

# Diagnosis of the Computer-Controlled Milling Machine, Definition of the Working Errors and Input Corrections on the Basis of Mathematical Model

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**Abstract.** Manufactures, machinery and equipment improve of constructively as science advances and technology, and requirements are improving of quality and longevity. That is, the requirements for surface quality and precision manufacturing, oil and gas equipment parts are constantly increasing. Production of oil and gas engineering products on modern machine tools with computer numerical control - is a complex synthesis of technical and electrical equipment parts, as well as the processing procedure. Technical machine part wears during operation and in the electrical part are accumulated mathematical errors. Thus, the above-mentioned disadvantages of any of the following parts of metalworking equipment affect the manufacturing process of products in general, and as a result lead to the flaw.

## Introduction

With a view to provide the necessary precision and quality of manufactured products, machine tools, by convention to fractionalize of accuracy by achieving sizes. At the same time, in consequence of equipment deterioration is transferred from a precise group in the less precise group. For this purpose, large machine-building enterprises use centralized diagnostic and repair services serving turning lathes, milling machines and grinder machines respectively.

The purpose of this study is the definition of errors that occur during the convoluted surface processing of oil and gas products on CNC milling machines.

To achieve this purpose it is necessary to solve following problems:

1 Perform a diagnostics operation of executive work tools of the milling machine with the impact force and without it.

2. According to information diagnostic operation, determine the errors caused by process system, and form deviation and measurement of machined detail surfaces from the ideal model.

3. Identify ways of elimination arising errors without repairs.

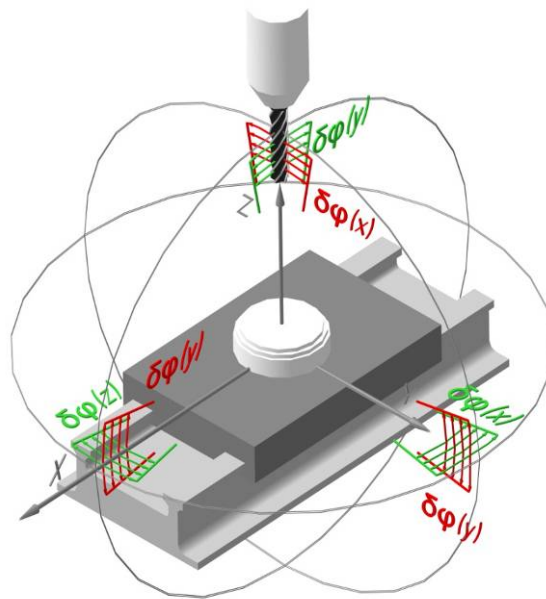
At this stage, we made diagnostic operation of executive work tools of the milling machine without forced action. The device for diagnostics in detail processing is developed for the following experiment.

1. Materials and technique of research

Milling machine diagnostic identifies imprecisions of finish and the accuracy of the workpiece, the straightness of the slide ways, the flatness, the levelness and plumbness of actuated parts. Diagnosis can be performed by methods of functional and testing diagnostics.

Testing of geometrical accuracy involves in verifying capability of the real precision specified parameters to the parameters from milling machine check, depending on the accuracy class (N – normal grade of accuracy, P – heightened grade of accuracy, B – high grade of accuracy, A – extended high grade of accuracy, C – super-accurate grade of accuracy), which are defined by GOST "Standards of accuracy". However, these normative documents require that the geometric machine errors are systematic and completely transferred to the workpiece.





**Figure 1.** Errors arising from the movement of forming machine components.

Diagnostics related to determining positioning error of the shape-generation by cutting tool and moving the shape-generation machine units. These errors include: precision motion (radial and axial runout of the spindle, the straightness of working bodies movement, etc.); accuracy of mutual situation and movement (perpendicularity of longitudinal and transverse movement of the table, perpendicularity of the spindle axis to the lathe table, etc.); positioning accuracy (moving to the predetermined position); the accuracy of the surfaces defining the relative position of the workpiece and tool; the accuracy of the guide surfaces.

On figure 1 is shown chart for accuracy appraisals of the two main types by shape-generation machine units with progressive advance and circumduction. At the first moving inaccuracy may occur imprecisions of linear position  $\delta x$  in the direction of travel and error  $\delta y$   $\delta z$ , characterizing deviation from straightness in mutually perpendicular directions.

As a result, there are variations in the angular movement of the table,  $\delta\phi(x)$  with respect to X-axis errors associated with revolution bodies. Uncertainties about the transverse axis  $\delta\phi(y)$  and the vertical axis  $\delta\phi(z)$  are mainly associated with the shape and position error of the guide with the obligatory account of the rigidity of the lathe.

With the second movement arises angular error  $\delta\phi(z)$ , related to the accuracy of positioning and angular error  $\delta\phi(x)$  and  $\delta\phi(y)$ , determining bias when axes X and Y are moving.

On the diagnostic, the numerical values of tolerance depend on the type, size and class of machine accuracy. Imprecisions are measured for turning machine by normal accuracy, which largely influence over machining accuracy (radial and axial run-out of the spindle, positioning accuracy), at an average deviation should be within the range of 10-30 microns. At the same time, it uses a variety of tools and tooling metrology. In order to obtain results of measurements completely characterized the accuracy of the machine necessarily make measurements of its strength and heat deformation.

For tolerances of geometric accuracy of lathes limit values determine in accordance with GOST 17734-88. According to GOST 17734-88 vertical milling machines are subjected to the following types of inspections:

- estimation of radial runout of the outer centering spindle neck;
- axial runout of the spindle;

- perpendicularity of the spindle rotation axis and the working surface of the table;
- radial runout of the axis of the conical spindle bore;
- flatness of the working surface of the table;
- parallelness of table surface of longitudinal slide;
- parallelness of table surface to guideway console etc.

Table 1 shows the limit values of tolerance on the listed types of inspection of normal accuracy lathes and diagnosed vertical milling machine VDL-500.

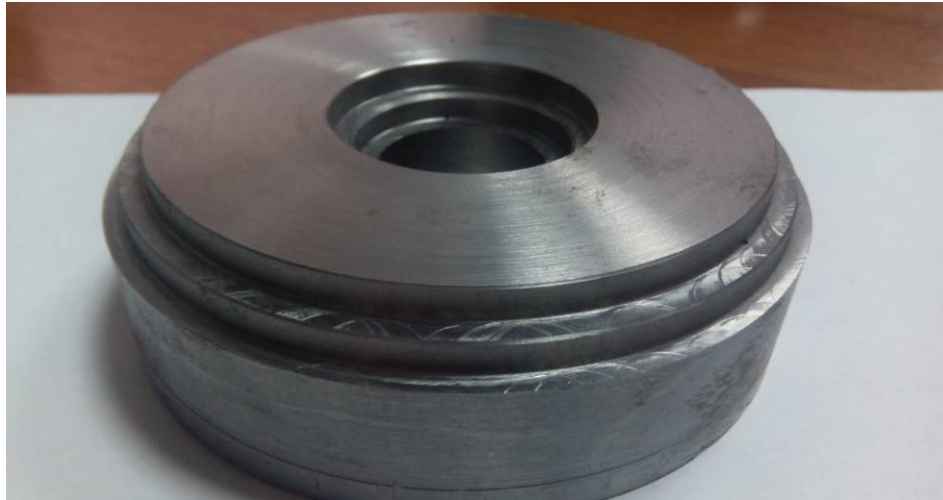
These diagnostic methods (as above) do not include errors caused by the dynamic load, temperature and elastic deformations. A more objective picture of existent inaccuracy can be obtained after processing the product by using the circular interpolation. Measurements are made on the inner and the outer cylindrical surface treated. Using the proposed method of measurement, with the benefits that working error of workpiece surface, that is not the geometric accuracy of the machine, without disassembling the machine to appraise its technical condition, identify the individual components and spare parts that are defective. Due to this, the repair will be carried out purposefully to address the specific defects. This will ensure the stability of production, will predict the time of trouble-free operation of the equipment, pre-ordering the necessary components for repair.

Table 1. - Comparative analysis of limit values of permissible variation.

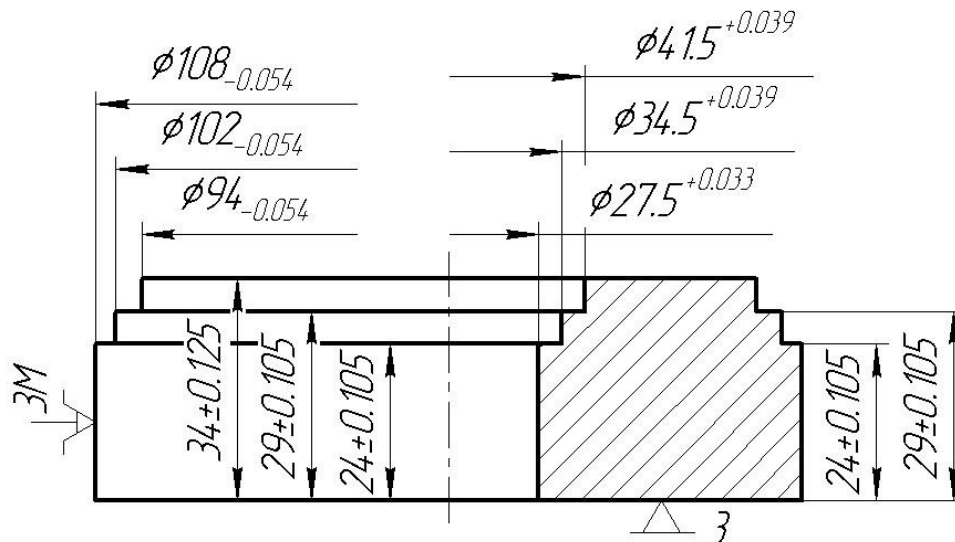
Type of verification	Tolerance for the class of accuracy of lathes, micron	
	N – normal grade of accuracy	VDL-500 (milling machine)
magnitude of radial run out of the outer centering spindle neck	10	6
axial run out of the spindle	10	6
perpendicularity of the spindle rotation axis and the working surface of the table	20	12
radial runout of the conical spindle bore axis	12	8
flatness of the working surface of the table	25	16
parallelness of table surface of longitudinal slide	20	12
parallelness of table surface to guideway console	20	12

To determine the milling machine accuracy VDL-500 based on the power and thermal load, using detail - a disc (Steel 40), are based on three-jaw chuck mounted on the lathe table. This form workpiece shows fully potential manufacturing errors. The shank milling cutter Ø16mm (R6M5) was used as a cutting tool.

Processing details (Figure 2) was carried out on the outer and inner cylindrical surface with the dimensions given in Figure 3.



**Figure 2.** - Picture of ready detail.



**Figure 3.** - Dimensional parameters of the measured detail.

## 2. Results and discussion

After machining of the prototype on a milling machine, measurements were made on the inner and outer surface contact method on the control-measuring machine CNC EOS 5-4-4, direct probe with thread M2, ruby ball 2 mm, length: 20 mm, ERE 14 mm stainless steel rod 1.4 mm in diameter. For the interpretation of these measurements has been used the software Metrologic group.

The measurement results are presented in the following figures:

- 8 and 9 - processing of interior cylindrical surface (hole), B = 8 mm, B = 4 mm, respectively (B - milling width);
- 10 and 11 - processing of external (outward) of the cylindrical surface, B = 8 mm, B = 4 mm, respectively.

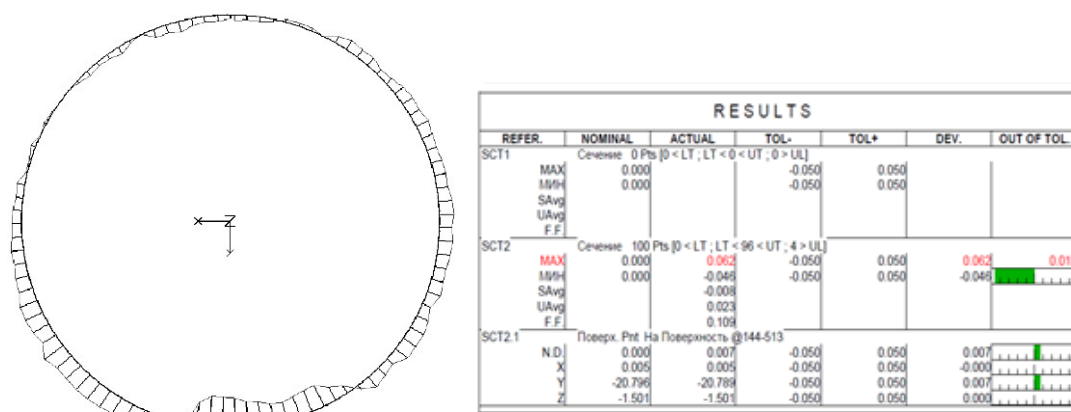


Figure 4. - The interior surface 1/2 of diameter.

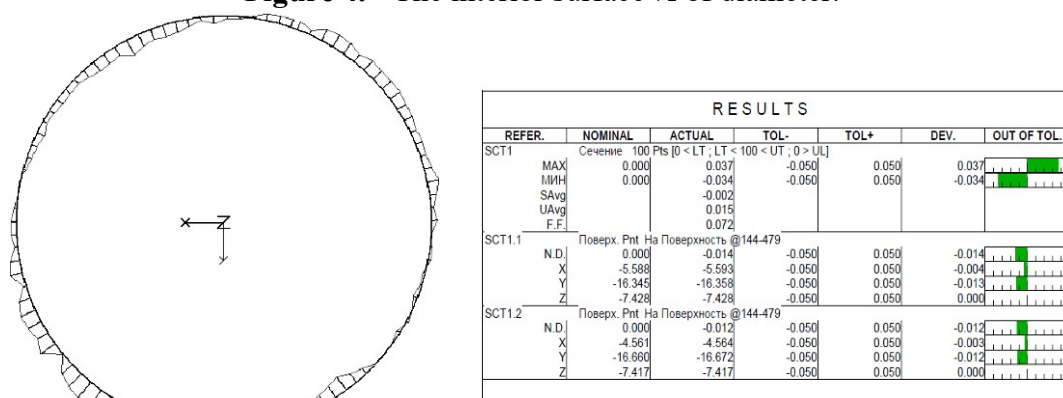


Figure 5. - The interior surface 1/4 of diameter.

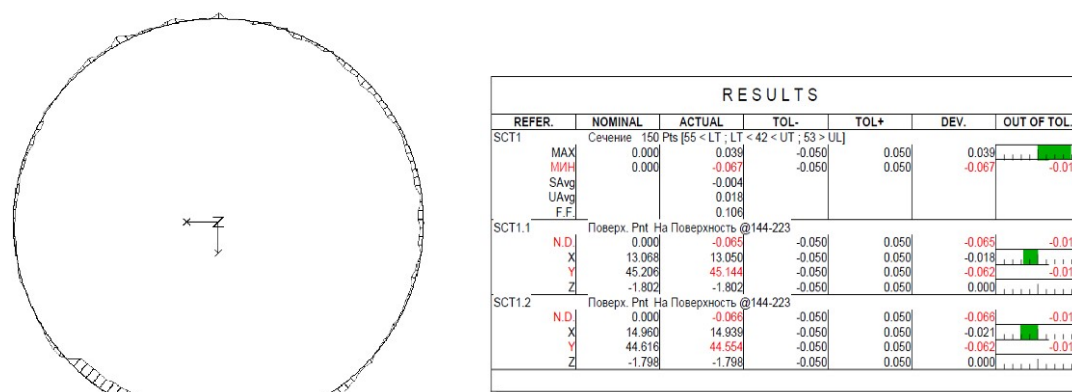
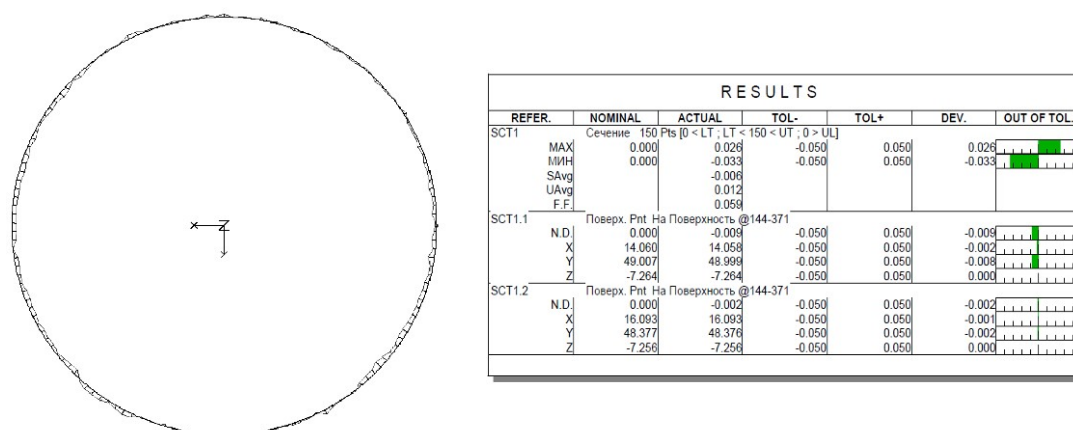


Figure 6. - The exterior surface 1/2 of diameter.



**Figure 7.** - The exterior surface  $\frac{1}{4}$  of diameter

Due to the circular interpolation was ascertained that the form accuracy of surfaces (interior and exterior) varies depending on the position of the machined surface. The closer the surface to the center of the part, the more error handling. Based on the decryption of polar diagrams obtained results allow to state:

- arising inaccuracy exceeds the circularity form tolerance;
- in moments of cutting accord of motion data, as a consequence of its elastic deformation.

According to GOST 17734-88 has been made machine diagnostics VDL-500, a comparative analysis of its results are presented in Table 1.

## Conclusion

1. From the results of polar diagram was seen that by reducing the contact of the working surface of the cutting tool, the resulting size errors due to the reduced contact stress will decrease. Also was educed that in the place of cutting tool is arised upgrade of dimensional allowance.
2. When changing the motion path of the tool perpendicular to tangent (outer surface) and helical (internal surface) is maintaining the size within a tolerance

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