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INCREASING THE ACCURACY OF PROCESSING PARTS ON CNC LATHES

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Abstract: The article examines the effect of the movement trajectory of the cutting tool on the longitudinal cross-sectional accuracy of the details processed on digitally controlled (DC) lathes. Opportunities to improve the accuracy of details are analyzed. The article investigates the influence of the trajectory of the cutting tool on the accuracy of the longitudinal section of parts processed on lathes with computer numerical control (CNC). The possibilities of increasing the accuracy of parts are analyzed. The article describes a method for calculating the trajectory of a turning tool on a machine with numerical control to compensate for elastic deformation when processing of the workpiece. In the process of turning bodies of rotation with low rigidity, elastic deformations occur under the action of cutting force, which negatively affects the accuracy of the machined surface. As a result, an error appears in the form of barrel-shaped, saddle-shaped, or a combination of these errors, depending on the stiffness machine and its individual parts. Based on the calculation of deformation at a constant depth of cut, it is proposed to determine the error, which must be further compensated using the given calculation method. It allows compensation to be carried out by predistortion the trajectory at the stage of programming the control program. Thus, during the turning process, the required diameter will be obtained with minimal errors, which in turn will have a positive effect on the reduction additional processing to remove form errors and improve the quality of part processing.

Keywords: *processing accuracy, shape error, machining, workpiece, part, machine tool, cutting tool, trajectory.*

Introduction.

The development of all branches of mechanical engineering and instrument making is characterized by a continuous increase in requirements for the precision of manufacturing parts and product assembly. The issue of increasing accuracy in all technological operations is considered relevant. Increasing the accuracy of milling, as well as the accuracy of machining operations, starting with roughing operations, allows us to minimize the number of processed operations on the surfaces of parts, save material, and also reduce labor costs. In addition, it should be noted that with increasing accuracy of machining parts, labor costs for assembling machines and devices are minimized due to partial or complete elimination of transfer operations. All this requires a special careful approach to ensuring and increasing accuracy at each stage of product creation - at the design stage, the manufacturing stage, as well as at the assembly and testing stages [1].

Studying the possibilities of increasing the accuracy of machining. The quality of the product as a whole directly depends on the precision of manufacturing of each of its parts. Among the well-known groups of parts, one of the parts that require increased manufacturing accuracy are parts processed on lathes. Because many of these parts are subjected to a variety of stresses, inaccurate preparation increases the corrosion and failure of the parts. Turning today remains a more labor-intensive operation in the manufacture of parts of this type.

The accuracy of detailing is understood as its compliance with the requirements for the drawing in terms of linear and angular dimensions, geometric shape, waviness and unevenness [2-5].

The process of mechanical processing of parts with pastes is accompanied by the occurrence of errors from the influence of systematic and random factors. One of these factors is the elastic deformation of the elements of the technological system (machine-layout-tool-part) under the influence of the cutting force. As a result, the position of the cutting tongue of the tool relative to the processed paste changes. A change in the cutting force and rigidity of the technological system during the movement of the cutting tool leads to deformation of its elements, as a result of which shape errors, as well as size variations, occur on the processed surfaces of individual pastes, as well as in batch pastes [5].

Increasing accuracy usually leads to increased labor intensity and cost of manufacturing parts. When designing operations for preparing parts, it is necessary to take into account errors that may occur during machining and be sure to determine the possibilities for their reduction or compensation. The general basic methods for improving machining accuracy are as follows:[6-9]:

- with increasing rigidity of the technological system;

-reducing the cost of construction errors (using the principle of overlapping bases; correct choice of price and direction of compression force, etc.);

- increasing the accuracy of tool adjustment by size;

- with the correct choice of material for the cutting part, optimization of cutting mode elements and increasing the wear resistance of the cutting tool through the use of cooling and lubricating fluids;

- reducing the influence of temperature deformations of the machine, tool and paste on the accuracy of machining;

- using active controls and various automatic debuggers;

- with the introduction of management systems.

Precision control in flexible manufacturing using CNC machines to improve production culture in modern industrial enterprises is more typical. Accuracy control gradually, as a result of the improvement of modern CNC installations, there is a need to move to software control of the accuracy of machining.

In this regard, important issues include the study of factors influencing the accuracy of machining, the study of the causes of errors and the patterns of their change. This is especially true for parts mounted on consoles and centers during turning.

A very important and pressing problem is the study of the law of change in errors that arise when processing parts mounted on lathes in consoles and centers, and the determination of the equidistance of the trajectory of the cutting tool in accordance with the law of change in error, as well as the study of software control of the error that may arise. [10-13]

Increasing the accuracy of machined parts can be achieved by studying the causes of errors, as well as partial and complete prevention of elastic deformations of the paste, taking into account the cutting force, the rigidity of the technological system and the method of installation of the paste. Figure 1 shows methods for increasing the accuracy of machining shaft-type parts on CNC lathes.

Formulation of the problem.

Increasing the accuracy of parts processed on CNC lathes. In CNC lathes, when processing the outer surfaces of plates of low hardness, the bending of the tip and the compression of its cutting force under the action of the radial organizer P_y lead to their deformation under the influence of this force. Their deformation in the diametrical direction when the rods are cantilevered (for example, in a lathe chuck) is determined by the following well-known expression (1) [4]:

$$\Delta x = \frac{P_y \cdot l^3}{3 \cdot E \cdot J} \tag{1}$$

here, E-modulus of elasticity of the formation material, N/mm^2; J is the moment of inertia of the cross section of the mold, mm^4; l is the distance between the point of application of the cutting forand the place of attachment of the form, mm (Fig. 1).

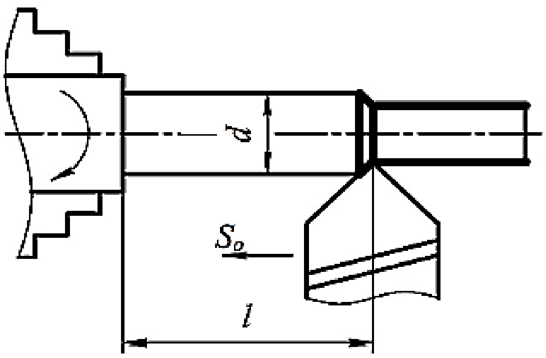

Figure 1. Scheme of processing a shape fixed in a chuck on a lathe

As the distance l increases, the deformation of the shape increases significantly, which leads to an increase in shape errors in the longitudinal cross section of the shape (or part).

The radial organizer of the cutting force during the top processing operation is determined by expression (2) below [4]:

$$P_y = 10 \cdot C_p \cdot t^x \cdot S_0^y \cdot V^n \cdot K_p \tag{2}$$

here, C_p, K_p are coefficients; x, y, n are strength indicators. When upper processing of molds made of structural steels for bits made of hard alloy $C_p = 243$, $x = 0{,}9$, $y = 0{,}6$ and $n = -0{,}3$; and for bits made of high-speed steels $C_p = 125$, $x = 0{,}9$, $y = 0{,}75$ and $n = 0$ [4].

The coefficient K_P is determined by the expression below (3)[4, s. 96-103]:

$$K_p = K_{M_p} \cdot K_{\varphi P} \cdot K_{\gamma P} \cdot K_{\lambda P} \cdot K_{rP} \tag{3}$$

here, is a coefficient depending on the tensile strength of the material being processed; - coefficients depending on the geometric parameters of the cutting tongue of the bit. $K_{M_p} \cdot K_{\varphi P} \cdot K_{\gamma P} \cdot K_{\lambda P} \cdot K_{rP}$

For bits made of hard alloy and high-speed steel with a planning angle $\varphi = 45^0$, an inclination angle of the leading edge $\gamma = 10^0...20^0$, an inclination angle of the main cutting edge $\lambda = 0^0$ and a tip radius $r = 2$ mm $K_{\varphi P} = K_{\gamma P} = K_{\lambda P} = K_{rP} = 1$; , where $\sigma_B \langle 600$ MPa, $m = 0,35$ (for high-speed steel bits) and $m = 0,75$ (for hard alloy bits); t, S_0, V - respectively depth of cut (mm), longitudinal gear (mm/cycle) and cutting speed (m/min). $K_{M_P} = \left(\frac{\sigma_B}{750}\right)^m$

In CNC lathes, it is possible to compensate for shape errors that arise during processing, and in some cases, positional errors, by first changing the trajectory of the cutting tool using a numerical control program (NC-numerical Control).

There are three known ways to compensate for errors in the shape of parts:
- correction of the trajectory of movement of the cutting tool when performing the last working stroke;
- change in transmission and resulting cutting force during the movement of the cutting tool;
- correction of the trajectory of the cutting tool to obtain an uneven cutting depth when performing the last working stroke to process a given working surface.

Solution of the problem.

Let us assume that the shape of the surface to be formed corresponds to straight line 1 (Fig. 3). The actual shape of the surface, formed as a result of elastic deformation of the mold during processing, will correspond to curve 2. In order to compensate for the shape error, a correction is made to the tool path taking into account the current value of the shape error. To do this, the trajectory must necessarily correspond to curve 3, which is considered a mirror image of curve 2 if you look at straight line 1, corresponding to the nominal contour of the part. Since the specific operation of a lathe does not allow the tool to move along a smooth curve, the actual tool movement curve will be stepped (curve 4 in Fig. 2).

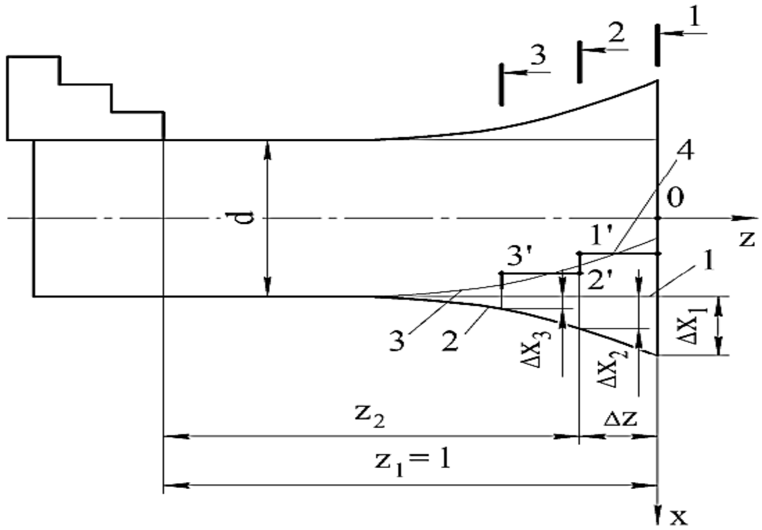

Figure 2. Scheme of formation and compensation of errors in the shape of the cantilever fastening in the chuck

The adjusted trajectory ($1'$, $2'$, $3'$, ... support points) can be written in several blocks of the control program. Therefore, at the support points, the transfer motion of the tool approaches zero at short intervals, and the cutting force decreases. This is due to the formation of ring-shaped marks on the treated surface. In addition, the contour formed as a result of the influence of the stepwise nature of the tool movement becomes non-linear after processing. Therefore, it is more advisable to use this method only for roughing or primary surface treatment.

The deformation of the shape in any kth cross section (Fig. 1) can be calculated using the following expression (4):

$$\Delta x_k = \frac{P_y \cdot (l-(k-1)) \cdot \Delta z^3}{3 \cdot E \cdot J} \tag{4}$$

here, l is the distance between the side surfaces of the cams and the mold, mm; ΔZ - distance between adjacent cross sections, mm.

If the deformation of the shape in any cross section is less than half the discreteness of coordinates in the diametrical direction on CNC machines, then in this section and in the section with a higher number the deformation is assumed to be zero.

The coordinates of the support points of the adjusted cutting tool path will be determined by the following expression (5):

$$\left. \begin{array}{l} point\,1^{/};\, x = \frac{d}{2} - \frac{\Delta x_1 + \Delta x_2}{2};\, z = -\Delta z \\ point\,2^{/};\, x = \frac{d}{2} - \frac{\Delta x_2 + \Delta x_3}{2};\, z = -\Delta z \\ for point\,k^{/},\, if k even number: \\ x = \frac{d}{2} - \frac{\Delta x_k + \Delta x_{k+1}}{2};\, z = -(k-1)\cdot \Delta z \\ for point\,k^{/}+1,\, if k even number: \\ x = \frac{d}{2} - \frac{\Delta x_k + \Delta x_{k+1}}{2};\, z = -k \cdot \Delta z \end{array} \right\} \tag{5}$$

here, d is the nominal diameter of the part, mm; - the distance between cross sections at which the shape deformation is calculated, mm. Δz

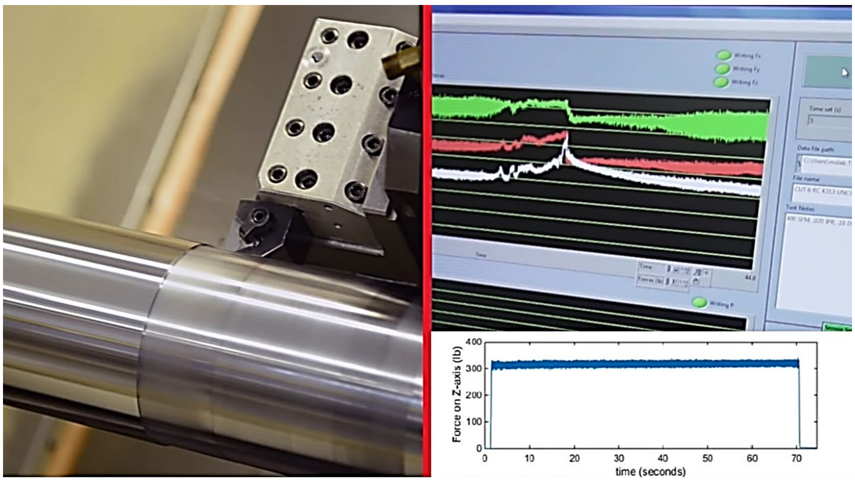

Figure 3. Measurement of cutting force using Kistler's RCD dynamometer

The shape error of the workpiece is calculated as the difference between the largest dmax $d_{\max}$ and smallest dmin $d_{\min}$ diameters according to (6):

$$\Delta_f = d_{max} - d_{min} \tag{6}$$

For the experimental implementation of the problem posed in the article, the study was conducted on the SL-10 digital program controlled machine of the HAAS company. Rods made of Steel 45 material with a length of 8÷12 mm were taken for the study. A three-punch cartridge was used as a clamping arrangement. The Kistler RCD dynamometer was used to determine the value of the cutting force applied to the pasta during processing (figure 3).

Table 1. Displacement of the axis of the stick workpiece

In the current sections of the passage of length L (x), mm	Axis displacement -y, mm				Cutting force P_y, N	Processing modes		
	J=0,05 sm^4 d=10 mm					t, mm	S, mm/per	n, dövr/min
	theoretical	experience	without compensation	with compensation				
10	0,00063	0,00055	0,00032	0,0002	198	0,5	0,3	500
20	0,005	0,0044	0,0021	0,0012				
30	0,017	0,014	0,008	0,004				
40	0,04	0,036	0,014	0,008				
50	0,078	0,068	0,004	0,02				

During the experiment, the value of the displacement of the cutting force of the rod in 5 equal parts along the length from the value of the component P_y was calculated using expression (2) and written in table 1. Then, according to these values, the dependence graph $y = f(L)$ reflecting the theoretically calculated displacement was constructed (figure 4).

Then, $t = 0,5$ mm of the pastes, in processing modes $S = 0,3$ mm/cycle and $n = 500$ cycles/min, processing was carried out without taking into account the center axis shape error compensation scheme (figure 2). During processing, the values of the central axis displacement in 5 equal parts along the length of the workpieces measured by the indicator are written in table 1. On the basis of these values, the $y = f(L)$ dependency graph was constructed for processing the center axis shape error without considering the compensation scheme (figure 4).

Then, the processing of the stick pashto was carried out in the same processing modes, taking into account the shape error compensation scheme of the central axis (figure 2). Again, with the same rule, the values of the displacements of the central axis of the workpieces in 5 equal parts along the length were measured and written in table 1. On the basis of these values, the dependence graph $y = f(L)$ for processing was built taking into account the compensation scheme for the shape error of the central axis (figure 4. - curve). In all these experiments, the range of shear force variation was $P_y = 157...256N$.

As can be seen from figure 4, the value of the displacement of the axis increases as the price of the transitions along the length of the plate increases at the value of the cutting force $P_y = const$ At a large value of the moment of inertia, the value of the displacement is small, and at a small value of the moment of inertia, the value of the displacement is large. Comparing the graphs constructed with a known dependence for the determination of the deformation of the central axis of the cantilever fixed part, it is known that the difference between the processing modes with and without taking into account the compensation scheme for the central axis shape error is $10 \div 12\%$.

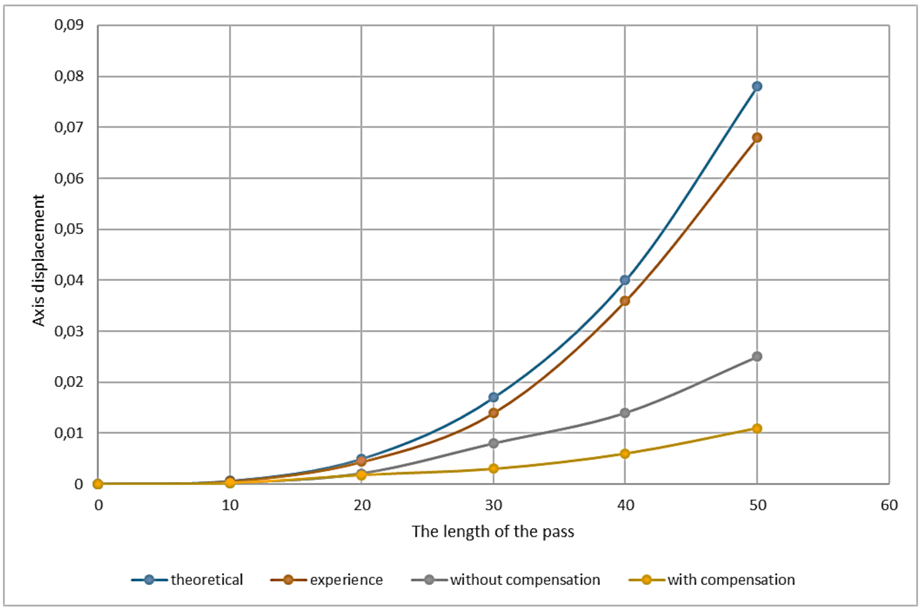

Figure 4. The graph of the displacement of the axis of the stick workpiece as a function of length.

Results and conclusions.

The article explores the possibility of compensating for shape errors that arise during processing on CNC lathes, and in some cases, for errors in relative position, by first changing the trajectory of the cutting tool using a digital control program (NC-numerical control), with which the circuit was built formation and compensation of errors in the shape of a fixed plate fixed to the chuck by a console. Since ensuring accuracy in machining and assembly processes is considered one of the important issues, this paper examines the factors affecting the machining accuracy in turning and how they can be prevented. To this end, the article analyzes the factors influencing the accuracy of machining during turning of parts to which the console is attached, and explains ways to reduce them. Elastic deformations that occur in the technological system due to the action of the cutting force have been identified; special attention is paid to the occurrence of shape errors as a result of bending of the central axis of the workpiece during processing. To compensate for the error by adjusting the value of the cutting force (an organizer that can be taken into account in the control program) in order to reduce the cost of the error arising from the deformation of the shape axis under the influence of the cutting force, it is proposed to implement this issue through the NC program.

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