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ADAPTIVE - OPTIMAL CONTROL OF THE CUTTING PROCESS

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ABSTRACT

Adaptive-optimal control involves re-identification of the machining process and the model obtained is used to calculate the optimal process parameters.
Optimal control characterizes the addiction of the technical and economic indicators to process parameters. Characteristic for performance technical indicators is that their dependence to parameter values of process has a limitative character, which leads to one of the following conclusions, appropriately or inappropriately, and therefore can serve as restrictions in optimization problem.
Economic indicators have a continuous dependence of process parameters and therefore they are used as objective functions.

KEYWORDS: manufacturing system, adaptive-optimal control, cutting process

1. MONITORING OF THE CUTTING PROCESS

During the cutting process, the monitored sizes are the following:
- cutting regime parameters
- processing error
- position of the tool subassembly at a time (CNC machine)
- the actual size of the processed surface
- surface roughness
- static and dynamic stability of the cutting process
- cutting force
- temperature of the cutting area
- cutting power.

For monitoring parameters or the performance indicators of the manufacturing process the following techniques are used:
- for position of the cutting-tool subassembly is used the transducers system of CNC machine;
- for measuring the processing error are used dimensional inspection tools;
- for the cutting force are used transducers attached at the subassembly of the tool or piece;
- for temperature measurement are used the natural thermocouple (tool-piece) or thermal radiation of the machined surface.

Monitoring is carried out at large intervals. In cases where monitoring is done online, the interpretation of monitoring results is the same as for offline monitoring. Even when both the measurement and interpretation of results are on-line (continuous), the result is used to maintain constant parameters of the process and not to recalculate its optimum value.

2. CHARACTERISTICS OF CONVENTIONAL CONTROL

It is characterized by the fact that the model of the process remains unchanged and the result of the management represents necessary values of the process parameters. Values of the process parameters are set before and held constant during the development of process. For example, remain constant the cutting regime, geometry of the cutting tool, processing material and features of the technological system.

Sometimes instead of the parameters v, s, t of the regime of cutting, the values of cutting speed, force and feed rate of cutting are maintained constant, and other times are maintained constant the speed, power and depth of cutting. So, from the process parameters is selected an independent set of parameters whose values are held constant during the process. Selected values of process parameters (which are held constant) is calculated on the basis of general mathematical models that are used in the management of any process. For example, speed cutting is determined depending on the tool durability, feed rate of cutting is determined depending on the roughness of the required surface, the depth of cutting is determined depending on the size of the performed and achieved size, the geometry of the tool is determined depending on the geometrical features of the processed surface.

Dimensional control in conventional regime is characterized by:

- off-line measurement of surface dimensions processed;
- the change the position of the tool relative to the materials just after the surface has been generated completely;
- even when dimension measuring is done online, change of the position of the tool relative to the material is made after the surface has been generated completely.

3. DISADVANTAGES OF THE CONVENTIONAL CONTROL

Basically, it is found that processing system evolves in time and space, making as a model, valid at a time and in a certain place, not to be suitable at another time and in another place. Other disadvantages would be:
- it does not take into account the characteristics of each specimen processed;
- it does not take into account errors of the technological system;
- there is no forecast on the evolution of the system in time and space.

4. OPTIMAL CONTROL OF THE MACHINING PROCESS

Optimal control in conventional regime is characterized in that:
- determining the optimal parameter values is based on general mathematical models applied in all particular cases encountered;
- the optimization criterion is the cost or productivity;
- the restrictions from the problem of the optimization are given by the limitations imposed by the technical indicators of performance of the process, such as minimum and maximum speed of the principal axle of the machine-tool, the minimum and maximum value of the feed rate, the maximum power of the motor drive, the maximum roughness of the surface ;
- the geometry of the tool is determined based on general qualitative indications;
- overcoming restrictions initially considered is ascertained after the processing occurrs;
- the monitoring of the performance indicators of the process is not done, but only that of the inputs in the process.

The objective of the optimal control is not getting imposed values of performance indicators, but getting the most favorable values of them. The parameter values corresponding to the most favorable performance indicator values are called optimal values.

Adaptive-optimal control involves re-identification of the machining process and the model obtained is used to calculate the optimal process parameters.

Optimal control characterizes the addiction of the technical and economic indicators to process parameters. Characteristic for performance technical indicators is that their dependence on the parameter values of the process has a limitative, which leads to one of the following conclusions, appropriately or inappropriately, and therefore can serve as restrictions in optimization problem.

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

5. STRATEGIES FOR OPTIMAL MANAGEMENT OF MANUFACTURING PROCESS

To achieve various optimization criteria and, sometimes, to achieve such concomitant criteria, it uses different strategies. So,

A) in order to obtain high productivity, the following strategies are used:

a) feed rate strategy adapted to the cutting path - in which the processing time is reduced by a cutting operation along the cutting direction with minimum force and a reduced error and maximizing the advance speed;

b) selection of process parameters (feed rate, cutting depth, cutting speed) can have significant influence on system performance on productivity;

c) another piece of work [1] analyzes productivity and the problem of the preventive control maintenance for a manufacturing system on a machine-tool that processes multiple tracks simultaneously. The objective of such a study is to determine productivity and ensure a continuous supply of the machine-tool so that the total costs will be minimal.

In the work [5] the author refers to the fact that adjusting the cutting forces leads to significant economic benefits by increasing productivity and improving quality operations. This is a challenge since the variation of the forces varies significantly in cutting normal conditions. The controllers cannot guarantee system performance and stability since the force varies and substantial research effort was conducted to develop an adaptive controller. Consequently, in industry this technology it is applied in a reduced manner

B): to get a surface with a good quality it is used:

a) - the surface control strategy in which processing errors are minimized by using an offset control of the surface, based on a prediction of the processing error ;

b) - [1] presents an optimization model in terms of selection parameters of the machine tools that lead to a certain amount of material removed for a certain quality of surface and a certain durability of the cutting tools. The interpretation is based on the models presented by [2] to predict the surface roughness, the maximum temperature cutting, distribution of the residual stress on the processing surface and use of the parameters of the machine-tool and of the cutting conditions. The numerical results demonstrate that the procedure can be considered as an advantage used to specify variations of the machine-tool for developing the data base of the variables of the machine. This unified model is proposed to represent the strategy for a adaptive control system of the machine-tool process. In conclusion, this computerized procedure is presented to illustrate the potential of the car planning by determining the optimum parameters that maximize material removal rate to achieve the desired parameters of the surface. The procedure takes into account the limits and plastic deformations of the tool. An interesting result of this study is that the increasing of the compressive residual stress limits desired reduces the optimum value of the cutting speed and obviously the rate of the reduction of material removed. This is because the cutting speed generates fractional heat and residual gradient produces residual stresses in the surface of the part [6]. This work describes a unified optimization model that takes into account the integrity of the surface and stability of the tool and it was based on physical relations of the processes of the machine. Model and simulated results can be applied in the development of the decision basic data for adaptive control of the machining process.

c) Another approach in terms of optimization is done in [1]. In this paper it is studied an algorithm based on optimizing stimulated and Hooke-Jeeves search model is developed to optimize cutting operations in multiple passes. Machine parameters are determined to optimize conditions and cost minimization per unit of product, taking into account certain limitations. The results of experiments demonstrate that the optimization algorithm for nonlinear limitations, called SA / PS, is effective for solving complex optimization problems.

The algorithm SA / PS can be inserted into a CAPP system for generating optimum parameters of the machine-tool. In this paper it was presented a cutting operation with multiple passes and a hybrid procedure based on simulation algorithm of the normalization and SA / PS for search was applied to the problem of optimizing machine tool. The algorithm SA / PS can achieve a non-linear solution in an extremely rare spatial solution compared with the notion of time. The effectiveness of this algorithm was demonstrated by a base experiment.

C) o achieve two goals simultaneously:

a) proposed strategies to improve productivity when conditions generated by cutting force and certain dimensional limitations. This strategy proposes a new processing aid, namely drawing a map of the maximum feed rates. In this map, the maximum permitted feed rate, depending on the required limitations, every checkpoint along the direction of processing are determined using a generating model of the surface. With this help, a part of the program is able to select a optimum cutting direction and a feed rate to reduce processing time. The strategy consists of three modules:

1 - selection of the control point;

2 - map of maximum feed speed;

3 - feed rate. So:

- checkpoints are selected on the control surfaces. A number of points is selected depending on the imposed accuracy and density can vary. For each geometric point, cutting force and error of the processing are evaluated in sub-modules;
- The main goal is getting the feed rate map for surfaces control;
- The map reflects important information for choosing and selecting cutting speed. So, the processing time can be significantly reduced when surface processing, cutting forces and dimensional accuracy can be controlled using the proposed strategy.

b) A system type map is proposed in [3], too. This article proposes an algorithm for designing a control system of maps which consists of several separate maps, each of them is used to monitor the stage of a critical process from processing of a product. The algorithm consists of all maps integrated into an integrated system. Thus, the performance characteristics of a system as a whole can be significantly improved and product quality can be increased. One such improvement is achieved without additional costs or too much effort. Furthermore, operators can easily analyze, depending on the maps that are displayed on the display, the current situation at the some point.

D) To maximize profits:

a) The strategy is an optimization function from the point of view of geometrical quality, of productivity, of system and cost. Geometric quality of the product is modeled as a set of functions based on the general propagation of the model variation, the productivity being a function of the processing and the cost, represents the sum of cost of production and the quality cost. Solving optimization problem leads to the determination of the best parameters of price and tolerance. The researchers followed a specific target for optimal demonstration character of the processing. It may list a number of ways for determining:

- monitoring the durability of cutting and cutting tool;
- monitoring of the cutting process and the durability of tool cutting;

The determination of an optimal algorithm for the evaluation of process parameters;

- By looking for certain types of cutting tools;
- By monitoring tool wear;
- The determination of the parameters of the machine-tool.

The differences come from the definition of optimization criteria, the online and off-line character of the process, of the adaptive character or not of the algorithm.

Regarding the optimization of cutting in multiple passes, which imposed certain restrictions, [5] we consider that the operation in one pass is not always the most economical and productive in terms of restrictions and demonstrates that cutting process in two or three passes may be cheaper or shorter in terms of time spent.

Optimization is determined by the combination of the geometric and linear programming. The operation in one pass is optimum if it is limited only to reaching the highest speed possible - which is not a general requirement. Most common are the situations where restrictions are related to cutting force, of a certain roughness of surface, the durability of cutting tool and cutting speed.

In the last case, two or three passes may be more economical and can be performed in a shorter time than the processing operation.

c) In the work [6] we studied the optimal control of material removal rate to achieve a optimal rate of cutting of a cutting tool so as to be able to achieve maximum profit. This paper focuses not only on the rate of material which is removed in the manufacturing process, integrated in mathematical formulas as objective functions, but it implements the calculation of the variables to control the cutting rate.

E). Ensuring a longer durability of the cutting tool

a) In [7] is presented a statistical model that uses the idea taken from the rehabilitation theory and statistical control of quality. The model is based on Taylor's equation so that information can be used relative to the existing relations between the cutting data and cutting tool durability.

b) Another study which is based on the cutting parameters optimization is studied for increase of durability tool. Improving sustainability is essential in order to reduce production costs as much as possible. The tools have a limited durability, which is why we need to find ways to increase the sustainability and critical process parameters cutting. Cutting tools deteriorates either through gradual wear of the cutting edge or due to plastic deformation to which they are subject. Usually, criteria for establishing sustainability are established as predetermined values. Obviously, any development will lead to an increase in durability. The paper [4] shows the influence of the variation of speed on the durability when cutting. The paper [2] proposes a new equation for durability.

d) Another study is achieved by [5] which shows that in the series production it uses the same cutting tool for cutting the different parts having different cutting parameters. In such a case, the optimal moments are those when tools need to be changed when they reach the minimal production cost and a maximum rate of productivity. This paper analyzes the status of the processed surface and material waste from cutting tool using an algorithm of processing / analyzing and micro-optical images.

F) Minimize production costs

Such a strategy is presented in [5] which proposed a model of cutting in multiple passes. Using Lagrange method, cutting optimal time for each cutting tool is stored and the cost due Lagrange multiplier is multiplied.

5. CONCLUSIONS

Analyzing the current solutions for optimal or adaptive control of machining processes, the following conclusions are to be drawn:

- optimization of cutting is done by calculating the optimal parameters in its design stage of the technological process, following that they will be set and maintained at a constant value throughout the processing process.
- changing the parameter values is achieved over long periods and does not lead to the desired performance indicators;
- when monitoring is done online, the information obtained is used to delay and not for process optimization but for keeping constant or limiting values of some parameters.
- the mathematical models used to calculate the optimal parameters are generated and not resulted from the identification of real machining process or of the technological system used to achieve processing;
- the optimization algorithm of the technological process take into account neither the market success of the product nor neither actual characteristics of each processed piece.
- adaptive management system based on identification of the technological system-manufacturing process is not done currently at the available technological systems
- it finds that, through the current control techniques of management process, real values of parameters are not optimal, which shows that there are enough reserves to increase performance indicators of the process through better management and without significant additional costs.

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