Experimental studies of noise and vibration during milling of cast iron parts

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Abstract. Machining processes of cast iron parts are accompanied by significant noise and vibration. Exceeding the standard values of vibration and noise adversely affects the health of the operator and reduces the quality of the final product. The article deals with the scientific problem associated with the study of the causes of increased vibrations and noise during the milling of cast iron products. It has been experimentally shown that the existing ones create increased sound pressure in the range from 250 to 8000 Hz, while the sound pressure level reaches 80-92 dBa, which is 15-20 dBa higher than the maximum allowable. In the higher frequency part of the spectrum, the decrease in the intensity of sound radiation is from 4 to 7 dB per octave. The data obtained are the initial information for the calculation of noise reduction systems, based on compliance with sanitary standards. To simplify engineering calculations, vibrational energy loss coefficients for cast iron solid and hollow products are given.

1 Introduction

The production processes of machining cast iron products and metal-cutting machines for their implementation are noisy and accompanied by vibrations. Vibration and noise arise due to the action of cutting forces that excite the workpiece and machine elements to vibrations that emit sound waves into the environment. Noise emission is considered as a defect in the quality of machine tools, and therefore scientists are developing methods and means to reduce the sound pressure level to a level that meets the requirements of sanitary standards. In turn, since the metal processing process itself is the source of noise, a high sound pressure level carries information about the quality of manufacturing processes and indicates the state of the process, which can be effectively used to predict the quality of the final product.

The analysis of vibration during robotic milling carried out in [1] is a complex scientific problem. The authors proposed a new approach to vibration analysis based on an improved full ensemble empirical mode decomposition.

Increased noise and vibration levels lead to rapid tool wear, which negatively affects the quality of the product. The authors [2] proposed a method for identifying the cutter wear

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state based on an optimized variational mode decomposition. Entropy was chosen as the target function, which is minimized in the course of the study. The display of the relationship between eigenvalues and the degree of wear of the cutter is established by the Bayesian classifier method.

Intelligent diagnostics based on the analysis of triaxial vibration data was proposed in [3]. The authors proposed a technique that implements the diagnostics of malfunctions of rotating mechanisms based on the reconstruction of compressed vibration analysis data. The frequency spectra of the triaxial vibration signals are used as feature vectors in the classification. The method proposed by the authors allows for a prediction accuracy of 96.70%.

Non-destructive monitoring of the vibrational state was proposed in [4] to detect tooth cracks in gears. A new methodology using time series analysis, frequency analysis of statistical control charts is applied to detect cracks in gear wheels of a spiral bevel gear system. The analysis allowed the authors to identify faults based on the analysis of periodic vibration pulses. The results showed that the proposed technique allows the detection of all types of cracks at an early stage.

In article [5], the authors note that the control of the state of a metal-cutting machine based on the analysis of dynamic processes serves as the basis for preventing vibration and improving the accuracy of machining parts. The authors propose a method for assessing the dynamics of machine tool elements based on the dependence of the dynamics of the machine-spindle-holder-tool structure. The analysis of the frequency response between the tool tip and the spindle flange is determined based on the forced vibrations during milling.

In recent years, the effective application of artificial intelligence methods and neural networks for the study of vibrations in order to detect cracks has been growing [6-8]. Experimental studies of the vibro-acoustic characteristics of rotors, bearings, gearboxes and other machine elements based on deep learning make it possible to effectively diagnose the condition and implement fault detection algorithms. It is shown 6 that the average prediction accuracy is 100% when the signal-to-noise ratio is greater than or equal to −2 dB, and the average accuracy is 98.2% when −4 dB.

An overview of the methods used in the analysis of noise generated by motors for electric vehicles is given in [9]. Three main methods: the analytical method [10-12], the hybrid method using two-dimensional models [13] and the hybrid method using three-dimensional models [14] are widely used in vibroacoustic analysis of electric vehicle engines.

Experimental studies of the spectra of noise and vibration during abrasive processing of welded seams of transport machines are presented in [15-18]. In the course of experimental studies, dangerous and harmful production factors that arise during the processing of transport machine structures have been established. Models for the implementation of a theoretical approach to describing the regularities of the processes of noise and vibration generation are proposed. Vibroacoustic analysis [19-21] makes it possible to reduce pressure losses in the hydraulic system and implement adaptive control of hydraulic motors of multi-engine mobile machines.

This overview shows that noise and vibration analysis is widely used in industry and can improve the quality of the final product and provide a comfortable working environment for the operator. At the same time, there is a significant gap in scientific research in the milling of cast iron parts. Thus, the purpose of this article is an experimental study of noise and vibration during milling of cast iron parts with cutters of various types and geometries.

2 Materials and methods

During experimental investigations, the following stages are used for noise and vibrations measuring:

- studying the process of noise generation during milling of cast iron machine's parts;
- study of deformation of cutter teeth in dynamics and vibration during milling of cast iron blanks; the study of conditions of the operator being near the milling machine;
- measurement of vibrations and noise of the cleaning device itself;
- measurement of the noise and vibration spectrum for the conditions of milling with a face mill ⌀ 125 mm of the connector of the gearbox housing of a turret lathe.

When measuring acoustic characteristics, it is very difficult to assess the contribution of individual sources to the sound field at the source workplace. Therefore, in order to indirectly identify the contribution of individual sources, vibration levels were measured on the workpieces, the spindle bearing cap and the frame.

For measurements inside industrial premises, it is important to carry out noise measurements without the influence of extraneous sources. Vibroaccelerometers were attached to the measuring surface between the microphone using a magnet supplied with the measuring equipment.

Background noise levels in octave frequency bands and sound levels measured in industrial premises were less than the measured noise by 10-11 dB (dBA). Therefore, the results of measuring the noise levels of the objects of study do not require adjustment.

3 Results

Among all types of metal-cutting machines, milling machines are distinguished by the widest range of cutting tools, both in terms of geometric configurations and geometric dimensions. This circumstance explains the fact that the sound levels at the workplaces of machine operators vary widely. In particular, if the machine, on which experimental studies of noise and vibration during the processing of cast iron products, have a defect, then the sound levels change in the range of 80-92 dBA, which is shown in Figure 1

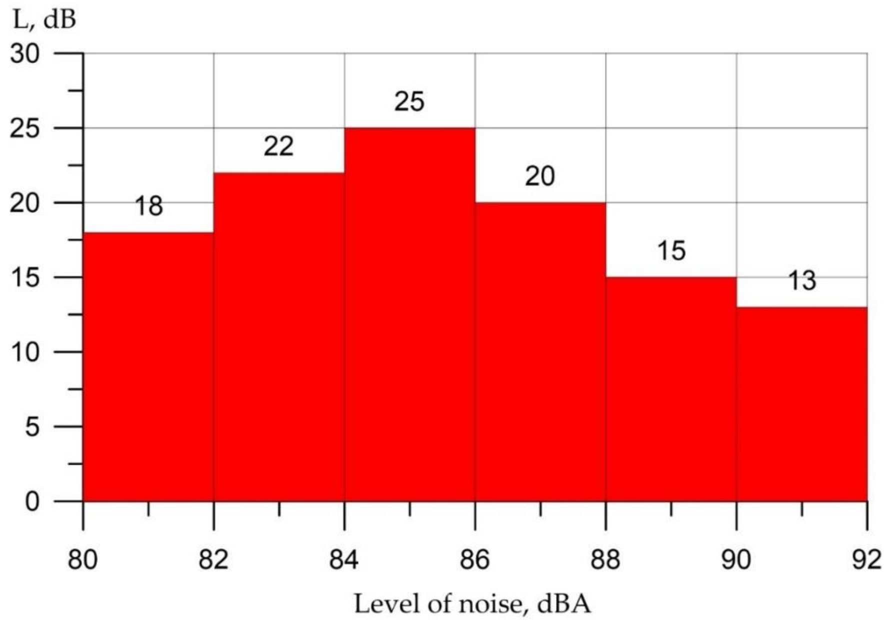

Fig. 1. Histogram of distribution of sound levels during milling of cast iron blanks.

The measurement results showed that in 13 cases of milling, the sound levels are 30-32 dBa, which practically corresponds to the maximum permissible value (30 dBA), because 2dBa can be explained by the accuracy of experimental studies of vibration and noise. 22 variants showed that the sound level is 32-34 dBA, which exceeds the standard by 2-4 dBA.

The maximum number of milling options - 25 showed that sound levels reach a value of 36 dBA, which is 6 dBA higher than the standard. The maximum values of excesses were fixed in 20 and 15 options for processing products, which are 10 and 12 dBA (respectively).

In terms of cutting tools and milling modes, 18 options correspond to the milling concept with cutters up to 30mm diameter. 22 variants correspond to the milling of the concept with cutters with diameters up to 50mm, 25 variants correspond to milling with end mills with diameters of 50-80mm.

20 options correspond to the milling of solid workpieces such as rectangular beams with end mills, the height of which is greater than the width.

15 of milling machines correspond to the milling of hollow workpieces such as body parts with end mills.

Experimental studies of the spectral composition for the above data showed the identity of the nature of the spectra, but with a significant difference in the intensity of sound radiation in octave frequency bands. It should be noted that compliance with the maximum permissible levels of sound pressure must be performed under any operating conditions of milling machines. Therefore, the analysis of the noise and vibration spectra is given for the conditions of milling with a face mill ⌀ 125 mm of workpieces such as beams and plates (Figure 2).

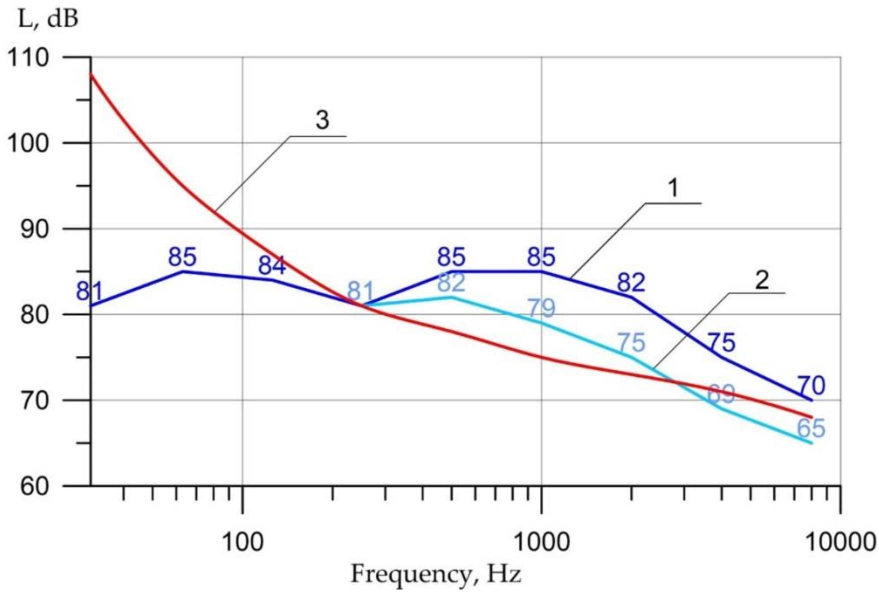

Fig. 2. Noise spectra during milling: (1) beam-type workpiece; (2) blank type plate; (3) ultimate spectrum.

The nature of the noise spectra has a pronounced mid-frequency character. Indeed, the maximum sound pressure levels are observed in the fifth and sixth octaves. In the higher frequency part of the spectrum, the decrease in the intensity of sound radiation is from 4 to 7 dB per octave.

When milling a beam-type workpiece, the excess sound pressure levels are: 7 dB in the fifth octave; 10dB in the sixth and seventh; 4dB in the eighth and 2dB in the tenth. Sound pressure levels when milling a plate-type workpiece are 3-7dB lower. Thus, the excesses are: 5dB in the fifth octave: 4dB-8 in the sixth and 2dB-3 in the eighth. When milling a hollow workpiece, sound pressure levels reach 88-39dB.

On fig. 3 shows the spectrum of noise and vibration for the conditions of milling with a face mill ⌀ 125 mm of the connector of the gearbox housing of the turret lathe model D325P (Figure 3).

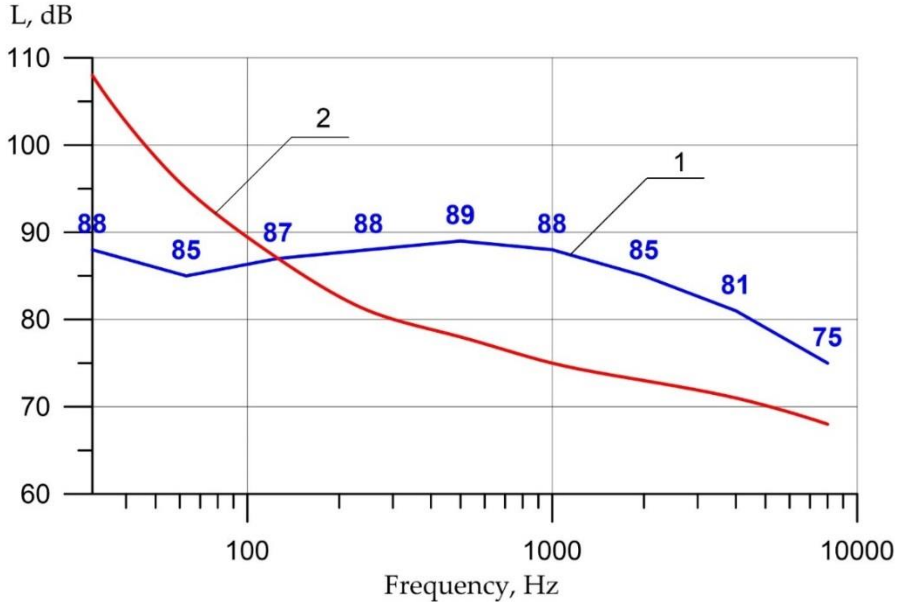

Fig. 3. Milling sound pressure levels: (1) hollow workpiece; (2) limit spectrum.

The sound pressure levels exceed the maximum permissible values in the frequency range that is -8000bts and their values are: 7dB - in the fourth octave; 12 dB in fifth; 13dB - in the sixth; 12dB - in the seventh; 11 dB - in the eighth; 7 dB - in the ninth.

Sound pressure levels are determined not only by the geometric dimensions of the workpieces and cutting tools, but also by the parameters of the technological processes - depth of cut (t), feed per tooth (S7), cutter insertion frequency (n) and number of teeth (t). Therefore, below are the theoretical and experimental data on the change in sound pressure levels for various combinations of the above parameters.

When measuring acoustic characteristics, it is almost impossible to estimate the contribution of individual sources to the sound field at the source's workplace. Therefore, in order to indirectly identify the contribution of individual sources, vibration levels were measured on the workpieces, the spindle bearing cover and the frame (Figure 4).

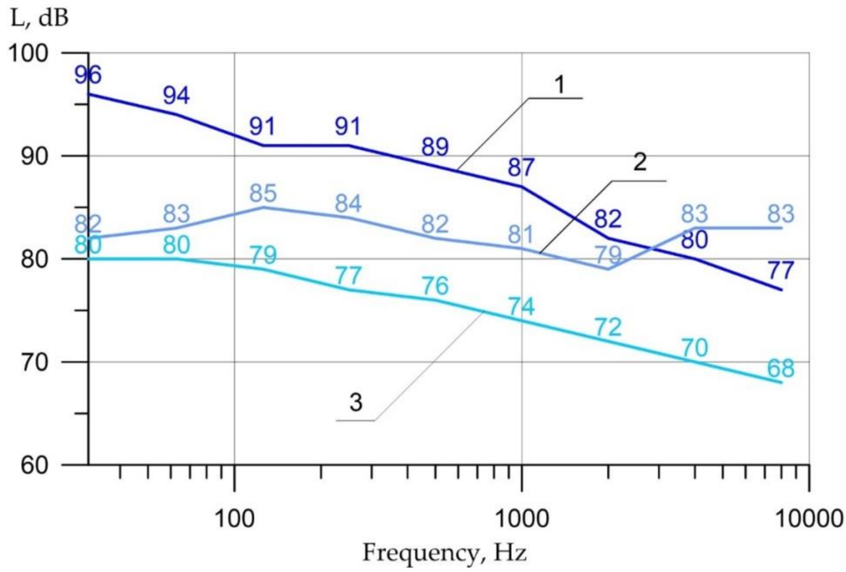

Fig. 4. Vibration spectra: (1) on a beam-type blank; (2) spindle bearing cap; (3) bed.

4 Discussion

The maximum vibration levels in the first - seventh octaves are created on the workpiece. In this frequency range, the vibration levels on the bearing cap are 5-13dB lower than on the workpiece. In the eighth and tenth octaves, the vibration levels on the bearing cap are 3-5 dB higher than on the workpiece.

The vibration levels of the table do not exceed 30 dB, and in the low-frequency region, and in the medium and high frequency regions, the vibration levels are 15-20 dB less than on the workpiece. This allows us to assume that the sources of noise that create excesses over the maximum permissible values are the workpieces being machined, the cutting tool.

Comparison of the obtained data with previous studies 15, 17, 18 showed that the noise level of metal-cutting machines when milling cast iron is comparable to the results of data on abrasive processing of welded joints of transport machines. This makes it possible to apply the same theoretical research methodology and propose similar noise reduction methods.

The data obtained are the initial information for the calculation of noise reduction systems, based on compliance with sanitary standards.

5 Conclusion

Experimental results of the study of the noise of metal-cutting milling machines during the processing of cast-iron blanks are obtained. Research has shown that the existing ones create increased sound pressure in the range from 250 to 8000 Hz, while the sound pressure level reaches 80-92 dBa, which is 15-20 dBa higher than the maximum allowable.

In the higher frequency part of the spectrum, the decrease in the intensity of sound radiation is from 4 to 7 dB per octave. The data obtained are the initial information for the calculation of noise reduction systems, based on compliance with sanitary standards. To simplify engineering calculations, vibrational energy loss coefficients for cast iron solid and hollow products are given.

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