

Entering the operative correction machining processes CNC

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Abstract. The article describes the solution to the problem of compensation of errors occurring during machining on CNC machines. We propose a method of mathematical modeling of processes diagnostics and control of technological equipment. The results of the diagnosis of the CNC machine, as well as the mathematical model describing the dependence of the positioning error of the executive bodies of operating component of cutting force P_z , in the range of movement OX.

Introduction.

The problem of improving the accuracy of process equipment associated with the cutting force caused by the deformation is solved for many years, but it is still not completely solved.

Errors, inaccuracies predefined positioning of the cutting tool in the operating space of the machine are determined or eliminated by CNC systems, where the bodies of stepper drives constantly monitor the position of the working elements of the technological system. However, attempts to solve the problem of occurrence of errors associated with strains did not find their wide application. So the use of adaptive control systems invented B.S. Balakshin not widely used due their improper conditions of modern market economy. After all, in order to stabilize the individual parameters of the cutting process had understate modes, despite the fact that she did not meet the stabilization of optimal performance.

Path to the maximum optimization of cutting process was found only in the 21st century. Scientists from the Tyumen State Oil and Gas University have proposed to introduce corrections in the work process equipment directly in the processing, based on operative diagnostic [1, 2, 3]. So for the regulation of the cutting conditions, it was decided to base, the defined directly in the process of machining, deformation coefficient of the shear layer, and to enter corrections to compensate for deformation in the process system data on power strain on the servo drive of the machine.

Figure 1 shows a diagram of the transformation commands required linear movement into control signals supplied to drive the technological systems that provide real displacement of technological system elements. In modern CNC systems installed better interpolators [4, 5], which provide an estimate on several coordinates and allow you to enter correction to compensate for the errors of single steps and accumulated leadscrew errors. However, the verification of accuracy of positioning is done periodically, and the error is determined by the entire length of the movement of the body of the machine.

Massive use of operative diagnostics and correction is not possible without the of the



universalization of process, which in turn requires the use of mathematical modeling techniques [6, 7].

So for process modeling, it was decided to use the language of mathematical logic, the possibility of having a clear description of the patterns of interaction of elements of technological system.

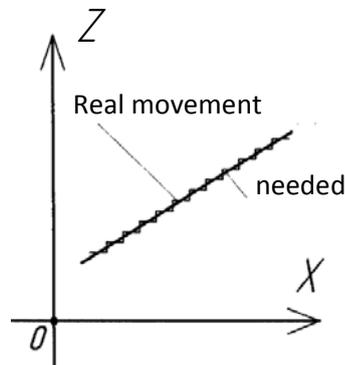


Figure 1. Linear interpolation of movement

To derive a mathematical model, by the language of predicate logic, necessary to draw the alphabet of its operands.

The operands may include elements of the technological system and thereof parts. In addition, alphabet must include all occurring in the process of diagnosis and management of processes and their parameters.

Table 1. The alphabet of operands of mathematical models of processes of diagnostics and management

Technological system elements		
A		Machine tool
	A1	Bed
	A1 ₁	Guide
	A2	Headstock
	A2 ₁	Spindle
	A3	Caliper
	A3 ₁	Instrumental head
	A4	Tailstock
	A5	Power elements
	A5 ₁	Longitudinal feed drive
	A5 ₂	Cross feed drive
	A5 ₃	Main drive
	A6	Table
	A6 ₁	Rails
B		Instrument
	Bn	Instrumental element
C		Workpiece
	Cn	Workpiece element
D		Load device
	D1	Simulating the cutting force P
	D2	Simulating the component of cutting force P _x
	D3	Simulating the component of cutting force P _z
E		Measuring device
	E1	Measuring device probe

	E2	Instrumental measuring device
	E3	Measuring ruler
	E4	Cutting layer deformation meter
F		Auxiliary tool
	F1	Holder
	F2	Front center
	F3	Rear center
G		Information system (CNC)
	G1	Diagnostic data registration system
	G2	Correction calculation system
	G3	Lathe management system
		Processes
L		Diagnostic system
	L1	Technological system cutting force deformation process
	L1 ₁	Cutting force workpiece deformation process
	L1 ₂	Caliper deformation diagnostic process
	L1 ₃	Instrumental head shift diagnostic process
	L1 ₄	Temperature deformation diagnostic process
	L1 ₅	Straightforwardness rails deviations process
	L1 ₆	Cutting layer deformation diagnostic process
	L1 ₇	Feed drive load characteristics diagnostic process
M		Machining process
	M1	Process parameters
	M1 ₁	Cutting modes
	M1 ₂	Cutting tool movement trajectory
N		Diagnostic data registration process
O		Correction calculation process
	O1	Correction vectors according to the operational diagnosis force parameters
	O2	Correction vectors according to of operative diagnostics of temperature settings
	O2	Correction vectors according to preliminary diagnostic
	O3	Cutting modes corrector
P		Corrections entering process
		Measurement parameters
S		Diagnostic parameters
	Δ^{tc}	Lathe technological system deformation
	ΔX^3	X-axis workpiece deviation
	ΔZ^3	Z-axis workpiece deviation
	ΔX^{A3}	X-axis caliper cutting force deviation
	ΔZ^{A3}	Z-axis caliper cutting force deviation
	ΔX^{A31}	X-axis instrumental head deviation
	ΔZ^{A31}	Z-axis instrumental head deviation
	ΔR	Cutting tool wear
	V^z	Longitudinal feed drive stress
	V^x	Cross feed drive stress
	ξ	Shear layer deformation coefficient

For example, to simulate the process of diagnostics deviations contour cutting tool [8, 9, 10], the operands are used, indicating the location of the operation, the object and the subject of the process, as

well as the conditions and the output function describing the result.

1) Model diagnostic tool wear:

$$A \exists \left(B \begin{matrix} 1^\circ \\ \exists \\ \varphi_1 - \varphi_2 \end{matrix} \Delta_R \wedge E2 \right) \in (f : \varphi \rightarrow \Delta_R) \Rightarrow G1 \exists G \tag{1}$$

Reading as: For A machine tool in there instrument B, where there are deviations from the original contour Δ_R in the range of $\varphi_1 - \varphi_2$ with steps 1° when measuring device E2, described by the function f with range φ and domain Δ_R of the recorded data acquisition system diagnostics GL, of the CNC G

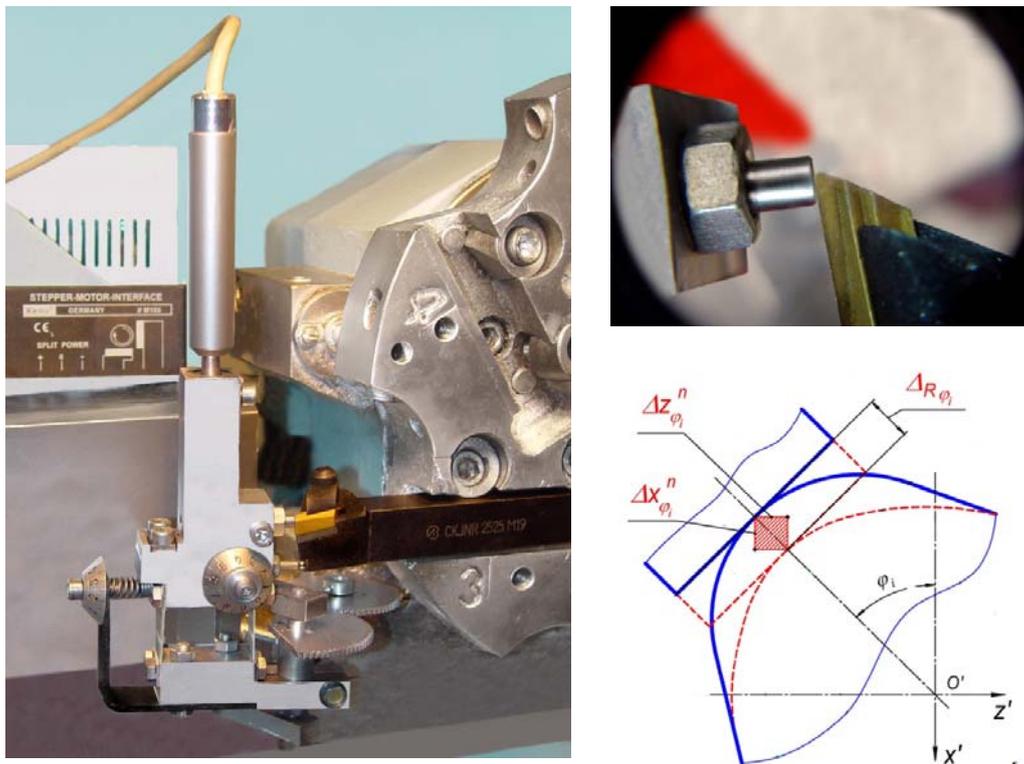


Figure 2. Tool wear diagnostic

Thus, the mathematical model of the process diagnostics of deformations in the technological system has the form:

$$A \exists \left(\begin{matrix} \exists A3 \\ \pm OZ \end{matrix} \exists \begin{matrix} A3 \\ \pm OX \end{matrix} \wedge D3 \exists \Delta X^{A3_1} \wedge E1 \right) \in (f : OZ \rightarrow \Delta X^{A3_1}; P_X) \Rightarrow G1 \tag{2}$$

Reading as: For A machine tool exists, having the ability to move along the axis OZ, caliper A3 and installed on it, which has the ability to move along the axis OX toolholder A3_L, measuring arising under the influence of the load device D3 positioning error ΔX^{A3} determined by reacting with measuring device E1, described by the function f range of values OZ and domain and P_X, recordable data recording system diagnostics GL.

For diagnostic results generated depending on the direction of movement and direction of the load elements of the technological system (figure 3) were constructed three-dimensional graphs of variation in the positioning of the load carriage operation range shown in Figure 4.

As a result of the approximation of diagnostic data we obtain the dependence of deviations positioning along the OZ axis of the component P_X of the cutting force over the entire range OZ

machine coordinate. So to determine the surgical correction is enough to know only the forces acting at a particular time on the elements of the machine.

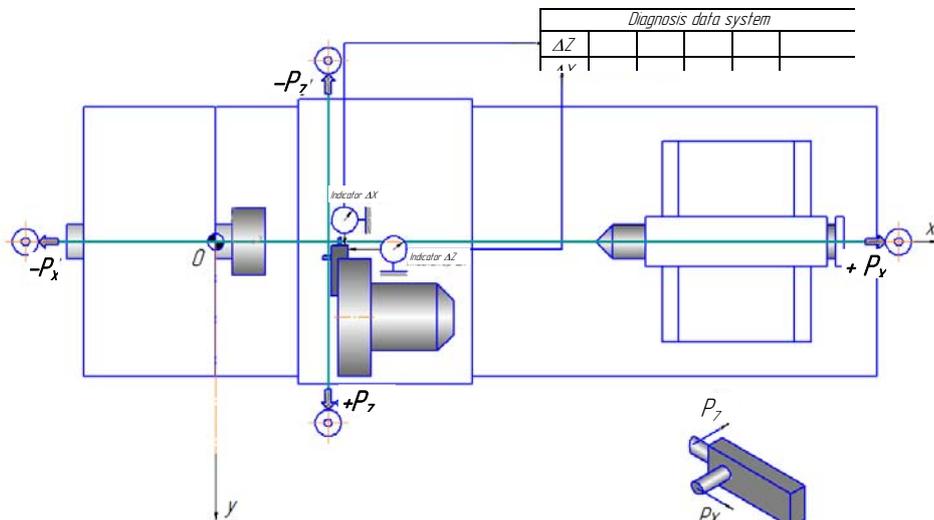


Figure 3. Technological equipment deformations diagnostic

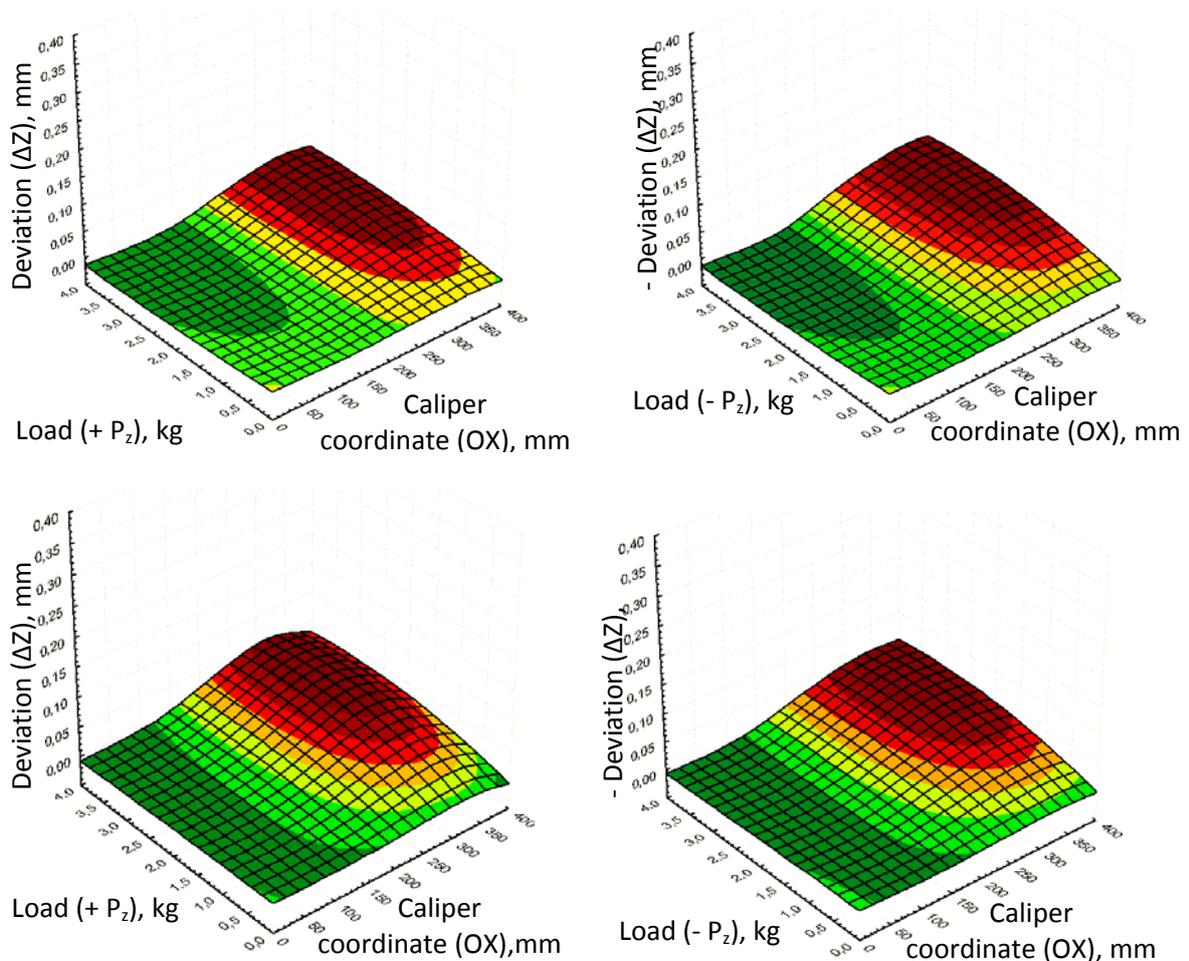


Figure 4. The dependence of deviations from the positioning of the load caliper in the operating range

After converting the surface by smoothing the quadratic polynomials we obtain the second degree, respectively, with positive and negative loading and forward and backward movement of the caliper.

Mathematical models of deviations with positive and negative loading and forward and backward movement of the caliper

$$\begin{aligned}\Delta Z &= -0,0027 - 2,9192 \cdot 5 \cdot X - 0,0039 \cdot P_z + 1,5938 \cdot 7 \cdot X^2 + 3,4677 \cdot 5 \cdot X \cdot P_z - 0,0005 \cdot P_z^2 \\ \Delta Z &= -0,0048 - 3,1299 \cdot 5 \cdot X - 0,0008 \cdot (-P_z) + 2,1588 \cdot 7 \cdot X^2 + 4,4859 \cdot 5 \cdot X \cdot (-P_z) - 0,0013 \cdot P_z^2 \\ \Delta Z &= -0,0134 + 0,0001 \cdot X + 0,0087 \cdot P_z - 1,7195 \cdot 7 \cdot X^2 + 3,8369 \cdot 5 \cdot X \cdot P_z - 0,0028 \cdot P_z^2 \\ \Delta Z &= -0,0069 + 1,6564 \cdot 5 \cdot X + 0,0067 \cdot (-P_z) + 8,5116 \cdot 8 \cdot X^2 + 4,2091 \cdot 5 \cdot X \cdot (-P_z) - 0,0025 \cdot P_z^2\end{aligned}$$

Supplied directly to the interpolator move command can take into account the necessary corrective feedback, calculated on the basis of the application submitted by mathematical models. That is counted identified errors of technological system.

In addition to the data obtained as a result of diagnostics, it is assumed the input error correction eliminates determined by operative diagnosis and regulatory regimes in order to optimize the cutting process.

Summary

The method of simulation processes using mathematical logic and the proposed method of surgical correction of the input to the control program of the CNC machine directly to the interpolator - tested and have been known for many years. However, to realize the full possibilities offered by these methods appeared only with the invention of new ways to diagnose the cutting process. Applying the proposed methods can also be offset and error caused by other factors

References

- [1] Putilova U S, Nekrasov Yu I and Lasukov A A 2014 Loading of the manufacturing systems elements in the process of unsteady mode cutting and the models of their arrangement deviations *Applied Mechanics and Materials* Vol. 682 pp 192-195.
- [2] Nekrasov R Yu, Soloviev I V and Putilova U S 2015 Laser interferometry method of stress determination in loaded cutting tool parts *Applied Mechanics and Materials* Vol. 698 pp 537-541.
- [3] Nekrasov R Yu, Putilova U S, Starikov A I and Kharitonov D A 2014 Diagnostics of cut-layer deformation and rational tool loading in numerically controlled lathes *Russian engineering research* vol. 34 No. 12 pp 826-828.
- [4] Tetia R, Jemielniakb K, O'Donnelle G and Dornfeldd D 2010 Advanced monitoring of machining operations *CIRP Annals - Manufacturing Technology*, Vol. 59 Issue 2 pp. 717–739.
- [5] Schneidera Ulrich, Olofssonb Björn, Sörnmob Olof and Drusta Manuel Anders Robertssonb, Martin Hägelea and Rolf Johanssonb 2014 Integrated approach to robotic machining with macro/micro-actuation *Robotics and Computer-Integrated Manufacturing*, vol. 30 Issue 6 pp. 636–647.
- [6] Kadira Aini Abdul and Xua Xun 2011 Towards High-Fidelity Machining Simulation *Journal of Manufacturing Systems* vol. 30 Issue 3 pp. 175–186.
- [7] Shalamov V G 2007 Mathematical simulation when cutting metals: study guide Chelyabinsk. SUrSU press.
- [8] Nekrasov R Yu, Starikov A A and Korchuganov M.A. 2014 Performance assessment of carbide tooling under thermal and loading conditions *Applied Mechanics and Materials* Vol. 682 pp 414-417.
- [9] Petrova V A, Bakanov A A and Walter A V 2014 Crack Resistance of Weld Seals, Hardening Methods and Composite Tools Quality *Applied Mechanics and Materials* vol. 682 pp. 431–437.
- [10] Ovcharenko V E 2012 Evolution of the structure of plasma metal-ceramic coating under pulsed electron-beam treatment *Inorganic Materials: Applied Research* vol.3 pp. 210-215