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APPLICATION OF RESOURCE-SAVING TECHNOLOGIES FOR MANUFACTURING MACHINE PARTS

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Annotation
The article covers an analysis of optimization of the technological process (TP) in order to select technological solutions at various design levels and ensure the minimum value of the reduced costs while simultaneous observing a number of technical restrictions.

Keywords: machining process, technological operation, technical solution, automated design, parametric optimization, structural optimization, optimization.

Introduction

The task of optimizing the technological process (TP) is complex and requires analysis and selection of technological solutions at various levels of design. It provides the minimum values of the reduced costs while meeting a number of technical constraints.

There are three types of TP optimization:

- structural optimization, which is the choice of the optimal technological route, operation, transition, type and methods of manufacturing a blank, methods of basing, equipment, fixtures, tools, etc.
- parametric optimization, which is the selection of optimal parameters: tolerances for inter-operational dimensions, allowances, cutting modes, geometric dimensions of the cutting tool, etc.
- structural - parametric, which is a combination of the first two types.

The last type of optimization reflects an integrated approach to the automated design process and is the most complex. Therefore, with parametric optimization, it is necessary to have a decision on the choice of the structure of the appropriate level. At the same time, structural optimization requires knowledge of the values of the parameters included in the corresponding structure. This contradiction can be eliminated when constructing algorithms for optimizing technological processes in several iterations.

Main part

The main feature of the optimization of technical solutions is the need to use various optimality criteria at all levels. Analysis of these criteria shows that from the point of view of coordinating optimal solutions at different levels, it is preferable to develop processes from the most general issues to their detailing, which is more characteristic of the first approach. In this case, the problem arises of obtaining an optimal solution in the design of TP as a whole by optimizing individual technological solutions at all design levels.

In order to implement the considered design process in CAD TP, an iterative multilevel optimization process is used, the content of which is multiple repetition of analysis, synthesis and evaluation procedures. Analysis of the initial data, conditions and constraints allows establishing the boundaries of the area of possible technological solutions. With the help of synthesis procedures, technological solutions are obtained that are admissible in terms of a set of boundary conditions. The best solutions according to some criterion are selected by the evaluation procedures.

In general, the problem of structural optimization can be formulated as the problem of choosing the best TP structure. For this, it is necessary, firstly, to present certain requirements to the set of operations performed, and, secondly, to introduce some criteria for the preference of one structure over another.

One of the most important stages of structural optimization of TP is the choice of technological operations of mechanical processing. The type of operations and the equipment used significantly affect the complexity of processing and the associated technological cost, which is usually chosen as a criterion for choosing options for TP for manufacturing a product.

Structural optimization of TP as a whole considers each task of technological design sequentially. Therefore, the entire design process is divided into several interrelated levels. The design process at each level is a multivariate procedure.

The problem of structural optimization is to find the branch of the graph that provides the extremum of objective function. Because of the disordered parameters, the main method of structural optimization is a sequential enumeration of possible options. To choose one optimal option, it is necessary to design a very large number of TP options admissible by technical and technological limitations.

There can be a huge variety of such options for a real TP of the manufacture of parts of even average complexity. Enumerating all the options, even with the help of modern high-speed computers, takes a very long time. To reduce the design time, the following methods are used.

Method 1. The efficiency of the design process can be dramatically increased if you organize the selection of rational options for design solutions at each design level. However, this raises the problem of forming criteria for the intermediate selection of the most rational options at various levels. For example, at the level (stage) of the selection of blank, variants can be analyzed according to the "prime cost of blank" criterion. This criterion can be reliably calculated at this stage. Nevertheless, this criterion is not completely objective.

"Cheap" blank (for example, round bars for the manufacture of a shaft) will give an "expensive" machining. In addition, "expensive" blank (for example, stamping for the manufacture of the same shaft) will provide a "cheaper" machining. Therefore, it is advisable to use the total cost of the blank and machining as a criterion. However, the cost of machining can be calculated only after the development of the entire TP. Consequently, the meaning of "phased optimization" disappears.

However, if criteria are successfully assigned at each design level, such an approach makes sense. When using it, there may be several equivalent TP options, but among them it is already much easier to choose the best option.

Method 2. "Pre-design optimization". The set of possible options for design solutions can be determined using correspondence tables, based on which algorithms are built that allow choosing a set of feasible solutions, from which the best solutions are selected by sequential enumeration according to one or another criterion of optimality.

Nevertheless, even with localized structural optimization, the enumeration and analysis of all feasible solutions selected from the correspondence tables takes a lot of time. To reduce the computation time during structural optimization using correspondence tables, the so-called pre-design optimization is performed at the stage of information support development. For this, from the set of admissible ones, solutions are distinguished that are preferable according to the criterion of prime cost. The search for solutions in the correspondence table is first performed according to the preferred solutions. In the absence of a suitable preferred solution, the search is performed on the remaining admissible ones.

This approach is effective for cases where there is an extremum of the objective function. However, in some cases, the solution turns out to be indefinite: for the range of the applicability condition, there may be several effective solutions.

Method 3. The next step in the development of pre-design optimization is the transition from logical correspondence matrices to evaluation matrices. In this case, in the corresponding cells of the matrix of correspondences, the values of the prime cost are put down. Similar matrices are filled in for all conditions of applicability. The algorithm for finding the optimal solution using the evaluation matrix is to search for a row of the same name in the evaluation matrices for all ranges of applicability conditions, which provides the least amount of costs for a given problem condition. The above procedure is repeated for each design level, ultimately leading to a variant with an optimal structure [1].

Parametric optimization of TP

In the context of a multilevel choice of solutions at various stages of TP design, the issue of structural optimization is initially resolved. After choosing a certain structure of the processing route, operation, position, transitions or various types of technological equipment, the task of their parametric optimization is posed. However, in most cases this is difficult to do due to the lack of mathematical models that link the structural components of technological processes with a certain group of parameters that determine the technical-economic indicators of these processes [2].

Parametric optimization of TP is usually performed after choosing the transition structure and is expressed mainly in determining the optimal cutting conditions (speed v, feed s and depth of cut t) from the standpoint of a certain criterion.

Parametric optimization can also include following calculations: on the choice of the optimal geometry of the cutting tool (cutters, drills, cutters, etc.); on the choice of precision, power and strength parameters of machine tools; on the choice of physical and mechanical properties of cutting tools; on determination of the optimal values of allowances and tolerances for the dimensions to be performed.

The task of determining the optimal cutting conditions is one of the most widespread and is encountered in the development of various types of TP for machining blanks. Due to the various specific processing conditions, goals and objectives of optimizing the cutting process, there are different options for setting this task.

When describing the processing process, input and output parameters are distinguished, which are interconnected by complex functional dependencies. The combination of these dependencies is usually considered as a mathematical model of the processing process. In the general case, the processing process is probabilistic in nature. However, due to the complexity of constructing dependencies that take into account the random nature of changes in a number of parameters, at present, deterministic models based on the averaged characteristics of the process are mainly used.

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In the problems of calculating cutting conditions, the input parameters are divided into the required (controlled) and specified (uncontrolled). The task of calculating the optimal modes is to determine those values that are the best (according to some indicators) in terms of a set of output parameters for given values of uncontrollable parameters.

When calculating the optimal modes, the cutting speed v and the feed s are usually taken as the required parameters, and sometimes the depth of cut t is used. It is also advisable to include the durability and geometric parameters of the cutting tool in the category of the required parameters, which can be controlled directly during processing. The degree of influence of individual controlled variables on the main indicators of the process being optimized is different, therefore, when choosing and constructing optimality criteria, it is necessary to take into account the most significant processing parameters.

In particular, from the theory of cutting [4, 5, 6] it is known that with external turning, an increase in the depth of cut than feed has a greater effect on increasing the productivity of processing at a constant area of the cut layer (ts = const). On the other hand, with a constant tool life, the increase in productivity is more strongly influenced by the increase in feed s compared to the speed v. Such a preliminary analysis allows, in some cases, simplifying the construction of algorithms for choosing the optimal processing modes.

In the general case, the formulation of the problem of optimization of processing modes includes:

- selection of the required parameters;
- determination of the set of their possible values;
- selection of the analyzed set of output parameters of the process;
- establishment of functional dependencies between the required and output parameters at fixed values of uncontrolled parameters;
- highlighting the objective function;
- assignment of ranges of possible values of output parameters.

The set of required parameters can be represented as a certain set

$$X = \{x_1, x_2, ..., x_n\}$$

Then the problem of calculating the optimal cutting conditions is reduced to the following mathematical programming problem:

$$F(x) \to \min(\max)$$

$$R_i(x) \in R_i ,$$

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$i = 1, 2, \ldots, m$

Where F(x) is the dependence for the accepted optimality criterion

$R_i(x)$ is the value of the i-th characteristic of the cutting process depending on the values of the required parameters x from a given set X

R_i is the specified limit value of the i-th characteristic of the cutting process.

Depending on the type and complexity of the representation of the functions F(x) and $R_i(x)$ different mathematical models for calculating the cutting conditions are used. These models can be classified according to the following criteria:

- composition of the set x of the variables to be optimized;
- composition of the process indicators taken into account;
- accepted criterion of optimality;
- form of the functions F(x) and $R_i(x)$ approximating the basic laws of the process.

The use of various mathematical models leads to the need to develop a variety of methods and algorithms for solving the problem under consideration [7].

Conclusions

To solve the set optimization problem, it is necessary to:

a) compose a mathematical model of the optimization object;

b) choose an optimality criterion and compose an objective function;

c) establish possible restrictions that should be imposed on variables;

d) choose an optimization method that will allow finding the extreme values of required quantities.

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