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AUTOMATION OF MANAGEMENT OF ECOLOGICAL PARAMETERS OF THE TECHNOLOGICAL PROCESSES OF CUTTING ON THE BASIS OF FORECASTING THEIR NEGATIVE IMPACT ON THE PERSON AND ENVIRONMENT

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ABSTRACT

The problem of improving the ecological and industrial safety of the technological processes of metalworking by cutting has been studied. The relation between ecological parameters and technological process parameters has been shown. The issues of forecasting vibration levels in the structure of metal-cutting machines using automation aids have been discussed. An algorithm has been suggested that offers forecasting vibration in machine elements based on vibration measurements in one point where a sensor is installed. An integrated criterion as a tool developed for rational selection of lubricant cooling technological means and their application systems has been created. A database and an information storage and retrieval system "ECO CUTTING FLUID" have been offered.

KEYWORDS: automation, vibration, lubricant cooling technological means, mathematic model, integrated criterion, control.

I. INTRODUCTION

Mechanical engineering and metalworking are among the leading sectors of industry, which include various types of technological processes, a main one of them being the process of cutting [1, 2].

The typical features of implementing the technological processes of metalworking by cutting are vibrations in the moving elements of process equipment during implementation of this process and noise resulting from them, also presence of lubricant cooling technological means (cutting fluids) in the working area, which have to be applied to achieve good quality of the cutting process, and contamination of ambient air by products of thermal destruction of lubricant cooling technological means. These factors render considerable impact on the environment and person and determine the ecological safety of the technological processes of cutting [1, 3, 4].

The source of vibration and noise is gaps in the moving elements of the machine, and kinematic elastic deformations in structural elements, while thermal destruction of the cutting fluid is caused by high temperatures in the zone of cutting. In this connection, technologies aimed at forecasting vibration and noise and rationally selected cutting fluid reducing air contamination with cutting fluid's thermal destruction products during implementation of cutting metalworking processes are essential for improvement of the ecological safety of the technological processes of cutting [4, 5].

II. FORMULATION OF A PROBLEM

Much attention is paid to the issues of abating adverse impacts of technological processes on the environment and person, including automation aids [6-11].

Vibrations arising in the process equipment when mechanic energy is transmitted from the engine to the actuator for implementation of the process of cutting are scattered energy representing vibration waste generated because the energy spent by the process equipment is not fully utilized in performance of this process. Besides, a part of energy is scattered directly in the metalworking zone due to tool's friction against the surface of the blank, occurrence of elastic and plastic deformations. For this reason, it is necessary to inject lubricant cooling technological means into the cutting zone to reduce friction and temperature in the metalworking zone and

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decrease energy scattering based on the lubricant cooling technological means damping effect consisting in decreasing the amplitudes of cutting force oscillations and those of processed blank.

One of the main directions of reducing oscillations arising in the process equipment is their minimization directly in their source, which is the elements of the machine kinematic chain; hence, it is most important to forecast vibrations in structural elements of equipment so as to be able to minimize generation of oscillations at the stage of process equipment development and optimize the existent structural designs based on this criterion. Rationally selected cutting fluids suitable for a particular technological mode, equipment, tools, processed material of the cutting fluid application system facilitate reducing vibrations generated in the cutting zone. Selecting necessary cutting fluids involves numerous limitations and criteria and is realized through analysis of a body of information; therefore, the issues of rational selection of cutting fluids may be resolved using integrated databases accumulating all necessary information including information about ecological parameters and safety parameters of technological processes, which allows making cutting fluid selection automated.

III. MAIN PART AND RESULTS

Forecasting Vibration Levels

Forecasting the vibration arising in the course of technological process implementation and spreading via structural elements of the process equipment was studied for lathe machining. The investigation results have allowed establishing qualitative and quantitative correlations between parameters characterizing vibration and changes in its level in the course of spreading in medium, making it possible to assess vibrations based on measurements in one control point.

The identified correlations and study results obtained found that vibrations spreading in structural elements of process equipment free of joints have linear relation [12]. This is important for two reasons: firstly, this relation allows simplifying the forecasting method considerably thanks to reduction of the number of analyzed points to two; secondly, linear relations are the most convenient to be used in automated process control systems. The authors have developed a linear mathematic model establishing vibration level depending on the distance and spindle rotation speed. In general, the mathematic model looks as follows:

$$V = C + A \cdot R + B \cdot n \qquad (1)$$

where V is the vibration level, dB;

R is the distance from the source of vibration to the point under study, m; n is the spindle rotation speed, min^{-1};

C, A, B are the mathematic model factors that may vary during investigation of different groups of process equipment.

Factor "*A*" in equation (1) determines the intensity of vibration attenuation in lathe structural elements as the distance from the main source of vibration in the lathe increases. It was obtained experimentally and is applicable to a particular group of metal-cutting machines. The value of factor "*A*" may vary depending on the analyzed structural element of a particular group of machines; for example, for the turning lathe guide, factor "*A*" is –6.04 [13].

The mathematic model obtained experimentally for the turning lathe guide is:

$$V = 74.59 - 6.05 \cdot R + 0.01 \cdot n \qquad (2)$$

To prove validity, the vibration values obtained with the help of the mathematic model were compared against actual values in control points. The performed experimental studies have demonstrated that deviations of the vibration values do not exceed 5 %.

This mathematic model allows forecasting vibration levels in process equipment elements based on measurements in one point. The mathematic model may include various factors affecting generated vibrations, such as equipment's spindle rotation speed, cutting depth, viscosity of cutting fluids, and other.

To provide automated forecasting of vibration spreading in structural elements of process equipment, an algorithm for realization of the obtained mathematic model has been developed. The algorithm shown in fig.1.

The developed mathematic model and algorithm make it possible to render the process of forecasting spreading of vibrations via the process equipment structure automatic on the basis of linear modeling [13].

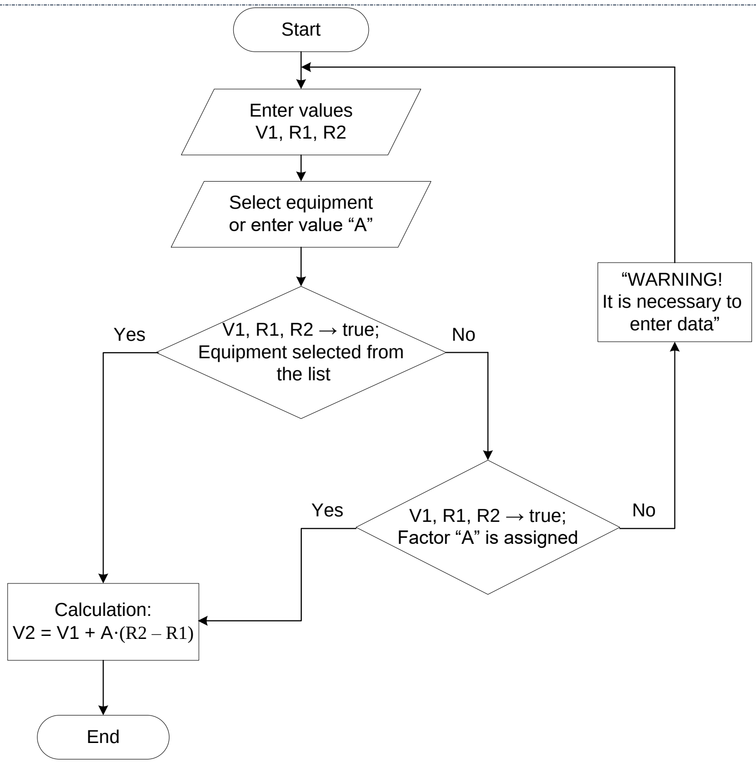

Fig. 1. Algorithm of the vibration forecasting software

To realize the algorithm of forecasting vibrations in structural elements of process equipment, a special software has been developed in Microsoft Visual Basic envelope. The software performs forecasting of vibration levels in a specified point of a lathe through linear modeling of vibration distribution in its structural elements, wherein forecasting is executed based on measurements performed by a sensor installed in one point, for example, the one the most convenient or accessible for measurement.
The software is based on relation:

$$V2 = V1 + A \cdot (R2 - R1) \quad (3)$$

where *V2* is the forecasted vibration in the specified control point of the lathe, dB;
V1 is the vibration level found by the sensor installed in one point of the lathe, dB;
R2 is the coordinate of the point for which it is necessary to forecast vibration;
R1 is the coordinate of the point where the sensor is installed;
A is the mathematic model factor.

Rational Selection of Cutting Fluids and Their Application Systems
Rational selection of lubricant cooling technological means (cutting fluids) and their application systems is a multi-objective problem. It is necessary to not only obtain the required process parameters for cutting but also ensure safety of cutting processes for the personnel and environment. The authors have developed and realized tools for rational selection of lubricant cooling technological means and their application systems. Such tools are the database and the integrated criterion for selection of options, which serves the basis of information storage and retrieval system (IRS) "ECO CUTTING FLUID" [14].
The integrated criterion comprises process, ecological, and economic parameters of the process system using a cutting fluid. The criterion provides an integrated solution of the task of ensuring cutting process safety through application of a cutting fluid.
To resolve specific safety tasks such as diminishing toxicity, improving fire safety and so on, the integrated criterion parameters are grouped into blocks according to the task to be solved. The blocks of parameters are formed by specialists in that particular field, taking into account the influence of a particular parameter on the subject property [15, 16].
This includes regression analysis and derivation of regression equations of influence of different parameters of

the process system using a cutting fluid on the safety of cutting processes for the personnel and environment.
The formation of the integrated criterion shown in Figure 2, where P1… PN is the assigning parameters.

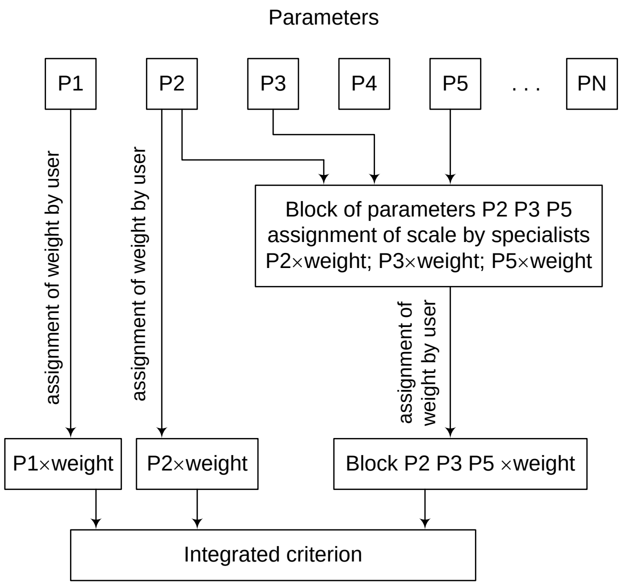

Fig. 2. The formation of the integrated criterion

Among others, a block of parameters determining vibration safety has been formed. It includes the following parameters: vibration level, vibration speed, vibration acceleration, the cutting fluid resistance factor, the cutting fluid kinematic and dynamic viscosity. These parameters are included in the block on the basis of theoretical and experimental studies. The cutting fluid viscosity is known to determine the cutting fluid damping effect. By increasing viscosity, one can reduce the amplitude of oscillations in the process system considerably. However, as the cutting fluid viscosity increases its cooling effect goes down. This brings the engineer, researcher back to the problem of rational selection.
The integrated criterion, with the help of which the authors are making a rational selection of the cutting fluid, allows prioritize particular tasks of process quality and safety assurance by assigning weight to specific parameters or blocks of parameters depending on the overall goal.

IV. CONCLUSION

1) The correlations between ecological and technological parameters of the production environment during implementation of metal-cutting technological processes have been established.
2) The linear mathematic model of vibration spreading in process equipment elements, the mathematic model realization algorithm, and the software allowing automating the process of forecasting vibrations in the process medium based on measurements in one point have been developed and supported experimentally.
3) The integrated criterion of optimal selection of cutting fluids and their application systems, information storage and retrieval system "ECO CUTTING FLUID" providing selection of a cutting fluid with regard to ecological, technological and economic parameters of process systems have been developed and validated.
The practical importance of the work consists in:

- the methodology of forecasting vibrations in process medium based on measurements in one point, which is based on creation of the algorithm and mathematic model taking into account most significant factors in terms of occurrence of vibrations;
- the methodology of making decisions in respect of selection of cutting fluids and their application systems based on building an integrated database structure and providing rational cutting fluid selection in terms of improved ecological safety of technological processes.

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