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RESEARCH ON OPTIMAL CONTROL IN MACHINING THROUGH THE CUTTING PROCESS

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ABSTRACT

In general, the optimal control of the cutting process is based on models with the help of which are determined the optimal values of the cutting process parameters, values that are kept constant throughout the machining process, although there are findings that highlight significant changes in the mathematical models that describe the process. Improved dimensional process monitoring systems have appeared, which also include the possibility of monitoring tool wear. The market success of the product is only qualitatively evaluated and used for controlling the machining processes. The list of monitored parameters of the system will have to include the machining error, surface roughness and tool wear rate.

KEYWORDS: cutting process, control, optimal, machining process

1. INTRODUCTION

The technological cutting process is the process of generating surfaces by chip removal. It is the basis for the construction of machine tools, machines that generate surfaces by removing the machining allowance. The removal is performed through a well-defined movement by the cutting edge of a cutting tool that moves relative to the processed piece [4].

The cutting edge of the cutting tool creates a new surface during its relative movement relative to the processed piece.

In the cutting zone a complex state of stresses and deformations is produced. Figure 1 presents a simplified scheme of the cutting process. The force P generated by the machine tool through the cutting tool is capable of overcoming the resistances that arise in the material to be processed [4].

The monitored parameters during the machining processes are the following:
- cutting regime parameters: *v* (cutting speed), *s* (cutting feed), *t* (cutting depth);
- the position of the tool subassembly at a given time (in the case of numerical control);
- the actual size of the machined surface;
- surface roughness;
- static and dynamic stability of the machining process;
- cutting force;
- temperature in the cutting zone;
- cutting power.

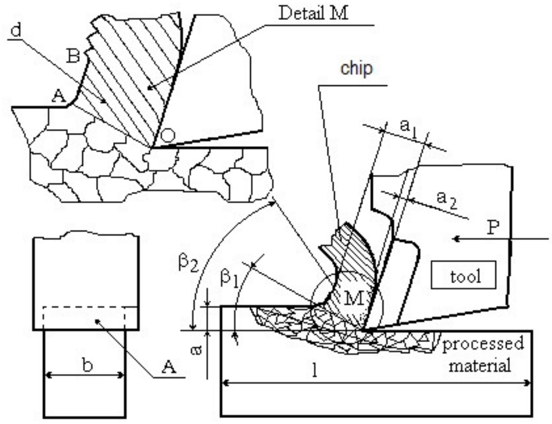

Figure 1 Simplified scheme of the cutting process

The following techniques are used to monitor the parameters or performance indicators of the manufacturing process:
- for the position of the tool subassembly, is used transducers system of machining with numerical control;
- for the measurement of the machining error, dimensional control instruments are used;
- for temperature measurement, the natural thermocouple tool-work piece, the thermal radiation of the manufactured surface or thermometers placed at different points of the technological system are used.

Monitoring is performed at long time intervals (for example, after complete machining of the surface or after a pass applied to the surface).

In some cases of "on-line" monitoring, the interpretation of the results is the same as in the case of "off-line" monitoring (for example, when grinding a surface, its size is measured by active control, but the information resulted from the monitoring is only the extreme value of the size resulting from measuring the surface in different areas of it).

Even when both the measurements and the interpretation of the results are done "on-line" (continuously), the result is used only to maintain a process parameter constant and not to recalculate its optimal value (for example, the "on-line" measurement of the cutting force has as a consequence the permanent modification of the cutting feed so that the cutting force is constant) [1], [2], [3], [4].

2. CHARACTERISTICS OF CONVENTIONAL CONTROL OF THE CUTTING PROCESS

The conventional control of the cutting process is characterized by the fact that the process model remains unchanged and the result of management represents the necessary values of the process parameters.

The values of the process parameters are established and kept constant during the process. For example, the following are kept constant: the cutting regime, the geometry of the cutting tool, the processed material and the characteristics of the technological system. Sometimes, instead of the cutting parameters v, s and t are kept constant the values of cutting speed, cutting force and feed and sometimes are kept constant the cutting speed, cutting power and cutting depth. Therefore, among the process parameters is selected a set of independent parameters , whose values are maintained constant during the cutting process. The set values of the cutting process parameters (which are kept constant) are calculated based on general mathematical models, which are used to control any process.

As a result of the multitude of random factors, some of them undetermined directly, in order to understand the cutting process a complex mathematical model will have to be adopted, but elastic in terms of the domain of variation of the process parameters in based on which to be established an operational algorithm on the computing from the modern lathes (microprocessors). Adopting such an operational mathematical model largely solves the knowledge of the cutting process. In order to manage this process, it is necessary to optimize the process parameters - which is done based on one of the three most important criteria: minimum cost price, maximum cutting capacity or maximum durability of the cutting tool, depending on the type of production within the lines and flexible technological systems.

Viewed through the lens of this great goal, the mathematical models describing the cutting process present essential shortcomings but also some noteworthy information:

1. The application of any optimization theory results in obtaining certain correlations, usually between two of the three cutting parameters whose values, in general, exceed the limits imposed by certain restrictions and which do not take into account the number of cutting passes and idle movements.
2. A minimum number of cutting passes is generally recommended, a solution that does not always ensure precision or is not economical, although it ensures minimal time machining.
3. Auxiliary movements, especially those related to idle movements, are not studied with optimization, although they have a significant share in the economy of the operation.
4. In general, and especially in finishing turning with tools reinforced with carbide or ceramic inserts, it is economically advantageous to increase the feed rate at the expense of the depth of cut.
5. The majority of known optimization methods do not treat the operation as a whole, but only certain phases of it, so the results obtained do not correspond to practical realities.
6. The concept of durability used in the development of optimization theories does not correspond to the tool wear rate and is inoperative in automated calculations.

3. ADAPTIVE-OPTIMAL CONTROL OF THE MACHINING PROCESS

The objective of optimal control is not to obtain imposed values of performance indicators, but to obtain their most favorable values.

The values of the parameters corresponding to the most favorable values of the performance indicators are called optimal values.

Adaptive-optimal control involves re-identifying the machining process, and the resulting model is used to calculate the optimal values of the process parameters. Optimal control is based on the dependence of technical and economic indicators of the process parameters.

Characteristic of the technical performance indicators is that their dependence on the values of the process parameters has a limiting character, which leads to one of the following conclusions: adequate or inadequate. Therefore, they can serve as restrictions in the optimization problem.

Economic indicators have a continuous dependence on process parameters and are therefore used as objective functions.

Adaptive control systems proposed by manufacturers and research companies in the field of cutting on machine tools start from certain initial values, usually introduced through programming.

Regardless of the number of cutting process parameters their values are established by technological preparation previous to the start of machining. Such an adaptive control approach simplifies the work of the technologist and the programmer to an insufficient degree, only succeeding in a research of reference parameters established most often arbitrarily or in conditions of insufficient and real knowledge of the cutting phenomenon.

Worldwide trends start from the fact that, the machine tool being the heart of any processing system, its placement at the center of researchers' attention is fully justified, especially since it also represents the most conservative component - compared, for example, to the computer industry - the most expensive.

From the study of the results of researchers in the cutting field, from Europe, America and Asia, presented at various international conferences, it is found that the trend is to move from the description of phenomena during material cutting to their prediction [1], [2], [3], [4], [5].

The most intense research's aims at:

- New methods for machining materials with superior characteristics using tools with inserts ceramic, cubic boron nitride or diamond and high cutting speed machine tools;
- Investigations of chip formation and monitoring of the cutting zone;
- Modeling and simulation of machining processes;
- Automatic acquisition and processing of cutting data for the development of systematic databases;
- Monitoring of cutting forces, temperature and tool wear rate;
- Precision machining at high speeds in the control regime and automatic process evaluation;
- Development of practical recommendations for the choice of cutting parameters in integrated manufacturing.

Technological systems sometimes evolve rapidly over time and in the workspace, which highlights the usefulness of adaptive control. This is most clearly seen in the dimensional control of the machining process.

The optimal control is based on fixed models, with the help of which the optimal values of the process parameters are determined, values that are kept constant throughout the machining process, although there are findings that highlight significant changes in the mathematical models that describe the process. Improved dimensional process monitoring systems have appeared, which also include the possibility of monitoring tool wear. The market success of the product is only qualitatively evaluated and used for controlling the machining processes. The list of monitored parameters of the system should include the machining error, surface roughness and tool wear rate.

The control of machining processes involves establishing the parameters that characterize the state of the process and these are:

- the cutting regime parameters, which represent the totality of the state parameters that define the interaction between the tool and workpiece to be processed by cutting;
- the geometric parameters of the tool, which result by relating the geometry of the tool to a set of measurement norms related to the functional role of the tool;
- parameters relating to the tool material, which are intrinsically linked to the structure of the material;
- parameters relating to the processed material, which are linked to the physical - chemical properties of the material, properties that determine its machinability;
- cutting force, which represents the mechanical interaction between the machining tool and the material to be processed;
- the temperature in the cutting zone or the thermal field, which is a measure of the molecular thermal agitation in the elements that interact during cutting;
- the level of vibrations of the technological system, which is a resultant of the system components stress, with a negative influence on the quality of the machined parts and the wear resistance of the cutting tool.

A part of the parameters are modified "off-line" and remain constant for a longer period of time (for example tool geometry, tool material, workpiece material) and another part of the parameters changes during machining (speed, depth, feed cutting) and in this way the process is controlled.

Parameters are input quantities into the process. Output quantities from the process will be called performance indicators, fig.2.

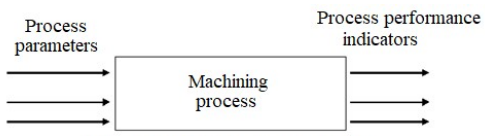

Figure 2 Machining process scheme

In the case of the cutting process, the performance indicators are:

- machining precision, which represents the extent to which the dimensions, shape and position of the obtained surface fit within the technical specifications;
- surface quality, which represents a complex of geometric and structural characteristics of the obtained surface;
- the cost of the processing process, which represents the ratio between the sum of the total expenses related to a processing operation and the volume of detached chips;
- technological productivity, which represents the ratio between the volume of chips detached in the

machining process and the total working time required for chip detachment;
- process stability, which represents the system's ability to return to its initial state after suffering a disturbance that removed it from this state;
- the profit rate, which is the difference between the selling price of the product and the manufacturing costs.

Controlling a process means establishing the set of parameter values, so that the indicators have the expected values.

For management, it is necessary to have both the processing process model, i.e. the relationships between performance indicators and process parameters, and a monitoring system, which ensures the measurement of quantities that characterize performance indicators ("on–line" and "off–line").

Knowing the values of the monitored quantities and the processing process model, the necessary values of the processing process parameters are determined.

4. CONCLUSION

From the analysis of current solutions, both applied and proposed, for adaptive or optimal control of machining processes, the following conclusions can be drawn:

a) the optimization of cutting processes is achieved by calculating the optimal values of its parameters in the design stage of the technological process, following that these being set and maintained at a constant value during the machining process;

b) the modification of parameter values occurs over long periods of time and does not lead to the extremization of the performance indicators for the completed machining process;

c) when monitoring is done "on-line", the information obtained is used with a delay and not for process optimization, but for maintaining constant or limiting the values of some of the parameters;

d) the mathematical models used to calculate the optimal values of the parameters are general and not the resulted of identifying the real processing process or the technological system actually used to perform the processing;

e) the technological process optimization algorithm does not take into account the market success of the product and neither the real characteristics of each processed piece;

f) adaptive control, based on the re-identification of the ensemble of the technological system- machining process is not achieved to the currently available technological systems;

g) there are only successful experimental trials that demonstrate the possibility of significantly increasing machining accuracy through adaptive dimensional control;

h) the monitoring techniques of the process parameters are not sufficiently efficient in terms of tool wear and temperature in the cutting zone;

i) attempts to identify the cutting process or technological system only take into account the "off-line" manner of achieving the identification;

j) it is found that through current techniques for control of the machining processes, the real values of the parameters are far from the optimal ones, which shows that there are enough reserves to increase the performance indicators of the process through better control and without significant additional expenses.

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