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# A New Method for Determining the Influence of Rigidity of a Technological System on the Accuracy of Mechanical Processed Parts

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**ABSTRACT:**n the article, processing errors arising due to deformation of the technological system. To determine the influence of technological systems on the accuracy of machining parts under dynamic conditions, a vibroacoustic method was proposed. The relationship of the vibroacoustic signal on the stiffness of the workpiece is studied. Based on the results, a mathematical model is created. Taking into account the error of the mechanical processing and the amplitude of the initial period of processing the vibroacoustic signal, a graph is constructed of the relationship of their initial processing period to the error of the part. The difference between the calculated error and the experimental result does not exceed 5-10%.

**KEYWORDS:** error, deformation, machining, rigidity, technical system, cutting forces, lathe, stiffness changes, chuck, center, system elasticity, tests, frequency, amplitude, degree, back center, elastic modulus, moment of inertia, caliper stiffness , stiffness of the headstock, stiffness of the tailstock, logarithmic graph, stiffness of the workpiece.

## I.INTRODUCTION

In many cases, processing errors arising from deformations of the technological system and its elements are dominant in the total processing error. When machining pig-iron prismatic parts on a cantilever vertical milling machine mode 6P10 with face milling, the error due to deformations is 64-86% of the total processing error [1]. When gear grinding [2] - up to 80%; during multi-cutting processing (ENIMS) in finishing operations -20%, in roughing up to 90%, and thermal errors 5-60%; processing errors during gear hobbing with worm mills due to insufficient rigidity of gear milling machines is 14-40% of the tolerance field; during shredding, the oscillation of the measuring center-to-center distance only due to the variability of the maximum value of the cutting force due to the kinematic features of the processing method is on average 77% of the total processing error [3].

## II.SIGNIFICANCE OF THE SYSTEM

As is customary, in the process of machining, under the influence of the technical system (AIDS), under the influence of cutting forces, they are deformed, which leads to a change in surface dimensions and, as a result, adversely affects the accuracy of processing. Therefore, the technical condition of the equipment and the accuracy of machining are periodically checked. The dependence of the technological system on each other is shown in Fig. One
As stated in (4), the rigidity of a 1K62 lathe is obtained from 5.6 * 107n / m to 2.67 * 107. after 5 years of operation, the rigidity of these machines decreases in the range from 5.6 * 107 to 1.27 * 107n / m.
As shown in [4], measurements and static rigidity analysis of a large group of 1K62 lathes showed that for new machines, static rigidity varies from 5.6 * 107 to 2.67 * 107 n / m with a mathematical expectation of 3.16 * 107 n / m For machines of the same model, which have a service life of up to 5 years, the range of rigidity changes increases downward: 5.6 * 107 - 1.27 * 107 n / m with a corresponding decrease in the average value to 3.09 * 107 n / m .

A large interval of scattering of the rigidity of the machine leads to a change in the error of machining the part. Processing errors arising due to deformation of the technological system. Given the dynamic deformation of the processed workpieces, the determinant can be determined by the formula:

With console mount in chuck

$$\Delta = P_{bend}\left(\frac{l^3\mu}{3EJ} + \frac{1}{j_{\sup}} + \frac{1}{j_{f.g}}\right); \qquad (1)$$

When attaching workpieces to centers

$$\Delta = P_{bend}\left[\frac{l^3\mu}{48EJ} + \frac{1}{j_{\sup}} + \frac{1}{4}\left(\frac{1}{j_{f.g}} + \frac{1}{j_{b.g}}\right)\right]; \qquad (2)$$

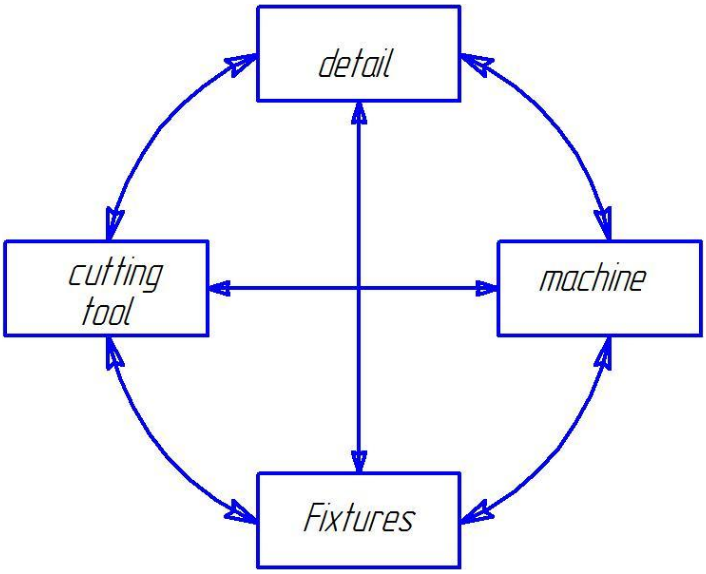

Fig. 1 Scheme of the relationship of the constituent elements of a technological system.

When pressing the workpiece in the chuck and rear center

$$\Delta = P_{bend}\left[\frac{l^3\mu}{102EJ} + \frac{1}{j_{\sup}} + \frac{1}{4}\left(\frac{1}{j_{f.g}} + \frac{1}{j_{b.g}}\right)\right]; \qquad (3)$$

Where μ is the dynamic factor;

E-modulus of elasticity; J moment of inertia; $j_{sup}$ - caliper stiffness;

$j_{f.g}$ - stiffness of the headstock; $j_{b.g}$ - stiffness of the tailstock;

EJ - rigidity of the workpiece.

Performance curves of the shape of the processed workpieces in the longitudinal direction for various fixing them are given in Fig. 2. [5]

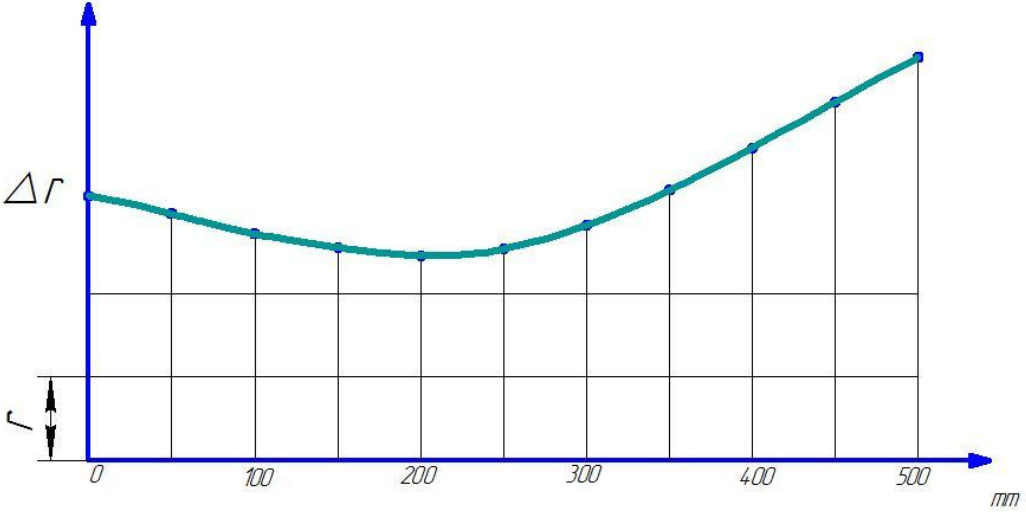

Figure 2. Curve distortion of the shape of the part during turning in the centers (taking into account the rigidity of the center and caliper)

When designing a fixture, its accuracy is taken from 1/5 of the tolerance of the part. Rigidity depends mainly on the length of the cutter. But the rigidity of the technological system is interconnected. Therefore, the sum of the error of the system is seen as the error of the movement of the error of the cutter and the workpiece among themselves.

The graph shown in Fig. 3 show that with increasing rigidity of the machine, which helps to reduce vibration, the wear of the cutting tool is significantly reduced [6].

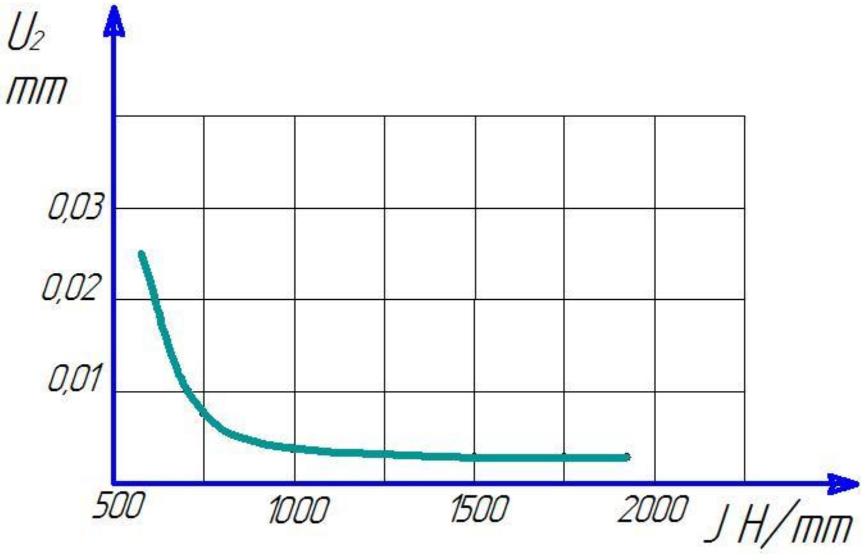

Figure 3. The effect of the rigidity J of the lathe on the wear of the U2 cutter. Material Steel 40x, V = 120 m / min, S = 0.2 mm / rev, t = 1mm

To calculate the processing errors associated with the elastic compression of the technological system, the stiffness of this system must be quantitatively expressed. The stiffness of the system elasticity is expressed by the ratio of the component of the cutting force directed according to the norms to the machined surface Py to the mixing of the tool blade relative to the part counted in the same direction y.

$$j = \frac{P_y}{y} Кн / m. \quad (4)$$

Ongoing tests on the rigidity of parts, assemblies and mechanisms of metalworking equipment were carried out under static conditions not inappropriate rigidity during their operation. Since the dynamic states of stiffness at the joints of parts, assemblies and mechanisms changes due to changes in the forces affecting them.
To determine the influence of technological systems on the accuracy of machining parts under dynamic conditions, we propose a vibro-acoustic method.

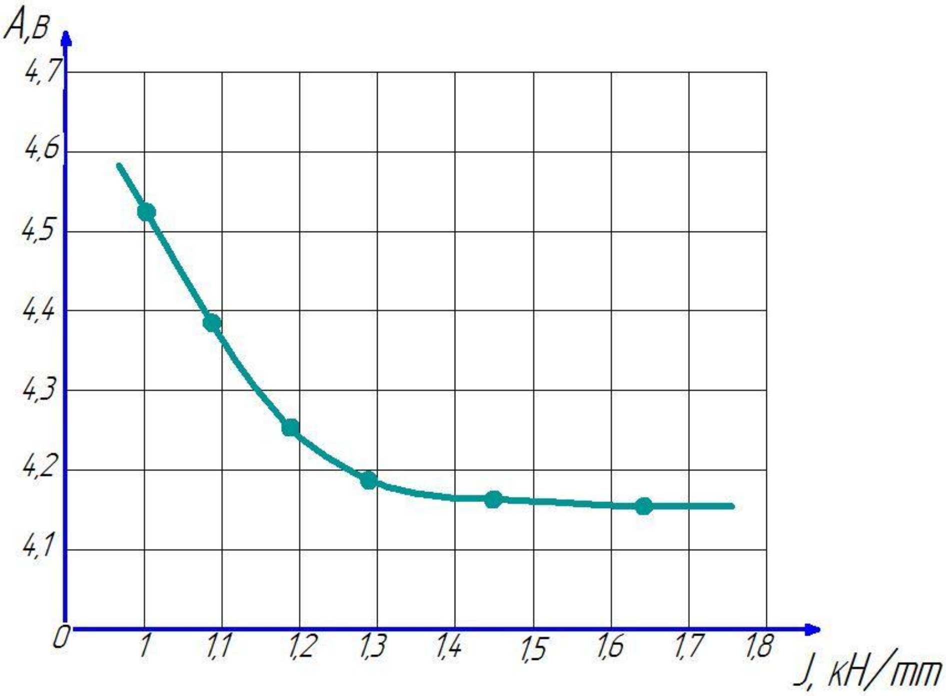

Figure 4. The graph of the relationship of the vibroacoustic signal on the stiffness of the workpiece. Material steel 40x, V = 120 m / min, S = 0.2 mm / rev, t = 1mm

## III. METHODOLOGY

It is known that in the initial period of machining with cutting, the amplitude of the vibroacoustic signal reaches its maximum value. A study of the relationship between the values of the stiffness of the cutter at the amplitude level is carried out on lathes. In this case, the cutting conditions do not change, but the value of the rigidity of the part is the difference. In fig. 4 shows a graph of the connection between the stiffness of a workpiece and a vibroacoustic signal. The graph shows that the stiffness of the part is linearly related to the values of the vibroacoustic signal for the initial period of machining with cutting.

$$j = EJ = kA^{x} \qquad (5)$$

Here is the k-correction factor. To determine the value of the degree of dependence, we construct a logarithmic graph (Fig. 5).
The degree values are determined by the formula. Then formula (5) is transformed into the following form:

$$j = kA^{tg\alpha} \qquad (6)$$

Define the correction factor, for this, the rigidity of the cutter is determined with the previous method:

$$k = \frac{j}{A^{tg\alpha}} \; (7)$$

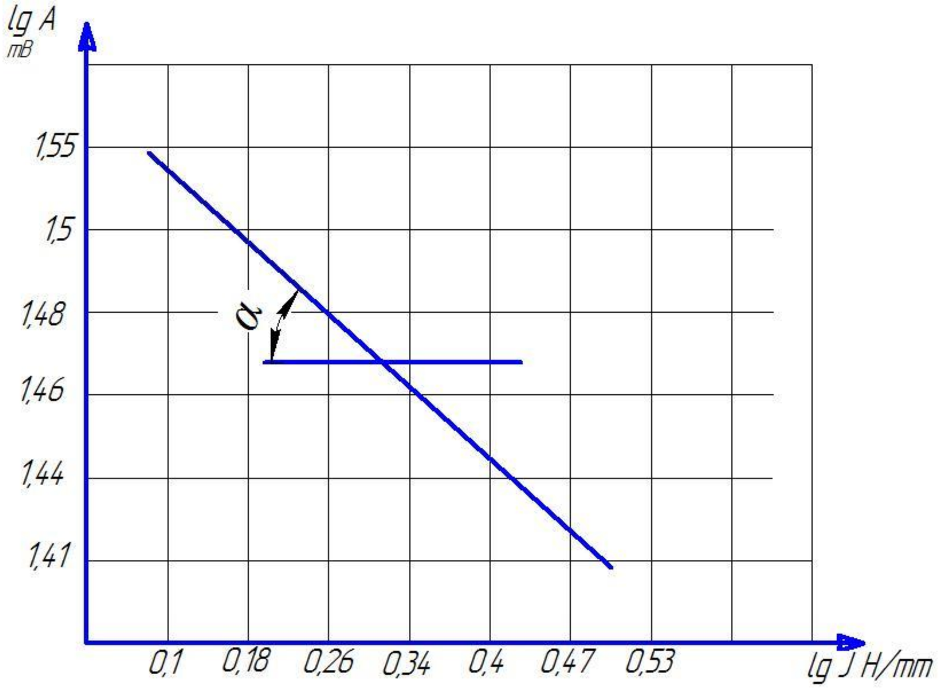

Figure 5. Log-log graph of the relationship of the vibro-acoustic signal to the stiffness of the workpiece. Material steel 40x, V = 120 m / min, S = 0.2 mm / rev, t = 1mm

When using this relationship in each transition, it is possible to determine and control the rigidity of the machine using the control computer in an automated method. For this, computer programs have been created. The studies performed for parts with different stiffness parameters are recommended by formula (6). This formula can be used for the dependences of the processing error on the amplitude of the vibroacoustic signal in the initial processing period on a lathe. To determine the dependence of the processing error on the amplitude of the vibro-acoustic signal in the initial period of processing the front headstock of the lathe, designating through C1 the sum of the suppleness of the support and the front headstock as $\frac{1}{j_{\sup}}+\frac{1}{j_{f.g}}=C_1$ we get:

$$\Delta = P_{bend}(\frac{l^3\mu}{3EJ}+C_1);$$

Then formula (1) is converted to the following form:

$$EJ=\frac{p_{bend}l^3\mu}{3(\Delta - P_{bend}C_1)}. \quad (8)$$

Substituting the formula (8) on the formula (6) we obtain

$$\frac{p_{bend}l^3\mu}{3(\Delta - P_{bend}C_1)}=kA^{tg\alpha}. \quad (9)$$

From formula (9) it can be seen that the amplitude of the investigated object has an inverse relationship to the processing error. Then, from the stated, it is possible to determine the processing errors of the object in the following form:

$$\Delta=\frac{p_{bend}l^3\mu + p_{bend}C_1kA^{tg\alpha}}{3kA^{tg\alpha}}. \quad (10)$$

Similarly, for machining parts on centers, from formula (2) we denote by C2 the sum of the suppleness of the support, the front and rear headstock as $\frac{1}{j_{\sup}}+\frac{1}{4}(\frac{1}{j_{f.g}}+\frac{1}{j_{b.g}})=C_2$ we get

$$\Delta = P_{bend}\left[\frac{l^3\mu}{48EJ}+C_2\right], \qquad (11)$$

$$EJ=\frac{p_{bend}l^3\mu}{48(\Delta-P_{bend}C_1)}. \qquad (12)$$

By delivering formula (12) to (6), we establish the relationship at the centers

$$\frac{p_{bend}l^3\mu}{48(\Delta-P_{bend}C_1)}=kA^{tg\alpha} \qquad (13)$$

$$\Delta=\frac{p_{bend}l^3\mu+p_{bend}C_1kA^{tg\alpha}}{48kA^{tg\alpha}} \qquad (14)$$

Similarly, the established relationships in the cartridge and in the rear center:

$$\Delta=\frac{p_{bend}l^3\mu+p_{bend}C_1kA^{tg\alpha}}{102kA^{tg\alpha}} \qquad (15)$$

## IV. EXPERIMENTAL RESULTS

Taking into account the error of the mechanical processing and the amplitude of the initial period of processing the vibroacoustic signal, we construct a graph of their relationship (Fig. 6).

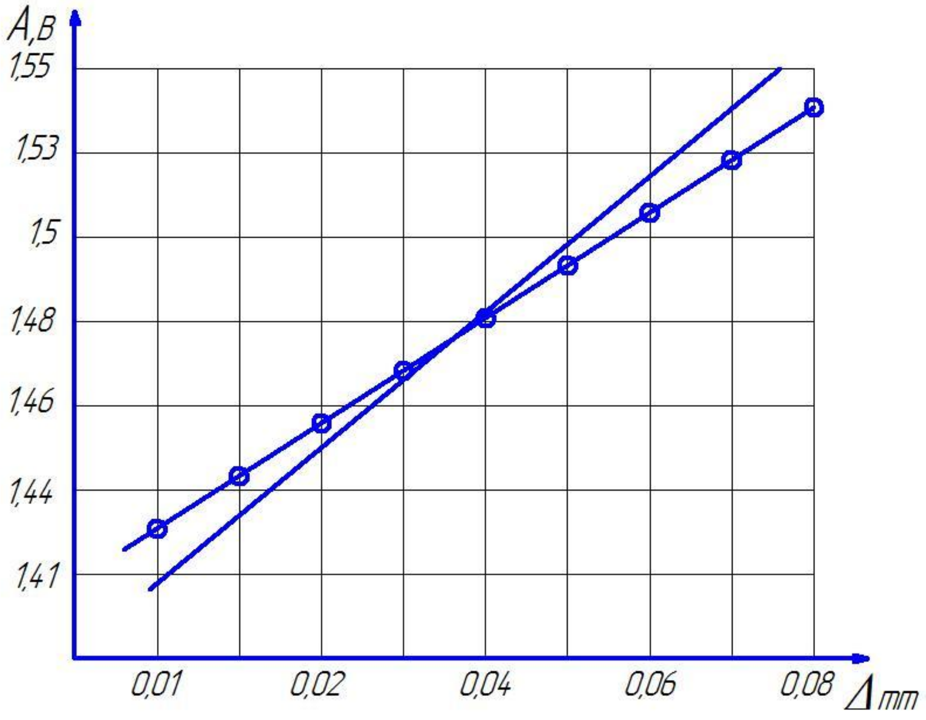

Fig. 6. Graph of the relationship of the amplitude of the vibroacoustic signal received in the initial processing period for the error of the part. 1-result of research; 2-calculated result; Material steel 40x, V = 120 m / min, S = 0.2 mm / rev, t = 1 mm.

From the graph in Fig. 6 you can determine the degree of accuracy of processing. The difference between the calculated error and the experimental result does not exceed 5-10%.

## V.CONCLUSION

Conducted scientific research shows that in the initial period of machining by cutting, the amplitude of the vibro-acoustic signal reaches its maximum value and the level of this value is related to the rigidity of the technological system. A mathematical model of this interconnectedness, the effect on the accuracy of machining, has been created. A study of the relationship between the cutter stiffness values and the amplitude level is carried out on lathes.

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