Selection of rational algorithms for controlling high-precision details

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Abstract. One of the most important and complex issues in the automation of technological processes is control automation. At present, active control is the most promising, aimed at ensuring the required quality of dimensional and other parameters of products in the very process of their production, at automating high-precision technological processes, reducing losses from rejects and control costs. In modern production with the help of active control means, the problem of increasing the manufacturing accuracy can be solved by choosing a rational control algorithm. To create an effective control system for the accuracy of machining a part, active control devices are often used that work according to various algorithms. Most modern machine tools are equipped with active control sensors that allow measuring the dimensions of the manufactured parts and setting up the machines during operation. The sensors are controlled by microprocessor blocks, which allow additional control to be introduced and the machine to adapt to changing processing conditions, which increases productivity and accuracy. Modern software allows you to effectively control the processing process, therefore, the choice of a rational control algorithm plays a special role.

1. Introduction
Currently, mathematical and statistical research methods are the most important element of quality management at an industrial enterprise. With high requirements for the accuracy of manufacturing products, current control is necessary to regulate the technological process and prevent the appearance of defects. The well-known mathematical and statistical sampling methods are used mainly in acceptance control in order to verify compliance with technical requirements for the quality of products. Thus, they do not have a direct impact on the production of products, but reveal defects in finished products.

Certain costs when carrying out control measures take place on a permanent basis, and with ineffective control, when the consumer gets low-quality products, these costs increase significantly due to the completion of products or the return of defects. Therefore, the task is to develop effective control methods that allow providing both a certain output level of quality and its improvement.

The main point of using active control when processing parts on machine tools is to increase technological accuracy by compensating for errors caused by tool wear, thermal and force deformations of the technological system, since these factors lead to a dispersion of the size of parts when processing them on metal cutting machines.

Modern machine tools with numerical control allow precise sizing of the part. The touch probe transmits the coordinates, and all other values that allow the machine to be readjusted are obtained after
performing a series of calculations. To the greatest extent, the processing accuracy is affected by such errors as the kinematic accuracy of mechanisms and the positioning error of the working elements of the machine. Also, as the equipment wears out, the sensitivity of the machine to external and internal influences (power, heat, etc.) decreases.

To improve the accuracy of product processing, several algorithms were proposed and their influence on the processing process was investigated.

2. Main part

Automatic devices for control of products after processing allow to sort waste and, during selective assembly, to sort suitable parts into groups, as well as stop the machine in case of tool breakage.

In addition, when a certain number of parts with dimensions outside the specified limits appear, the machine automatically performs readjustment. But with such an algorithm of actions, adjustment occurs after the appearance of defective parts. Therefore, it is necessary to select the appropriate calculation algorithm that allows you to evaluate the fluctuations in the dimensions of the measured parts and to make the necessary adjustment of the machine before the appearance of defective products.

The following algorithms were used in the study:

\[
\begin{align*}
    k_1 x_i \\
    k_1 x_{i-1} + k_2 (x_{i-1} + x_i) \\
    k_1 x_{i-1} + k_2 (x_{i-1} + x_i + k_1 x_{i-1}) \\
    k_1 (x_i + x_{i-1})
\end{align*}
\]

\( i \) - control factors, \( x_i \) - current measurement result.

The calculations are carried out as follows:

\[
    x_3 = \frac{x_1 + x_2 + x_3}{3};
\]

\( 2 \)

\[
    U_3 = K \cdot x_3;
\]

\( 3 \)

where \( K \) - control factor calculated using one of the above formulas.

In this case, we obtain (3) and calculation of the average for the subsequent value will be carried out already taking into account the correction. We obtain the average value (7) :

\[
    x_4 = x_4 - U_3;
\]

\( 4 \)

\[
    x_4 = \frac{x_2 + x_3 + x_4}{3},
\]

\( 5 \)

\[
    U_{4} = K \cdot x_{4};
\]

\( 6 \)

\[
    x_{i-1} = \frac{x_{i-2} + x_{i-1} + x_{i}'}{3};
\]

\( 7 \)

The performed calculation allows comparing the variances of the studied process before and after the introduction of the correction. If the ratio of the variance of the controlled process to the original process turns out to be less than one, then the introduced control is effective.

Since the distribution law of the process under study, as well as the ratio of the random and systematic components, is initially unknown, it is not possible to mathematically prove the effectiveness.

A single case of the effectiveness of the introduced adaptive control cannot guarantee the effectiveness of all subsequent experiments.
For this, a program was compiled that processes sequences according to this algorithm, and an array of 100,000 random processes was processed. In none of the processes under study, after the introduction of corrective regulation, there was a deterioration in the results.

Also, to confirm the results, functions were built, where the first several values \( x_1, x_2, x_3 \) were selected using a random number generator, and then the dependence of the control efficiency on the coefficient \( K \) and the subsequent number \( x_4 \) was plotted. The graph confirms that for any value of \( x_4 \) there is a range of values of the coefficient \( K \) at which the ratio of variances will be less than one, which proves the effectiveness of regulation.

The graph shows that for any value of the initial data, there are correction values that can improve the process and increase the processing accuracy. With a random change in the first three values of the process under study, the function graph changes its form, but the area of regulation efficiency continues to exist, although it narrows in “unfavorable” cases with a strong scatter of the studied values. All values below the single plane in the graph are examples of effective adjustments.

The proposed method for making adjustments is carried out with active control, therefore, the number of measurements during the experiment is continuously accumulated. Therefore, it is necessary to prove the effectiveness of introducing adaptive control with a different number of measurements. For this, sequences of values of 10, 25, 50 and 100 numbers were generated using a random number generator, and then processed by the program using a control algorithm. Then the dependence of the variance ratio change on the sequence value is calculated.

Based on the results of calculations, we can conclude that when the array decreases, the numbers behave less randomly, that is, due to the small amount of data, we convert the random component into a pseudo-systematic one. But even with a large amount of values (up to 1000), the calculation algorithm allows you to make appropriate adjustments to improve the processing process.

An example of one of the sequences is shown in figure 2.

**Figure 1.** 1 - the function of the dependence of the efficiency of regulation on the coefficient \( K \), 2 - a single plane.
Based on the analysis of models of random sequences, one can put forward a hypothesis:
In the random sequences obtained in practice, either there is a systematic component, albeit on a
limited interval, or we have the opportunity to interpret the sequence so that it contains a set of random
and systematic components. This is of practical importance in managing these sequences.

3. Conclusion
The use of control algorithms can have a different effect on the process under study - from a small (about
1%) to a significant decrease in variance (several times), but does not lead to a deterioration in the
results. The hypothesis is confirmed on the basis of numerous statistical studies.
With a small volume of measurements, random variables do not fully manifest their properties.
To implement the methodology for prompt adjustment of the machining procedures of products in
the system of technological preparation of production, a database on technological equipment is needed,
containing the results of an automated assessment of the dynamic state of machine tools. This will make
it possible to efficiently correct the route of the technological process depending on the data of the
monitoring system about changes in the dynamic state of the equipment.

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