Analysis of Modeling, Optimization and Control Methods of Multifactor Operations and Complex Technological Processes

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Abstract

Modeling, optimization and management of multifactor operations and complex technological processes of machines and equipment parts' enameling was discussed in the article. It has been established that the main advantage of mathematical models construction for individual processing operations is the possibility to create mathematical models in new variants for different technological processes using these models. It was clarified that mathematical models reflecting processing operations and technological processes used to manufacture machine and equipment must take into account the key factors that characterize them. Studies show that the mode and technological factors of separate processing operations and technological processes are directly related to the accuracy and quality of the prepared parts. Taking all these factors into account not only complicates the proposed mathematical models, but also makes difficult, in some cases completely impossible to use and analyze them. From this point of view, they should be divided into main and second grade factors according to their impact level. Therefore, it should be considered appropriate to the purpose to take into account mostly main factors that characterize operations and processes to build mathematical models.

Key words: machinery, equipment, operation, technology, processing, process, modeling, optimization, management, factor.

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Çoxfaktorlu əməliyyatların və mürəkkəb texnoloji proseslərin modelləşdirliməsi, optimallaşdırılması və idarə edilməsi metodlarının analizi

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Annotasiya

Məqalədə, maşın və avadanlıqların detallarının emalının çoxfaktorlu əməliyyatlarının və mürəkkəb texnoloji proseslərinin modelləşdirliməsi, optimallaşdırılması və idarə edilməsi məsələlərinə baxılmışdır. Müəyyən edilmişdir ki, ayrı-ayrı emal əməliyyatları üçün riyazi modellərin qurulmasının əsas üstün cəhəti, bu modellərdən istifadə etməklə fərqli texnoloji proseslər üçün yeni variantlarda riyazi modellərin yaradılması mümkünlüyüdür. Aydınlaşdırılmışdır ki, maşın və avadanlıqların hazırlanması üçün tətbiq edilən emal əməliyyatlarını və texnoloji prosesləri əks etdirən riyazi modellər, onları xarakterizə edən əsas faktorları nəzərə almalıdır. Tədqiqatlar göstərir ki, ayrı-ayrı emal əməliyyatlarının və texnoloji proseslərin rejim və texnoloji faktorları, hazırlanan detalların dəqiqlik və keyfiyyət göstəriciləri ilə birbaşa əlaqəlidir. Bu faktorların hamısını nəzərə almaq təklif edilən riyazi modelləri mürəkkəbləşdirməklə bərabər, onlardan istifadəni və analizini çətinləşdirir, bəzi hallarda isə tamamilə mümkünsüz edir. Bu baxımdan faktorları təsir səviyyələrinə görə, əsas və ikinci dərəcəli faktorlara ayırmaq lazımdır. Buna görə də riyazi modelləri qurmaq üçün yalnız əməliyyatları və prosesləri daha çox xarakterizə edən əsas faktorların nəzərə alınması məqsədə müvafiq hesab edilməlidir.

Açar sözlər: maşın, avadanlıqlar, əməliyyat, texnologiya, emal, proses, modelləşdirmə, optimallaşdırma, idarəetmə, faktor.

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Анализ методов моделирования и оптимизация управления многофакторными операциями и сложными технологическими процессами

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Аннотация

В статье рассматриваются вопросы моделирования многофакторных операций и сложных технологических процессов обработки деталей машин и оборудований. Установлено, что основное преимущество построения математических моделей для отдельных операций обработки заключается в возможности создания с помощью применения этих моделей новых вариантов математических моделей различных технологических процессов. Математические модели, описывающие операции обработки и технологические процессы, должны учитывать характеризующие их факторы. Исследования показывают, что режимные и технологические факторы отдельных операций обработки и технологических процессов непосредственно связаны с точностными и качественными показателями изготовленных деталей. Использование всех факторов усложняет создание математических моделей иногда делает их неприемлемыми для практического применения. Поэтому для построения математических моделей следует применять те факторы, которые наиболее полно характеризуют операции обработки процессов.

Ключевые слова: машина, оборудование, операция, технология, обработка, процесс, моделирование, моделирование, оптимизация, управление, факторы.

Introduction

Multifactorial technological processes of machine and equipment parts processing differs by their specific features and complexity. These factors manifest themselves first of all in the influence on accuracy and quality indicators of the enameled details of separate operations' different and numerous factors, which are an integral part of technological processes. Most of these factors are usually in interaction with each other, the change of one causes the change of the others, and seriously affect the accuracy and quality indicators of the processed details surfaces.

Thus, arise mutual relation between the factors characterizing operations and accuracy (eg, geometric parameters) and quality (eg, roughness, residual stress, micro hardness) indicators of the processed parts surfaces. These relations put additional technological reliability requirements on processing operations. Although there are large enough data for each processing operation in various researches, the vast majority of them differ by their unsystemacity, characterized by chaotic scattering, and in some cases, can be completely unfit condition to use. Therefore, there occur problems in systematizing such information, in extracting some of them and in storing the most important of them. The solution of these issues can be achieved by the modeling of processing operations and technological processes. Such approach actually means understanding of the investigated operation or technological process through modeling.

In general, the data flow is analyzed in two stages. In the first stage, are compared events occurring in model enameling operations or technological processes. If the difference is not big, then it is considered satisfactory. In the second stage, expectations are compared with the model indicators. This process can be considered as modeling.

Purpose of work is to investigate and research the application of methods for modeling, optimization and management of multifactorial operations and complex technological processes in the processing of machine and equipment parts.

Solving of problem

If we denote all the output parameters of the investigated operation or technological process by y, the input parameters by $x_1, x_2, x_3, \dots, x_n$, then the modeling will be expressed in the form of the following mathematical dependence characterizing the relationship between output and input parameters

$$y = F(x_1, x_2, x_3, \dots, x_n).$$

The form of this function is determined by the characteristics of the investigated operation or technological process. Dependence shown in determined (relatively simple) processing operations is brought to (1) differential equations, and in stochastic (eg, in free abrasive processing) processing operations to statistical probability equations.

It is usually differentiated two types of modeling - physical and mathematical modeling.

It is more expedient conducting experiments directly at research facilities for physical modeling in processing operations of details. So that, the results of experiments can be expressed in the form of physical quantity units, values of geometric parameters, discrete and continuous quantities, linear dimensions, combinations of different quantities, dependencies between complex variables, dimensionless complexes and other forms.

Measureless complexes can be obtained by the help of differential equations or through the measurement theory methods.

Special attention should be paid to the stability of the defining similarity criteria in physical modeling. That is, the experiments should be carried out in several stages, the main factors of processing operations and their values should be changed by certain regularity.

Thus, the formation of physical model takes place in the research object itself (for example, in the processing operation or in the technological process), during the implementation of preparation process of details.

Such approach can play an important role in the modeling of machine or equipment parts processing operations or technological processes.

It is known that the technological processes of details preparation are quite complex systems, consisting of numerous processing operations. Their technological capabilities checking require large-scale experimental research in factory conditions. However, similarity principle and physical modeling can be fully justified in relatively low factor processing operations and in noncomplex technological processes (for example, in low-throughput operations of simple geometric shapes). Because it is enough to take into account a limited number of criteria as the number of technological factors in such situations is small.

Therefore in machine building, it is more appropriate to use mathematical modeling in the modeling of technological processes with a complex structure and in the processing operations of parts having different constructive forms, which are given high accuracy, quality and wear resistance requirements. As a result of the application of this method, it is possible to realize modeling, optimization and management of various processing operations, technological processes and systems using a wide range spectrum of computer technology capabilities.

Mathematical modeling consists of three interrelated stages [1]:

1) Formation of the studied process - construction of a mathematical model (compilation of mathematical explanation);

2) Programming (algorithmization) of the solution of the issue to determine the assigned parameter numerical values;

3) Determining the conformity (adequacy) of the model to the studied process.

The simplification and systematization of the separate operations and technological processes studied during the construction of mathematical models depending on the complexity is one of the important conditions. The obtained schemes are explained by using different mathematical methods, taking into account the characteristics of the studied objects.

The held researches and their results correctness should be assessed by the accurate and correct reflection level of the main characteristics of studied processing operations and technological processes in the mathematical models.

Mathematical models reflecting processing operations and technological processes used to manufacture machine and equipment must take into account the key factors that characterize them. Studies show that the mode and technological factors of separate processing operations and technological processes are directly related to the accuracy and quality of the prepared parts. Taking all these factors into account not only complicates the proposed mathematical models, but also makes difficult, in some cases completely impossible to use and analyze them. From this point of view, they should be divided into main and second grade factors according to their impact level. Therefore, it should be considered appropriate to the purpose to take into account mostly main factors that characterize operations and processes to build mathematical models.

The mathematical description of the model structure can be given in the form of an algebraic or differential equations system, depending on the operation and process. These equations along with reflecting the interaction of different technological factors, should not exclude each other. To determine the type of dependencies which clearly define the relationship between the defined parameters, the sought parameters can be calculated from any set of parameters values of the mathematical expression equations by the help of algorithms.

The most important thing here is that the model expresses qualitative and quantitative indicators of the modeled process quite correctly, ie its full compatibility to the modeled operation or technological process.

It is necessary to compare measurement results performed during operations and processes with the obtained results from the model to verify fully consistence of the mathematical model to the real process.

Models reflecting the processing operations of machine and equipment parts, technological processes of preparation and assembly can be expressed in various mathematical dependencies form. The obtained information as a result of the experiment must be summarized, and the relationship between technological factors and the accuracy and quality indicators obtained as a fulfillment result of operations and technological processes should be determined. Experimental data can also be widely used besides theoretical methods to build mathematical models.

In mathematical modeling, the course of processing operations and technological processes can be studied directly by using mathematical models unlike physical modeling. Application of computer technology is quite effective in this case. For this purpose, it is possible to change factors which characterize separate processing operations and whole technological processes by using different programs, manage details accuracy and quality indicators.

In principle, physical modeling methods of processing operations and technological processes are based on similar mathematical expressions obtained as a mathematical modeling result. Physical modeling methods can be used to determine variation limits of the coefficients obtained as a mathematical modeling result and to determine the suitability (adequacy) of the mathematical models themselves to the studied processes.

Two main aspects should be taken into account depending on the mathematical expression level of the studied processes a) the whole system of equations which express all the main features of the modeled processes and numerical values of these equations parameters are known; b) the process does not have complete mathematical expression.

The second aspect is characteristic to the management of the processes with no available complete information about them and uncertain affecting factors. In most cases, mathematical modeling is more convenient than physical modeling.

It is possible to use mathematical models with similar or identical in form for different

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processing operations and technologics. Expression of different events by similar shaped differential equations can be given as an example to the application of such methods. For example, energy transfer (Newton's law), heat transfer (Fourier's law), mass transfer (Fick's law), and electricity transfer (Ohm's law) laws are identical in writing, but differ in entered parameters (speed, temperature, union, voltage). By entering certain calculation coefficients to each expressions of these laws, it is possible to get unit mathematical model fitting all of them.

Such method can be used to get unit mathematical models that may be useful for different processing operations and technological processes of various details of machine and equipment. Processing of internal, external and side surfaces of cylindrical and conic shaped details on lathes, processing of shown surfaces of these details on internal, external and side polishing machines, creation of mathematical models which can be used for processing of cylindrical and conical surfaces in internal, external, eccentric, rotation honing operations and for other similar operations can be given as an example. Mathematical models can be used for technological processes used in processing of details which have simple and complex constructive parameters consisting of differing each other processing operations [2-5].

Modeling of machine and equipment parts processing operations and whole technological processes in most cases base on optimization principle of their main technological factors to ensure requirements given to the accuracy, quality and wear resistance of the parts surfaces.

The types of mathematical models are selected depending on the machines, devices, processing tools, measuring and control instruments and devices, as well as other ancillary technical means used in the processing operations, performed on the details or technological processes.

If the main factors of detail processing operations or technological processes change simultaneously according to time and in space, the models expressing such operations and processes are called mathematical models parameters of which are distributed. It is more appropriate to present such models in differential equations form.

If the main factors of processing operations and technological processes do not change in space, then, they are called models parameters of which are centralized (collected in one place).

Complex technological processes are used in the preparation of machine and equipment parts, taking into consideration different geometric shapes of their vast majority, high demands on the accuracy and quality indicators of their surfaces, and numerous used operations in their processing. Therefore, it is necessary to divide the processing technological processes of detail into separate operations, and build component models for each of them, which can be included in the overall model of the process.

One of the advantages of mathematical models forming for individual processing operations is the possibility of forming models for new technological processes in different variants by using these models, ie the aggregation of modeling of process

The complete model of the technological processes of details processing should reflect the interaction of the processing operations main factors in predetermined modes or in a certain period of time, as well as during the transition from one mode to another.

In the first case, the model is called static, in the second case dynamic.

The static model does not consider changes of parameters in a certain period of time. Before creating static models of processing technological processes, must be analyzed the physico-mechanical (in some cases physico-chemical) nature of the process itself, the purpose of appointment, responsibilities, basic equations to be expressed and distinguishing features.

Determination of input factors and output parameters of the process arrange the next phase in the modeling of technological processes processing. They include controllable factors, changes of which associated with the nature of the process, changes that directly affect the course of the process (it is possible to measure and purposefully change them), factors that affect the course of the process (it is impossible to change them purposefully), factors changes of which indirectly related to the course of the process (intermediate factors). The relationship among shown factors and the course of the process are determined by boundary conditions [1-4].

Static models of operations and processes should be made taking into account the main technological factors of operations and processes used in the processing of details. Shown belong to the models of assembly technological processes at the same time.

Dynamic models are intended to reflect the dynamic properties of processing operations and technological processes. They are used to determine the relationship between the main factors during the change in a certain period of time. Dynamic properties can be determined by theoretical and experimental methods, or by using both of them together.

Experimental determination of dynamic characteristics is based on accuracy and quality indicators determination obtained as a result of changing of processing operations main factors or technological processes in different ways. The experiments results are analyzed taking into account basic laws and provisions of probability theory, mathematical statistics, information and management theories.

Models of processing operations and technological processes should be built in a transmission function form, the dependence of the processed parts and a whole machine and equipment accuracy and quality indicators on key technological factors. Mathematical models can also be given in the form of ordinary or special derivative differential equations. In such cases, the differential equations must contain in it all dependent and independent factors. Mathematical models of technological processes developed for separate processing operations can be considered as freely usable mathematical models.

Mathematical modeling, optimization and management methods are widely used not only for processing operations and processes, but also in various sphere of industry [6-12].

Conclusion

Complete mathematical models of processing operations and technological processes of machine and equipment details must cover the followings:

- main technological factors of operations and processes, accuracy and quality indicators of processed parts and ready machines and equipment, relationship among key factors in static condition, restrictions put on processing operations and various technological process-

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ses, optimality criteria, optimality functions, relationship among key factors in dynamic situations and so on.

Analysis and research of mathematical models should be carried out by using computer technology in the following sequence to perform processing operations and technological processes in optimal conditions:

- conducting initial reports, modeling of process, optimization of key technological factors, operations and processes management etc.

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