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MEASUREMENT OF NOISE AND VIBRATION IN THE CUTTING ZONE DURING TURNING

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Abstract: *Turning is a complex machining process due to the influence of numerous factors and is accompanied by the occurrence of noise as well as forced and self-excited vibrations. Measuring these quantities enables more accurate modeling of the cutting process and the determination of optimal machining conditions. In this study, sound energy and vibrations during the turning process were measured, and the measurement methodology was described. The selected input machining parameters were: cutting speed (v), depth of cut (a), and feed rate (s). Optimal machining conditions were then determined using the Particle Swarm Optimization (PSO) method.*

Keywords: *Noise, Vibrations, Particle Swarm Optimization (PSO)*

1. INTRODUCTION

The metal cutting process, particularly turning, represents one of the most widespread and significant technologies in modern mechanical engineering. Despite its long-standing application and continuous technological progress, the cutting process remains an extremely complex dynamic system, whose complete understanding presents a constant challenge for researchers and engineers. A particular problem in this context is the occurrence of noise and vibrations in the cutting zone, which directly affect product quality, process productivity, tool life, and also the health aspects of the working environment.

Noise and vibrations in the turning process arise as a consequence of complex physical phenomena involving elastic and plastic material deformations, friction on the contact surfaces of the tool and workpiece, and dynamic interactions in the tool-holder-workpiece system. These phenomena not only degrade the quality of the machined surface and reduce machining accuracy but can also lead to accelerated tool wear, machine tool damage, and long-term exposure to high noise levels can have serious consequences for the operator's health.

The relevance of this issue is particularly pronounced in the conditions of modern production, which strives for increased productivity, quality, and energy efficiency, while simultaneously ensuring ergonomically acceptable working conditions. Growing demands for reducing production costs, increasing competitiveness, and implementing the principles of sustainable production necessitate a comprehensive study and optimization of the cutting process from the perspective of dynamics and acoustics.

2. PREVIOUS RESEARCH

A fundamental contribution to the study of the cutting process was made by A. D. Makarov in his work "Optimization of the Cutting Process" from 1976 [1]. Makarov thoroughly investigated the physical foundations of the cutting process, tool wear mechanisms, and the influence of temperature on the cutting process. His concept of a constant optimal cutting temperature represents a significant theoretical contribution that enabled the understanding of the basic principles of cutting process optimization. Although Makarov did not explicitly study noise and vibrations, his works on the mechanics of the cutting process and contact phenomena on tool surfaces provide valuable insights into the physical processes that are sources of noise and vibrations.

Vibrations in the cutting process can be classified as forced vibrations or self-excited vibrations (chatter).

Forced vibrations arise due to uneven movement of machine parts, imbalance, or periodic changes in the cutting force [2]. Self-excited vibrations arise due to the regenerative effect and nonlinearities in the cutting process [2].

Tobias [3] and Tlusty [4] developed models explaining the mechanism of self-excited vibration occurrence, emphasizing the role of the regenerative effect and system stiffness. Kudinov [5] highlighted the importance of chip thickness variation and the influence of friction. Modern approaches use statistical methods for vibration identification through analysis of the machined surface or direct measurement of machine structure oscillations.

Numerous studies have shown that modeling of the machining process can be successfully carried out using factorial design of experiments and artificial neural networks. Also, vibrations and noise during machining directly affect surface quality, accuracy, and tool wear. Papers emphasize the importance of acoustic emission and vibro-diagnostics in monitoring the cutting process.

Within the doctoral dissertation of Mirfad Tarić [6], significant contributions were made in the field of cutting process research, particularly in the context of machining parameter optimization. Tarić thoroughly analyzed the influence of various factors on the cutting process and developed a methodology for determining optimal machining regimes. His work is particularly important in the context of experimental determination of cutting process characteristics and understanding the interrelationships between machining parameters and process output characteristics. Tarić's contribution in applying modern methods of analysis and optimization of the cutting process represents a solid foundation for further research in this area.

Contemporary research in the field of cutting processes is directed towards the application of advanced measurement techniques, numerical modeling, and the application of artificial intelligence for process optimization. Numerous authors deal with the analysis of cutting process dynamics, identification of noise and vibration sources, and the development of methods for their suppression.

Particular attention is paid to the application of sensor technology, signal analysis in the time and frequency domain, and the development of adaptive control systems that adjust machining parameters in real time to minimize unwanted dynamic effects.

3. METHODOLOGY FOR MEASURING NOISE AND VIBRATIONS ON A CNC LATHEE

3.1. Eksperimental setup

For measuring vibrations on a CNC lathe, the following are used:

- Piezoelectric accelerometers (range: 0-10 kHz, sensitivity: 100 mV/g),
- Laser vibrometer for non-contact measurement of tool oscillations,
- Microphone for noise measurement (range: 20 Hz-20 kHz).

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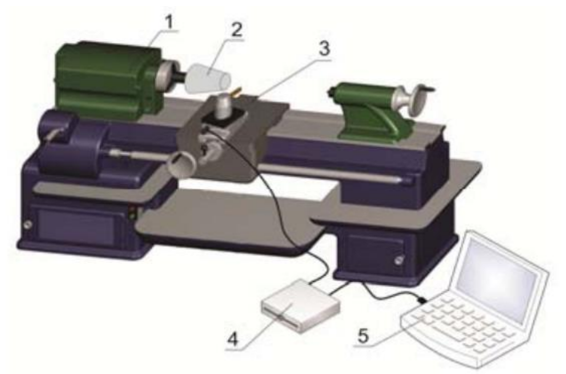

Figure 1. Vibration Measurement during Turning [7]

All sensors are connected to a data acquisition system (DAQ) and a computer with analysis software (e.g., LabVIEW or MATLAB). Measurements are conducted on the CNC lathe itself, equipped with a data acquisition system (DAQ) and sensors:

- Microphone for noise measurement (frequency range: 20 Hz – 20 kHz)
- Accelerometers for vibration measurement (mounted on the tool holder and spindle)
- Signal analysis system (e.g., LabVIEW or MATLAB with Signal Processing Toolbox).

3.2. Measurement procedure and locations

Before the actual measurement, sensor calibration must be performed according to standards (e.g., ISO 16063). Sensors are positioned such that the noise measurement microphone is at a distance of 1 m from the cutting zone, and accelerometers are at strategic points. Signal recording is performed during different cutting regimes (v, s, a). Signal analysis involves:

- FFT analysis for identifying dominant frequencies.
- RMS values for vibration and noise intensity.

Accelerometers are placed on:

- Tool holder
- Spindle
- Machine bed

During the experiment, turning parameters are varied:

- Cutting speed V [m/min]
- Depth of cut a [mm]
- Feed s [mm/rev]

3.3. Signal processing

Vibration and noise signals are analyzed in:

- Time domain (RMS, amplitude),
- Frequency domain (FFT, spectral analysis),
- Statistical domain (correlation function, power spectra).

4. RESULTS AND DISCUSSION

Using the PSO algorithm, optimal machining parameters that minimize noise and vibrations can be identified. Cutting speed has the greatest influence on process stability. Increasing the cutting speed above a critical value leads to the occurrence of self-excited vibrations, which is also confirmed by Tobias [3] and Tlusty [4].

Correlation analysis of the workpiece surface showed a good correlation between the presence of periodic components and the occurrence of self-excited vibrations [8].

Using a three-factor central composite design and neural networks, reliable models for predicting cutting forces, temperature, and roughness were obtained. The correlation between measured vibrations and tool wear parameters indicates the possibility of early detection of tool blunting.

4. CONCLUSION

The metal cutting process represents one of the most significant and prevalent operations in modern industry. Although tool materials and machining technologies are continuously improved, the existence of unwanted physical phenomena such as noise and vibrations remains a current and complex problem. These phenomena are inherently present in the cutting zone and have a direct impact on multiple aspects of the production process.

Noise and vibrations negatively affect: the quality of the machined surface, lead to accelerated tool wear and reduction of its durability, and can lead to damage to the machining systems themselves.

From the aspect of the working environment, operator exposure to excessive noise poses a serious health risk, requiring the application of additional protective measures. Therefore, the research, modeling, and control of noise and vibrations are not only a matter of technological efficiency but also of economic viability and workplace safety. Understanding their causes and mechanisms of occurrence is crucial for developing strategies to mitigate them and optimize the machining process.

REFERENCES

[1] D. Makarov: Optimization of the cutting process, Technologist's Library, Moscow, 1976.

[2] V.R. Milačić: *Forced and self-excited vibrations of machine tools, Proceedings of the Fifth Conference on Production Engineering*, *15-16. V 1969, Kragujevac, pp. AM1.1-AM1.14.*

[3] Tobias S.A.: *Machine Tool Vibration*, Blackie, (1965).

[4] Tlusty, J.: Selbsterregte Schwingungen an Werkzeugmaschinen, VEB Verlag Technik, (1962).

[5] Kudinov, V.A.:Dynamics of Machine Tools*. Mir Publishers, (1968).

[6] M. Zarić: *Modeling of the turning process of heat-treated steel*, PhD thesis, Faculty of Technical Sciences Novi Sad, Novi Sad, Srbija, 2018.

[7] Košarac A., Željković M., Mlađenović C., Živković A.: *Identification of self-excited vibrations during turning using modern diagnostic equipment*, IMK-14 – Research and Development in Heavy Machinery Engineering, pp.SR105-SR111 (2013).

[8] Peklenik, J., Gartner, J.: Workpiece Accuracy Criterion for the Dynamic Machine Tool Acceptance Test, MTDR, (1966) .