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INTELLIGENT LATHE TURNING COMPUTER CONTROL SYSTEM MODEL

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Abstract: *This paper presents an intelligent computer system for controlling CNC lathes, allowing optimization of work cycles, increasing precision and productivity of turning. Using database about the machine, the equipment, the tools and the process, this system will adapt the controlling program to the specific conditions of turning, which results in increasing the precision of the finished parts and the productivity of the operation.*

Key words: *mechanical engineering, adaptive control, active control*

1. INTRODUCTION

Over the last years there has been an increased scientific interest in applying intelligent computer control to CNC metal-cutting machine tools. A number of researchers from the USA [1] and Japan [2] have published results on designing and developing such systems. The underlying idea is to combine the experience gained in automated control of modern metal-cutting machines with sophisticated information technologies with the purpose of increasing mechanical processing efficiency.

2. PREREQUISITES AND MEANS OF SOLVING THE PROBLEM

Widening of the areas of application of CNC metal-cutting machine tools in serial production is a prerequisite to seek new possibilities of increasing their precision and productivity. One of these possibilities is to develop an intelligent computer control model through combining adaptive control and active control without complicating the sensor system of the machine inordinately.

This concept has been developed as a project for intelligent computer control of CNC lathe CT 161. A block-diagram of the system is shown in fig.1.

The system comprises three modules:

- Measuring Module;
- Lathe and CNC process module;
- Computer control module.

The intelligent computer control is achieved through integrating the three modules into one system by creating the necessary connections between and among them.

The control is carried out in two directions:

- Adaptive control, which registers the disturbing factors in the quality of the workpieces and their influence on precision in the process of turning;
- Active control, carrying out dimensional sub tuning, depending on the systematic error measured in the finished parts.

3. INTELLIGENT COMPUTER CONTROL SYSTEM MODEL

The intelligent computer control system consists of three modules, each performing specific functions. Connections between the separate modules are created to ensure their functioning as an integrated system. The diagram in fig.1 shows the model of the intelligent computer control and the connections between the modules.

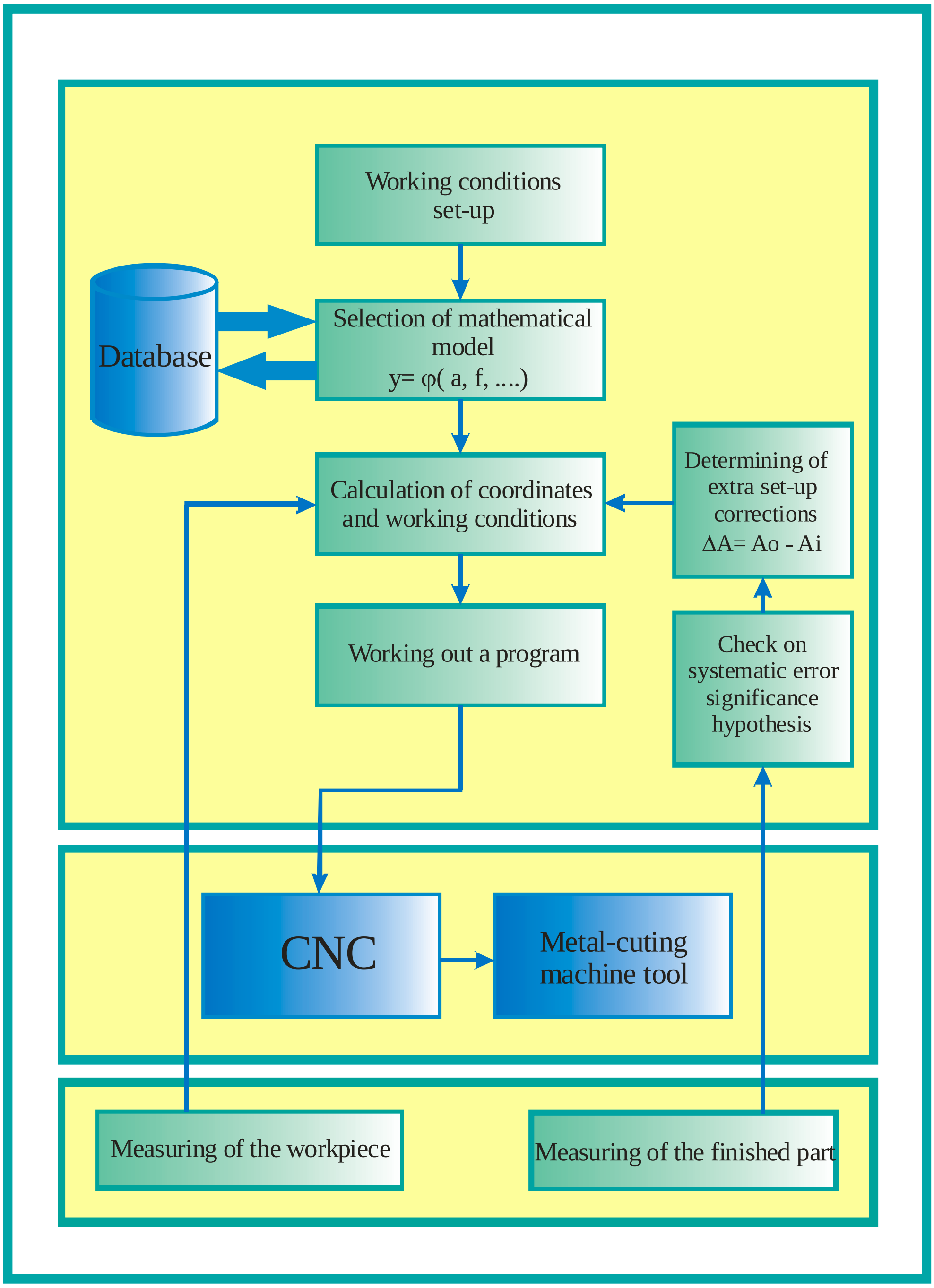

Fig.1 Block-diagram of an intelligent computer control system with adaptive control and active control

3.1. Measuring Module.

This module checks the workpieces before processing and then measures the finished parts. The purpose of the workpiece check is to determine the dimensions of the workpiece, the precision of its shape and the positioning precision of the surfaces, all of which can result in uneven allowance during the working stroke of the too.

It is necessary to assess to what extent the allowance is significant to provoke changing of the dimensional set-up or the working conditions during the power stroke.

The control of the finished part registers the appearance of any systematic error, which is then assessed by its significance to proceed if necessary with sub tuning.

3.2. CNC Machine Tool.

It incorporates the metal-cutting machine tool and the CNC system, which is connected to the computer system.

3.3. Computer Control Module.

This module is responsible for the working out of the controlling program and correcting it on the basis of the results received from the workpiececheck and the finished part control. It could be divided in two parts: adaptive control and active control.

3.3.1. Adaptive Control.

The major disturbing factors in the quality of the workpieces are their dimensions, shapes and physicomechanical properties. Measuring of these characteristics prior to turning makes it possible to change expediently the mechanical processing conditions, thus obtaining the desired quality of the finished part.

In order to make this type of control efficient, it is necessary to know the relation between the workpiece quality characteristics and the precision of the processed surface. Dispersion in workpiece quality results in dispersion of the force induced-errors of the technological system. The relation between them is determined by the following equation (1):

(1) $$y = \varphi\left[a, f, V_c, (HB), M\left(x_M, y_M, z_M\right)\right].$$

Therefore, after measuring of the workpiece dimensions and its rigidness prior to turning, the force-induced error of the technological system can be determined by function (1), which allows making the necessary corrections in the cutting conditions or in the dimensional set-up to compensate for that error.

If we consider the function with two variable parametres: depth of cut *a* and cutting feed *f*, it can be represented by the following polynomial of the second power:

(2) $$y = b_0 + b_1 a + b_2 f + b_{12} af + b_{11} a^2 + b_{22} f^2 .$$

Its graphic interpretation is shown in fig.2

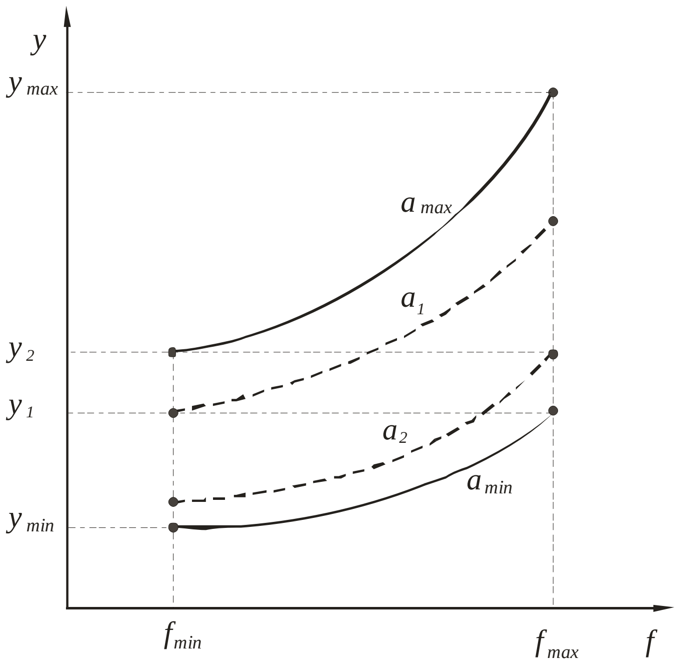

Fig.2 Force-induced errors model

It is clear that two approaches of reducing force-induced errors are possible.

If we use cutting feed $f = const$ for each depth of cut a from the polynomial, the force-induced error y is determined so as to make a correction in the dimensional set-up to compensate for that error.

Should the purpose be to achieve constant dimensions of the pieces *(A=const)* without dimensional sub tuning it is necessary to determine the cutting feed for this particular workpiece for each depth of cut a from the polynomial with $y = const$.

Adaptive control is achieved according to the diagram in fig.1:

- Set-up of working conditions (material, positioning of workpiece, cutting-tool parametres);
- Selection of a mathematical model of the process according to the input parametres;
- After the Measuring Module has passed information on workpiece dimensions into Calculation of coordinates and Working Conditions, the coordinates of the cutting-tool path and the feed f are determined;
- Controlling Program is generated;
- This program is transferred to the CNC system of the machine tool;
- Turning of piece.

3.3.2. Active Control.

It is difficult to install any dimension-controlling devices in the cutting area of a CNC lathe due to the very intensive chipping. Besides, cutting is accompanied by vibrations and significant heating whenever the surface happens to be comparatively rough. These are all factors reducing the precision of control when the controlling device is positioned on the machine tool. Hence, it is quite advisable that the control be exercised in a separate workspace, after turning. This is what actually makes the active control with dimensional sub tuning so very applicable.

CNC lathes are characteristically used to produce batches of small amount, which limits the applicability of the ensuing small number of samples to the comprehensive assessment of controlling possibilities. Besides, there is no statistical data about the process, due to time-unidentified batch repeatability, which keeps the process totally unidentified for lack of precision diagrams. Therefore, it is impossible to apply active control to a set of average values and since there is no sufficient initial data available to determine the control values or the magnitude of the sub tuning impulse, the active control algorithm based on individual values is equally inapplicable. In such case, the decision to make sub tuning should be made while turning is in process, on the basis of current incoming data on workpiece dimensions.

This paper offers an active control algorithm, suitable for CNC [4]. In the process of turning, after the fourth piece and on, the regression equation is determined and the dispersion S_N^2 of the finished parts in relation to it is calculated:

(3) $$S_N^2 = \frac{\sum_{i=1}^{n} \left(A_i - A_{Ti} \right)^2}{N-1},$$

where $\boldsymbol{N}$ is the number of the finished parts;

A_i is the size of piece number i;

A_{Ti} – the size of piece number i, determined by the regression equation:

(4) $$A_{Ti} = \tilde{a} + i\tilde{b} .$$

The assessment of sub tuning indispensability is made through checking on the significance of the difference:

(5) $$\Delta A = \tilde{a} - A_{T_N} .$$

This is done, using Student’s criterion:

(6) $$t = \frac{\left|\tilde{a} - A_{T_N}\right|}{S_N}\sqrt{\frac{N}{2}} > t_{\alpha,k}, \qquad \left[k = 2\left(N-1\right)\right].$$

The moment the difference (5) becomes significant, dimensional sub tuning of value and sign corresponding to ΔA is performed. The next piece, after the extra set-up, is considered the first in a new process, where the described active control algorithm is applied in the same way.

According to the block-diagram in fig.1, the active control procedure is as follows:

- The Measuring Module accomplishes measurements of the finished part;
- The result is transferred to the Determining of Systematic Error Significance Hypothesis Block. Should the hypothesis be confirmed, the Block receives a signal to correct the error;
- Sub tuning correction is determined;
- The sub tuning correction is entered into Calculation of coordinates and Working Conditions where the tool path coordinates for the next piece are recalculated, taking into account the correction just made.

4. CONCLUSIONS

The intelligent computer control model presented in this paper combines the possibilities of adaptive control and active control to improve precision in turning.

The model is applicable in CNC lathes, provided a connection between the computer and the CNC system has been built. The technological system has not been complicated with additional sensor devices. Adaptive control and active control are achieved through software.

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