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Making a Mathematical Model of Assembled Mill with Inserted Knives with Diffusion Fastening of Hard-Alloy Plates

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Abstract: In this article, analysis of mathematical model of designs of the cutting tool of assembled mill with inserted knives with diffusion fastening of hard-alloy plates is given.

Keywords: mathematical model, design of cutting tool, assembled face mill, insert knife, hard-alloy insert, dynamic model, elastic system

Introduction. Face mills are widely used in process of machining planes on vertical milling machines. Their axis is set perpendicular to the machined plane of the part. For face mills, only the tops of the cutting edges of the teeth are profiling. Face cutting edges are auxiliary. The side cutting edges located on the outer surface [1, 2] performs the main cutting work.

Face milling provides greater productivity. Therefore, at present, most of the work on milling planes is performed by face mills.

The most widespread in the industry are assembled hard-alloy mills. Mills with relatively small size are manufactured in most cases with hard-alloy inserts soldered directly to the body. Plates are made of relatively short length and thickness constant thhardout the entire extent. Therefore, in cases where it is necessary to have a tool with long cutting edges, several inserts are soldered onto the teeth of the cutters. The joints between the plates are made in the form of chip-separating grooves and are staggered.

Main part. Evaluation of the effectiveness of the developed designs of cutting tools includes two main stages: computational and physical experiments. In frame of automated research systems, the process of merging these two stages occurs. Analysis of the existing mathematical models of cutting tool designs showed that the accumulated volume of theoretical and experimental research is insufficiently generalized and systematized. Currently, there are no methods for making and using mathematical models in automated systems, the principles of forming the tanks of mathematical models of the cutting tool have not been determined.

In the developed models, the structure of the mathematical description often does not correspond to the structure of the described cutting tool. This makes it much more difficult to assess the adequacy of the model and to correct it.

In addition, sufficiently accurate and complex mathematical models are impractical to use in full for a qualitative assessment of technical solutions. In this regard, the problem requires a consistent solution of the following tasks:

- determination of the rules for the formation of technical specifications for a mathematical model;
- development of the principles of its construction to assess the designs of cutting tools;
- development of a methodology for the automated “making” mathematical models.

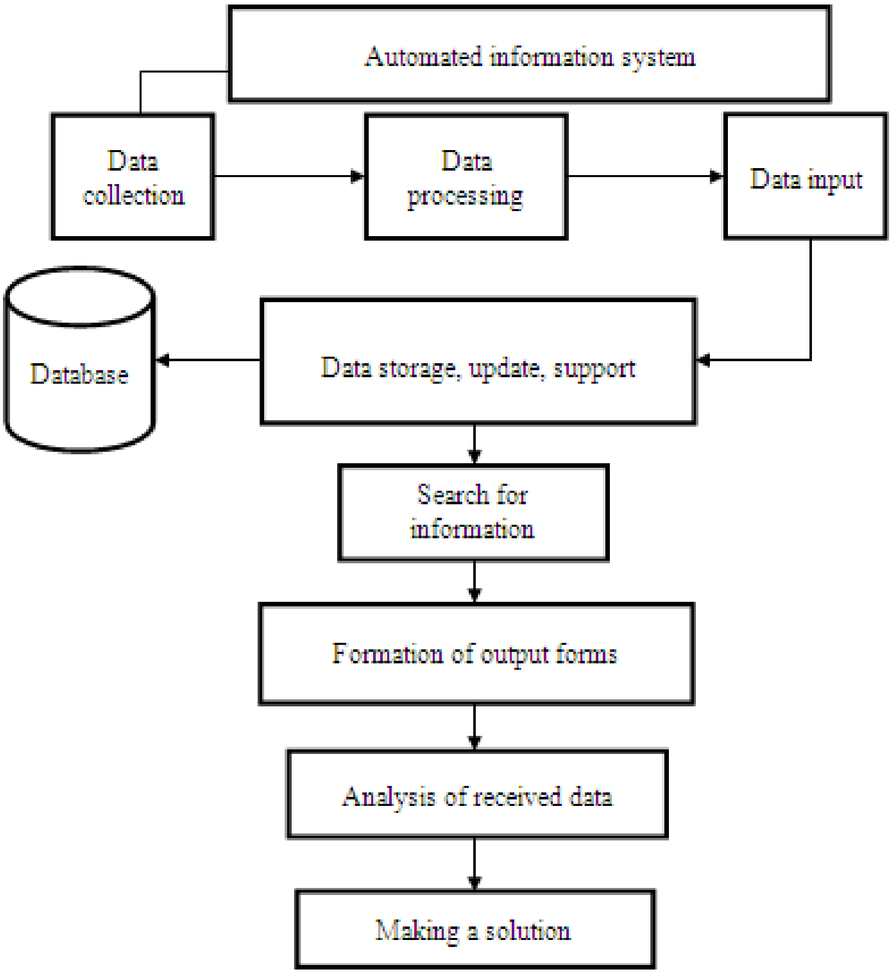

Fig. 1. Scheme of information links of the search design system of cutting tools

The essence of the method of synthesis of cutting tools on the AND-OR-graph is that information about prototypes and known technical solutions is presented and recorded in the form of an AND-OR-tree [3]. (Fig. 2). On its basis and based on a general list of requirements, a model for evaluating synthesized technical solutions is developed, which allows comparing various options, choosing designs that satisfy a given list of requirements, and also obtaining the best solutions.

Then the general list of requirements, including a set of functional, technological, economic requirements for tool designs, must additionally contain mathematical and algorithmic parameters that characterize special requirements for mathematical models and programs. These requirements include model accuracy, functional dependency, software implementation, and others. From the list of requirements expanded in this way, a technical task is formed for building a mathematical model. With this approach, AND-OR-tree can be used not only for the analysis and synthesis of designs of cutting tools, but also for the making their mathematical models.

The structure of the model should correspond to the structure of the described technical system. This serves as the basis for moving on to the consideration of the problem of automating the model design process.

When making a model, the principle of superposition of processing error components can be used [4, 5].

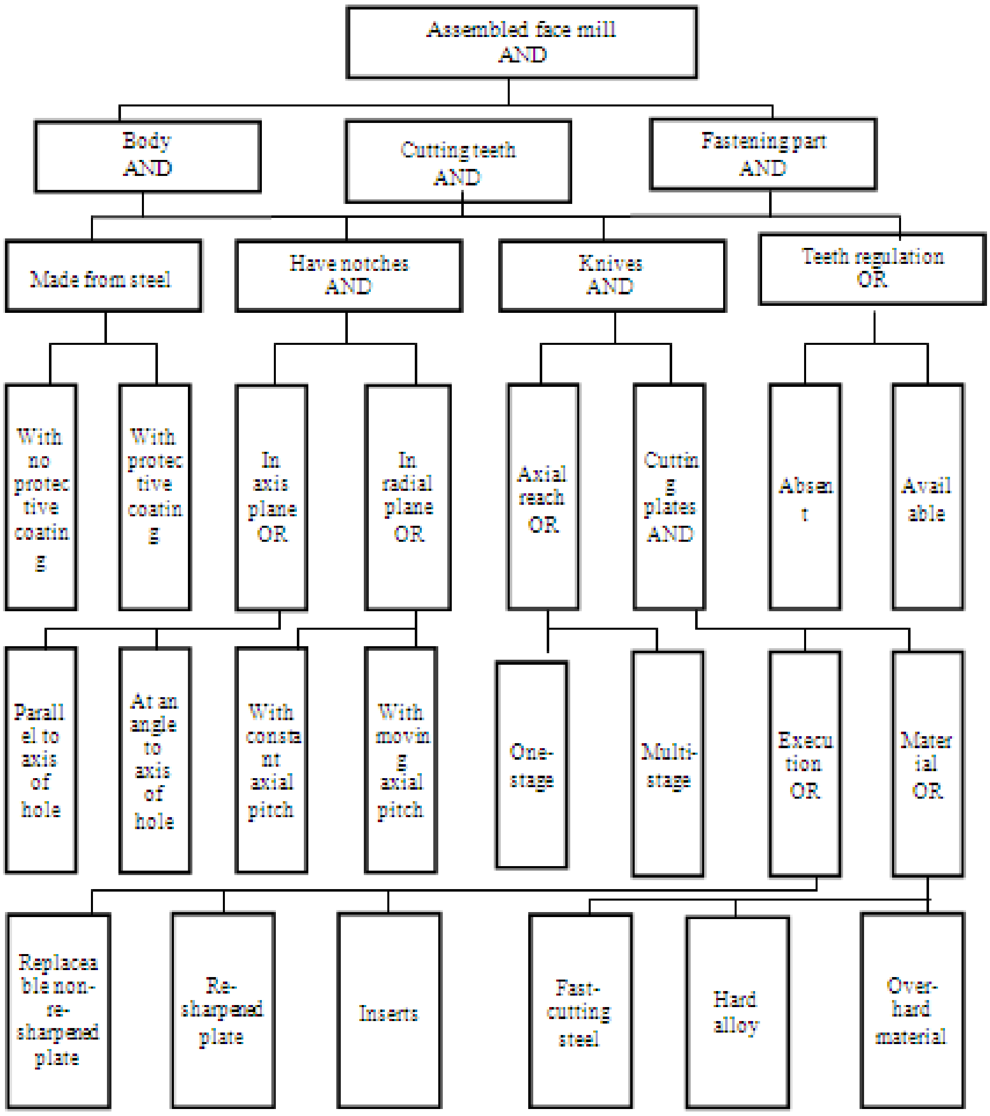

Fig 2. Fragment of the AND-OR-graph of the structures of assembled mills

This principle is as follows: each of the components of the error arises and acts independently of the others, while the total processing error is the result of the joint manifestation of its components. Using this principle allows creating a wireframe structure of the model.

Mathematical model of assembled face mill with inserted knives with diffusion fastening of hard-alloy inserts

The current position of the tops of the cutting teeth of the tool that forms the profile of the machined surface can be described by the following expression:

$$\vec{r}(\tau) = \vec{r}o + \Delta\vec{r}_{упр} + \Delta\vec{r}_{тем} + \Delta\vec{r}_{кон} + \Delta\vec{r}_{изн} \qquad (1)$$

The carried out literary analysis allows establishing that its vibrations caused by vibration of the cutting processes make the greatest contribution to the formation of errors in milling with a composite tool.

A model with two degrees of freedom represents dynamic model of the elastic system of the assembled tool.

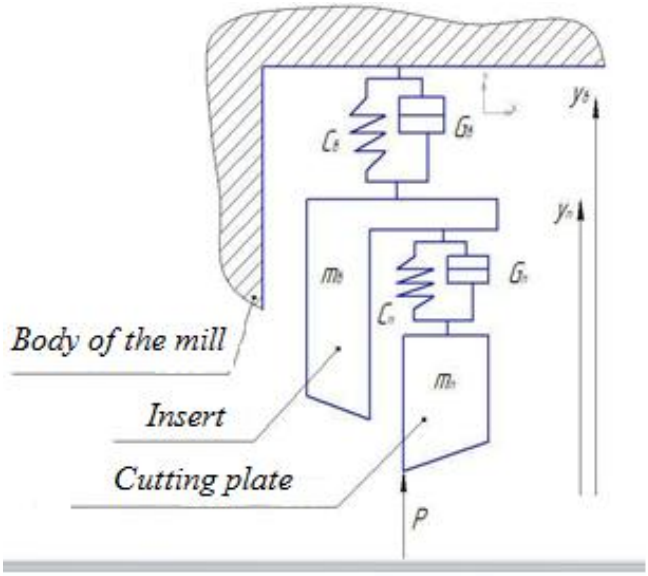

Fig.3. Design scheme

The model is made under the following assumptions:

1) the system is considered as linear;
2) trochoidal trajectories of the top of each cutting tooth of the mill are represented by movements along arcs of circles, with a diameter equal to the diameter of the mill;
3) cutting force changes periodically with a frequency equal to the rotational speed of the cutter;
4) elastic deformations of the elements of the precast cutter are considered within the implementation of Hooke's law;
5) elastic displacements of the cutting plate material are equal to zero;
6) only vibrations in the axial direction are considered.

The first assumption is justified by the fact that because of the rather high rigidity of fastening the structural elements, the vibration amplitudes during cutting are insignificant, which allows considering them as linear.

The second assumption is because when the ratio of the value of part feed to the speed of rotation of the tool, occurring during milling, the error of their replacement does not exceed 1%.

The third assumption is because the linear movement of the center of the cutter during its full revolution is insignificant; therefore, even with a constant change in the processing conditions, the law of change in the average value of the cutting force at successive revolutions of the tool are close to each other.

The fourth assumption is valid provided that a preload is created in the constituent elements of the technological system, excluding the appearance of the phase of choosing the gaps during their interaction.

The fifth assumption is because that the elastic deformations of the material of the cutting part during blade processing are much less than the amount of its removal.

For the accepted design scheme, the movement of the tip of the cutting insert of the assembled mill is described by a system of differential equations:

Vibrations of the plate relative to the insert:

$$m_n \ddot{y}_n(\tau) + G_n \dot{y}_n(\tau) + C_n y_n(\tau) = P(\tau) \qquad (2)$$

Vibrations of the insert relative to the body:

$$m_b \ddot{y}_b(\tau) + G_b \dot{y}_b(\tau) + C_b y_b(\tau) - C_n y_n(\tau) - G_n y_n(\tau) = 0 \qquad (3)$$

$$\begin{cases} m_b \gg m_n \\ C_b \approx C_n \end{cases} => y_b \approx 0$$

The terms of the equation can be determined in various ways, taking into account the influence of certain factors. This provides multiple realizations of the simulation model. When constructing a model, the principle of superposition of processing error components can be used [6, 2]. This principle is as follows: each of the components of the error arises and acts independently of the others, while the total processing error is the result of the joint manifestation of its components.

As the main operational durability of cutting inserts;

- the accuracy of the size of the surface processed by the tool data;
- the value of the parameters of the hardness of the processed surface.

The value of operational characteristics depends on a number of factors, including cutting conditions, physical and mechanical properties of the processed and tool materials; in addition, the vibration of the technological system has a significant effect on the characteristics, in particular, the vibrational displacements of the elements of the assembled cutting tool.

When calculating the hardness, it should be borne in mind that its formation occurs because of the combined action of two factors:

- geometric copying of the working profile of the cutting tooth, taking into account the plastic deformation of the resulting profile;
- oscillatory processes causing a change in the law of relative motion of the cutting edges of hard-alloy plate in the processed surfaces of the part.

Conclusions

Using casting methods [7] at the manufacture of cast tools opens up wide opportunities in the creation of high-strength structures.

The versatility of the technology allows obtaining a tool of a finished shape, using a hard-alloy of any shape and, therefore, to reduce the number of machining operations of the mill body and exclude the operation of brazing hard alloy to its body.

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