ALGORITHMIC FOUNDATIONS OF OPTIMIZATION USING FINITE ELEMENT MODELING OF HIGH-SPEED GRINDING TECHNOLOGY IN APPLICATION TO 3D MICRO-LEVEL MODELS

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Abstract

Optimization consists in choosing the best of all possible options for implementing high-speed grinding technology. A complete enumeration of all options may turn out to be inefficient or practically impossible. Therefore, to solve such a problem, we should apply fundamental mathematical results and numerical methods of optimization theory, which allow choosing the best option without directly checking all possible solutions. Such a choice is realized by means of calculations carried out using special algorithms and is practically impossible without the use of computer technology.

Keywords: 3D modelling, methodology, diamond wheel, high-speed grinding, finite element method, simulations, micro-scale, optimization.

1. Introduction

The results of dynamic 3D modeling of high-speed diamond grinding processes allow to solve the following problems: at the design stage - calculation of the tool design for certain processing modes; at the manufacturing stage - determination of rational conditions for sintering the diamond-bearing layer of the wheel; at the stage of application - the theoretical determination of processing productivity, specific consumption of diamond grains. The solution of these problems allows to significantly increase the efficiency of processing during high-speed grinding.

2. Research methodology

As applied to ultrahigh-speed diamond grinding, the above scheme for solving optimization problems takes the following form.

The boundary of the object under study separates this object from other objects interacting with it and allows to separate the characteristics (object parameters into external and internal). [1] When considering the problems of optimization of high-speed grinding, the boundary of the object under study is chosen by the content of the problem under consideration. The boundary of the object under study can be determined by the spatial area of the cutting tool when solving problems of choosing the optimal characteristics of diamond wheels at the stage of their design and manufacture. [2] When solving problems of optimizing high-speed grinding processes using available cutting tools, taking into account the characteristics of the processed material, the boundary of the object under study can be determined by the area covering the processing diamond grain with the processed material around their contact interaction.

The obtained preliminary results for the values of the characteristic function of the problem of optimizing the processes of super hard material (SHM) high-speed grinding show that such a function can be quite accurately represented by approximation in the form of a quadratic function (1), which in the general case of n independent variables (factors) is written as follows:

$$Y = b_0 + \sum_{i=1}^{n} b_i X_i + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} b_{ij} X_i X_j + \sum_{i=1}^{n} b_{ii} X_i^2 \quad (1)$$

3. Maximizing the performance of high-speed SHM diamond grinding

In accordance with the initial data obtained from the results of 3D modeling [3], the matrix [A] (function (1) presented in matrix form) and the vector {B} (variables of function (1) presented in matrix form) are obtained as:

$$[A] = \begin{bmatrix} -7{,}66 & -0{,}001 & 0{,}01 & -0{,}001 \\ -0{,}001 & -6{,}5 & -0{,}02 & 0{,}06 \\ 0{,}01 & -0{,}02 & -24{,}1 & 0{,}32 \\ -0{,}001 & 0{,}06 & 0{,}32 & -19{,}04 \end{bmatrix}, \{B\} = \begin{Bmatrix} 0{,}02 \\ -0{,}07 \\ -6{,}79 \\ 0{,}51 \end{Bmatrix}, B_0 = 55{,}91 \quad (2)$$

As a result of solving the system, a stationary point X_{stat} was obtained:

$$X_{stat} = \begin{Bmatrix} \text{-2.24194024298796E-0003} \\ \text{9.70029544277527E-0003} \\ \text{2.81441311184647E-0001} \\ \text{-2.20249223085138E-0002} \end{Bmatrix}, Y_{stat} = \text{5.3025585390789573E+001} \quad (3)$$

where X_{stat} is the coordinate vector of the stationary point of the function; Y_{stat} is the value of the characteristic function at the stationary point

4. Accounting and risk assessment in the process of quantitative analysis and decision-making in expert systems

To do this, we use the basic scheme of statistical tests, which we use according to the scheme of the well-known sampling method. In accordance with this method, we consider the object under study (in this case, the results of optimizing the processes of high-speed grinding and sintering of diamond wheels) in the form of a general population, which is a set of possible results corresponding to various initial data. Thus, the errors in the result of optimizing the processes of high-speed grinding and sintering of diamond wheels will be presented as a result of the error in the initial data.

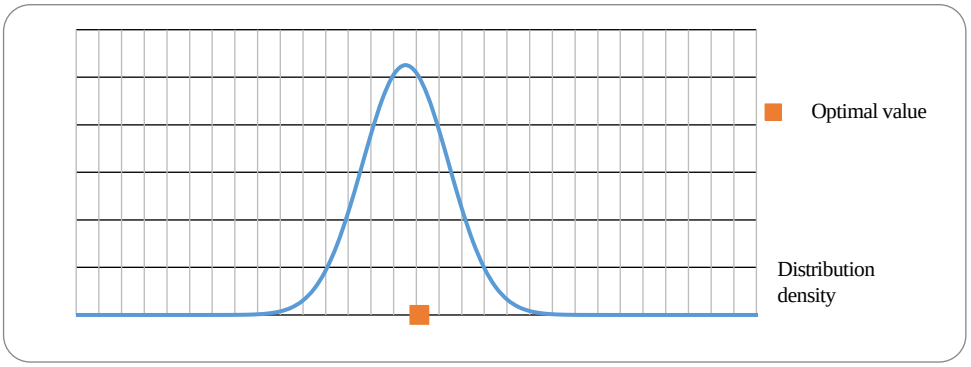

Fig. 1. The distribution density of the obtained optimization results and the optimal value for an example of optimizing the performance of high-speed diamond grinding

Conclusion

Fundamental mathematical approaches to optimization issues applicable to the study of the process of high-speed diamond processing of SHM are considered.

It is shown that in order to estimate the error of the results, it seems to apply the methods of mathematical statistics and consider the results obtained as one of the many possible implementations, i.e. estimate the probability that the result obtained has a predetermined error.

Special software has been developed that combines all the simulation results into an expert system that allows, with a certain probability and error, to predict the main indicators of the grinding process, depending on the various properties of the tool and processing modes.

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