dB, values of L_{SIL} parameter in the range of 58.1 to 61.9 dB. Poor speech intelligibility corresponds to values of SIL parameter containing in the range of 4.6 to 9.0 dB, L_{SIL} values are in the range of 63.0 to 67.5 dB.

4. Conclusions

Conducted study showed a significant effect of spindle speed of milling machine on sound pressure level at the workstation of CNC operator, emitted by the CNC spindle working without load. A level of A sound for speed of spindle running without load in the range of 1000 to 7000 rev/min remains constant at the level of 71/76.5 dB (A). The maximum sound pressure level of 80 dB (A) was measured for the spindle speed equal to 10,000 rev/min. Analysis of the level of speech intelligibility determined according to ISO 9921 on the basis of the SIL parameter showed that the spindle speed in the range from 1000 rev/min to 7000 rev/min is at a Fair level, and for the rotational speed from 8,000 rev/min to 10,000 rev/min at a sound pressure level of 76.9/80dB (A) is poor. At a distance of 1 meter from the machine communication is maintained at a fair level to 7000 rev/min. A level of A sound pressure is maintained up to 7000 rev/min at a level of 71.4 dB (A) - 76.5 dB (A). At 8000 rev/min speech intelligibility decreases, so in terms of A sound level of 76.9 dB - 80 dB at a distance of 1m. Probably reduction of the distance to 0.5m, so coming closer to the source of the noise, it can cause a big drop in verbal communication, but this requires further study. Lack of speech intelligibility in the position of the operator is a serious threat to human health and can lead to accidents. Adverse acoustic conditions in the work zone of the operator, especially the possibility of verbal communication, can adversely affect the communication man/machine. It is advisable to carry out any work to reduce the sound pressure level in the work zone of the operator, in order to improve comfort and speech intelligibility. Sound pressure level at the workstation of the operator of CNC can be reduced by carefully balancing dynamic and static parts of these machines that rotate, for example, spindle. It may be also helpful to systematically check and tighten loose parts (screws) and lubrication. In addition, machine guards or the room in which there is the machine can be coated with sound-absorbing material and noise-reducing screens.

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