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ANALYSIS OF MATHEMATICAL MODELS USED IN METALWORKING ADAPTIVE CONTROL SYSTEMS

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Abstract
Control algorithms are based on the use of a mathematical model of the control object. The control system, using one of the search algorithms, determines the best control action first on the mathematical model, and then applies the found optimal (in this situation) values of control actions directly on the control objectTo build a mathematical model of the machining process, it is necessary to analytically set a system of technical restrictions for the search area for optimal cutting conditions and express the dependence of the optimality criterion on the elements of cutting conditions. The measured parameters characterizing the cutting process, as a rule, are cutting force, vibration, temperature in the cutting zone, torque Mcr on the spindle,drive power of the main engine, etc.Such a customizable model can be used not only for control purposes, but also, for example, in diagnostic tasks, acting as a sensor of parametric disturbances and informing about the parameters going beyond safe limits. At the same time, the use of a customizable model in the control loop also leads directly to an increase in the reliability of the system in relation to less flexible controllers with fixed parameters.Thus, the solution of problems of building control systems is closely related to the development of algorithms for adapting the model in real time, the use and study of the speed and noise immunity of such algorithms.

Keywords: Algorithm, CNC, adaptive, processing, model, efficient, spindle, machine tool

Introduction

The problem of increasing the efficiency of metalworking has been and remains one of the most important problems. The annual production volume of mechanical engineering is the output of mass-produced mechanical engineering products. Machine tools for processing parts, in which the main technological process is the cutting process, and digital control systems are digital software systems. Control (CNC). Therefore, increasing the efficiency and productivity of the cutting process is a scientific and technical task. The complexity of solving the problem is due to the fact that it is characterized by the cutting process. Production depends on many influencing variables that influence the progress of the process. In addition, its results are dynamically random due to the cutting process, which is influenced by cutting forces. the influence of various factors affecting per part: change in dimensions, change in hardness and change in surface flatness, structure of the workpiece, constantly changing cutting characteristics of the cutting tool, etc. Without taking these factors into account, the CNC program performs cutting modes according to the parameters specified by a person and automatically moves at a given speed. In order for the cutting tool to work for a long time, it is necessary to select cutting modes taking into account the internal stress of the part and reduce the likelihood of defects, which leads to both a decrease and to an increase in production costs.

Main Part

A study of literary sources gives grounds to assert that the use of adaptive control systems is a very promising way to solve problems of quickly searching for optimal cutting modes based on the criteria of accuracy, quality, productivity, costs and dynamic adjustment of these modes depending on processing conditions. It is obvious that equipping existing CNC machines with adaptive systems significantly increases their capabilities.

The basis for constructing a control system is a mathematical model of a controlled processing process, and a mathematical model is required when constructing a control system both on the basis of classical control theory and using modern adaptive and optimal control technologies. The mathematical model is a set of optimality criteria and technical limitations [1]. Technical limitations are set taking into account the condition and design of the machine, the shape and accuracy of the part, the design of the cutting tool and other initial data. The main technical limitations include the strength and rigidity of the tool and machine devices, the drive power of the main movement, the clamping force of the part, thermal deformation of the part and the tool, etc.

Control algorithms are based on the use of a mathematical model of the control object. The control system, using one of the search algorithms, determines the best control action first on a mathematical model, and then applies the found optimal (in a given situation) values of control actions directly to the control object.

To construct a mathematical model of the machining process, it is necessary to analytically set a system of technical restrictions on the search area for optimal cutting modes and express the dependence of the optimality criterion on the elements of cutting modes. The measured parameters characterizing the cutting process, as a rule, are cutting force, vibration, temperature in the cutting zone, torque Mcr on the spindle, main engine drive power, etc.

An analysis of literature sources has shown that the most serious problem facing modern adaptive control systems and hindering the widespread use of automated control systems in metalworking is the lack of mathematical models of the cutting process. Mathematical modeling is implemented largely based on the assumption that the system is linear and therefore may not reflect its actual physical properties. Even if it is possible to construct complex mathematical models that accurately reflect the physical relationships between input and output, they may not be useful for control purposes. Models with low sensitivity in terms of parameters may be practically acceptable, which is quite difficult to achieve for nonlinear systems [2].

Statistical methods for analyzing technological objects, such as correlation and regression analysis, have become widespread [3]. Statistical models (autoregressive model, autoregressive-moving average model, crystal lattice model, etc.) are simple and can be checked for adequacy using spectral analysis and study of frequency characteristics. This statistical approach to solving metalworking control problems may seem very effective, but the approximations used are not sufficiently accurate for control purposes. Attempts to adapt linear models to the complex nonlinear system “Machine - cutting process” lead to a loss of accuracy. In addition, the parameters of such models may in some cases have no physical meaning. Thus, statistical models are also not without shortcomings. Currently, due to ease of implementation, simulation models based on empirical power-law relationships are used:

$$P_{x,y,z} = C_{P\,x,y,z} v^n s^y t^x K_p \qquad (1)$$

$$v = \frac{C_v}{T^m t^x s^y} \cdot K_v \qquad (2)$$

Where K p, K y - correction factors depending on the material being processed. These models are a fairly simplified simulation of the cutting process, do not take into account the changing conditions of the process (disturbances) and do not have sufficient accuracy. The effectiveness of the control system largely depends on the accuracy of the mathematical model. Thus, the main task of studying the control object becomes the construction of a model that has the smallest possible error.

Building accurate models is a difficult task. To determine an accurate mathematical model of an object, it is necessary to carry out more than one series of experiments that require time and materials, which will entail economic losses. Typically, such experiments are carried out before starting up the equipment. But the found mathematical model will have an ever-increasing error due to changes in operating modes and properties of the equipment itself. The accumulation of errors will lead to loss of performance and transition to an unstable mode. Therefore, it is necessary to adapt the model to such changes, that is, adjust the model while the system is operating.

Such a customizable model can be used not only for control purposes, but also, for example, in diagnostic tasks, acting as a sensor of parametric disturbances and informing about parameters going beyond safe limits. At the same time, the use of a customizable model in the control loop directly leads to an increase in the reliability of the system in relation to less flexible controllers with fixed parameters.

Thus, solving problems of constructing control systems is closely related to the development of real-time model adaptation algorithms, the use and study of the performance and noise immunity of such algorithms.

The introduction of an autonomous unit (identifier) into the block diagram of the control system highlighted the theory of identification as an independent direction. The identification approach, that is, the use in the control law of their calculated estimates instead of the unknown parameters of the object and the disturbance channel, has a wide range of applications in the control of technological processes [4].

The models used must meet the following requirements:

1.Have the ability to learn, flexibility, nonlinearity.
2. Be consistent with experimental data and a priori information.
3.Be realizable by modern computing means.
4. Allow algorithmic implementation adapted to the conditions of real-time information processing.
5.Have the ability to learn, flexibility, non-linearity.
6.Meet the requirements for speed and noise immunity.

The relevance of the problem is explained, first of all, by the complexity of such technological systems, such as the “Machine-cutting process,” which is characterized by significant nonlinear characteristics, a significant number of parameters that determine the course of the cutting process, a large number of internal connections between parameters and the occurrence of feedback between parameters that change the course of the cutting process.

Conclusion

The need to adjust the model due to continuously changing process parameters and determine the structure of the model in each specific case gives rise to research in the field of self-adjusting models. Self-organizing neural network models can significantly facilitate the process of building adaptive systems for metalworking management purposes. The use of neural network models significantly simplifies the modeling process, and this will not affect the final results, but, on the contrary, will allow solving the problem using methods that were previously unavailable. The main advantage of modeling based on neural networks is the ability of the network to construct any mappings X -» Г (where Y has an arbitrary dimension) with any given accuracy, and also to learn from examples of real data. This approach opens up broad prospects in the management of objects whose intrasystem connections are difficult or impossible to describe by linear dependencies.

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