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MATHEMATICAL MODEL OF TECHNOLOGICAL PROCESSES WITH PREDICTION OF OPERATING DETERMINING VALUE

Abstract:
The paper desribes a development of a new approach to simulation of dimensional wear of cutting tool with subsequent element of correction in limits of parametrically given optimal shifts. The articel describes aspect belonging to polynomic transformation of experimentally given discrete values of knife point position and their subsequent integrity into continuous funtional form compatibile with used software.

Keywords:
optical scanner, turning, approximation, regulation, monitoring

INTRODUCTION

Present could be characterized as the time of ever increasing requirements and demands for automated production facility. New principles and technologies are preferred especially in the area of supervision, regulation and control. In the area of machining are particularly addressed issues of measurement and correction of dimensional wear of cutting tool. The analysis of literary sources shows, that, because of application in the operating conditions, it is necessary to focus on indirect methods of active supervision, among which a perspective method seems to be the method of detection of blunting of cutting tools from changes of workpiece dimensions. But the geometry of a lathe blade changes in the course of usage because of wear. Wear is the loss of the original geometric shape of a cutting wedge. It may also be connected with the change of mechanical properties. The resulting dimensional wear of the cutting tool can be corrected by corrective movement of the lathe blade towards the workpiece by amount of wear. A sensor measures dimensions of a workpiece and the measured values are gradually feed into an evaluation device [2].

DESCRIPTION OF EXPERIMENTAL MEASURING PRINCIPLE

Measuring of dimensional wear of a cutting tool using a temperature sensor was developed on the basis of so far known very good properties of temperature sensors verified by measuring. From these results, that temperature sensors working with the change of heat output have dependence characteristics between the heat output Φ of the scanned part and electrical resistance. The method of dimensional wear measuring of cutting tools is significant for the fact, that during blunting of a knife there is increase in cutting force and thus increase in the creation of heat during lathe-turning. The Sensor *consists of a temperature-dependent resistor placed on the lathe blade. Position of the sensor on the blade constant to preserve the value of time constant τ , which is needed for further calculations. Amount of stabilized temperature during lathe-turning provides the information about tool wear. For a given type of an instrument it is necessary to measure the dependence of temperature on wear; measuring during operation is reliable, when the same parameters are ensured, particularly the preservation of the approximate hardness of machined materials. This measurement principle considers only static parameters; a dynamic system is being developed, with successful test results so far [1].*

PROCESS AND CONDITIONS OF EXPERIMENTAL SIMULATION

Modelling of the system ran discretely with sampling with a specific frequency. During the simulation, a maximum limit value of the temperature, which the knife would reach if the rise or fall in temperature followed the same trend, is calculated from two immediate values of measured temperature. Since the curve of dependence of blade wear on the temperature during lathe-turning is measured continuously, the temperature has continuous course as well. In practical machining, however, there often are interruptions of the process. As a result, the temperature value sharply changes. During a longer interruption of machining the temperature drops to ambient temperature value (in the simulation it is the value of 23 ° C) and several minutes can pass from the start of machining until relative stabilization of the temperature. Therefore, if the determination of tool wear was based on only one immediate temperature value, it would cause great inaccuracy in the determination of tool wear. Since the rise and drop in body temperature is a phenomenon that can be expressed mathematically, it is possible to determine a fixed value that we need to know from two consecutive temperature values.

It is possible to express the phenomenon in question by static system differential equation with delay of 1st degree. The general form of this equation is as follows:

$$J\frac{dx}{dt} + x = ky \qquad (1)$$

where x is a variable and J is a constant [3].

The course of increasing temperature in dependence on time is expresses by the formula (2):

$$T_1 = T_N.\left(1 - e^{-\frac{t_1}{\tau}}\right) \quad and \quad T_2 = T_N.\left(1 - e^{-\frac{t_2}{\tau}}\right) \qquad (2)$$

where:

T_N is the limit temperature value in measurement point, which can the cutting tool reach, if the temperature in the spot of cut don't change

T – immediate temperature in the measurement point

t – time of temperature value detection,

τ - time constant.

The time constant is a constant value for the given cutting tool and measurement point. It is necessary to know maximum trend value of temperature in each point for the correctness of measuring. For that it is necessary to measure the temperature of two consecutive measurement points t1, t_2:

Since after expression t_1 and t_2 the difference $\Delta t = t_2 - t_1$ is a known value, it is possible to express T_N as follows:

$$T_N = \frac{T_1 - T_2.e^{\frac{\Delta t}{\tau}}}{1 - e^{\frac{\Delta t}{\tau}}} \qquad (3)$$

This expression allows to determine the limit value of temperature in every point of measurement on the basis of known variables, and to accelerate the determination of the immediate value of cutting tool wear.

The simulation of given expression was conducted using simulation model shown in Fig. 1.

In Fig. 1 is the block scheme of the simulation model necessary for the process of determination of predictive limit value of dynamically changing temperature in actual operation. The model contains an experimental generator of temperature course with the possibility to set individual parameters. Another part consists of the block realisation of mathematic function for the calculation of limit *temperature. Since it is necessary to use two temperature samples in the formula, the second sample is defined on the basis of delay, but in the real time of process simulation. An appropriate element was a discrete delay block, output course of which is shown in Fig. 2.*

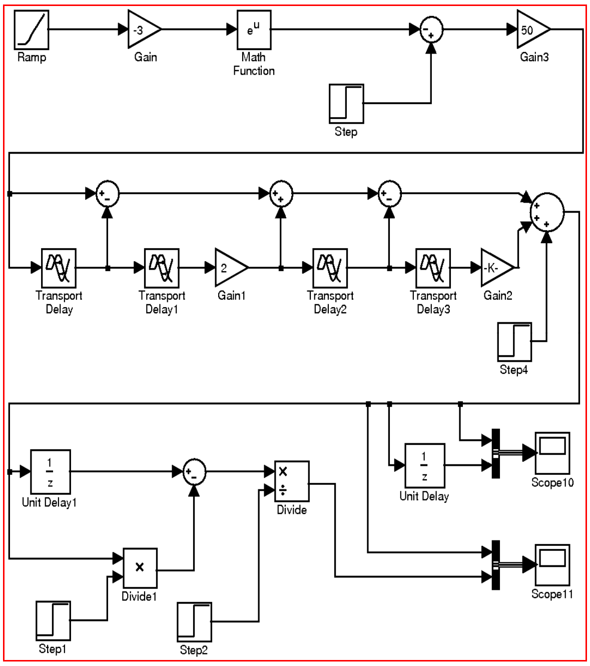

Fig. 1 Simulation model of determination of predictive limit temperature.

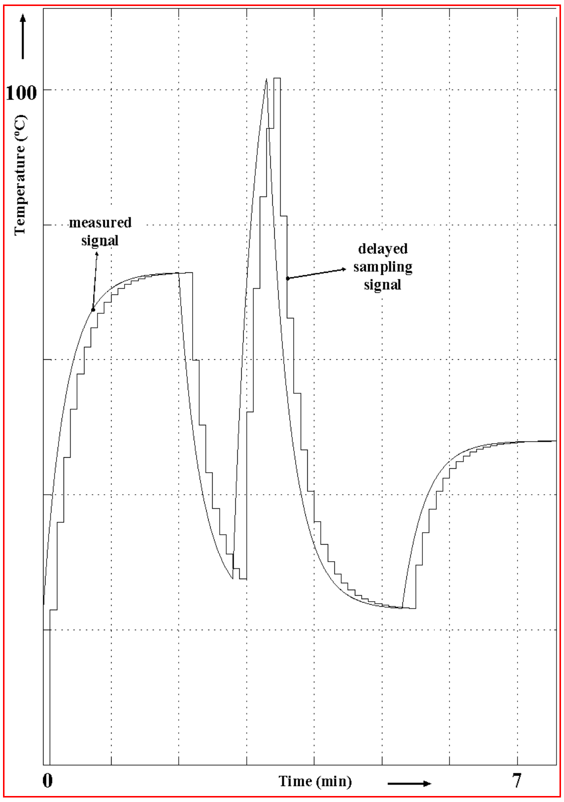

Fig. 2 Course of temperature simulation value and sampling signal with transport delay

It can be seen on the graph in Fig. 2, which at the time of temperature raise the difference of the measured temperature and predictive limit temperature is relatively large and is gradually decreasing. The wear value of the cutting tool would be determined incorrectly during transient process, if it was based only on the value of immediate measured temperature. It is therefore necessary to have two measured values of immediate temperature, which will allow calculating the limit temperature. All step points of sampling signal course in the graph are points at which the predictive limit temperature is updated.

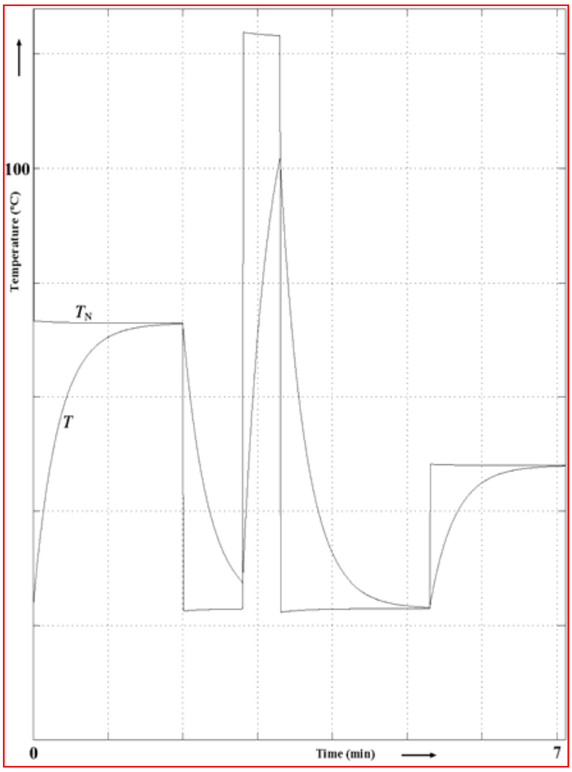

Fig. 3 Graph of dependence of temperature simulation value T on time and its prediction limit value T_N.

Fig. 3 shows the dependence of temperature simulation value T on time and its prediction limit value T_N. At the 2nd minute there was a reduction of heat at the spot of the cut and it was reflected by the changed slope of the increase of measured temperature. This change could be caused by the change of workpiece hardness, or change of other machining parameters. At the time of 2.75 mines, there was again a change of machining parameters. Heat creation at the cut spot increased, which caused steeper temperature increase as opposed to previous *increase in the 0 – 2 minutes interval. The predictive limit temperature was, however, determined on the basis of the calculation in the time of generation of the second sample of sampling signal since the beginning of the change. This method allows fast determination of end limit temperature in the area of frequent temperature changes, which is decisive for the evaluation of tool condition. By processing of measured condition of cutting tool it is possible to realize wear correction of given tool in the form of correction shift in the next step. It is very beneficial to verify the functionality of such regulating system by creation of its model and simulation model in an appropriate simulation environment.*

Given method of determining the limit temperature measurement in processes of measurement and regulation enables to make the information on process immediate condition more accurate using this determining variable, especially for the reason of its continuous dynamics. In this way it is possible to accurately determine the temperature limit value in every moment and during frequent changes of machining parameters, which create inharmonic dynamism of temperature flows. Without this principle of limit value determination, the whole process would contain a discrete error within the transport time delay pertaining to directly proportional time constant of heat transfer.

CONCLUSION

This mathematical model is an elemental result of solution of complex measurement and control system with partial mutually elements which are signally tied. In the process of supervision of manufacturing operation related to a single temperature parameter it is necessary to achieve a state of collection of discrete values in real time, especially if there is data processing in a comparative way. This method includes a reference member, whose values pertain to immediate states without transport delay. It is still necessary to take into account the size of introduced error in the area of dynamic changes under the influence of transport delay under the influence of prediction. There are ways of correction with prediction of immediate limit value on the basis of gradient and its changes also in the systems with transport delay. However, this method is computation-time intensive in the area with higher dynamics, since the sampling frequency increases with the dynamics of the defining variable in order to maintain the required accuracy.

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