range, are between *0,003s* and *0,005s.* Time-constants of executive element, which are applied during constructing SAC by elastic-deformable state, usually increase the pointed value by an order of magnitude. Hence, the range of important frequencies is defined by the executive element's inertia and is localized more to the left than range of frequencies that are defined by dynamical characteristics of considered object.

In case of interferences in the form of exponential-cosines function, the optimum controller for the model is the typical proportional controller, which proportionality coefficient is defined by selected level of limitations on the control reaction.

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MODELING PARAMETERS OF THE SURFACE COARSENESS IN AUTOMATED SHAFTS PROCESSING

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In article was introduced process of roughness parameters modeling by shafts turning. Introduced model comply influence of technological parameters of turning process, turning parameters, stages waste and working period of blade. The comparative analysis of experimental results and computer simulation the mathematical model was introduced.

Manipulating the products quality at metalwork designing process level requires modeling the process of forming the part quality parameters, e.g. roughness and corrugation. The most important forecasting parameter is quality. This is because defects at final process stage cannot be fixed. Turning process is usually final stage process. High quality of the numerically controlled machines, the high performance of the machining tool and rolling optimal parameters selection guarantees rolling without surplus, burnouts and vibrations.

Control quality parameters is possible both at the stage of designing technology - technological production preparation and as well as at direct control of technological processes and operations. Analysis and optimization of the technology variants is more appropriate at the designing stage. This is because choice of the optimal variant are shortening, new products preparing efforts are decreasing thus simplifying technical resources, directly controlling machining devices. To create such a forecast at the stage of preparing the production and control automatic of parameters quality in metalwork we need to build mathematical model of quality parameters shaping.

Carried out earlier the researches are enabling the irregularity at turning modeling, assuming that:

- the knife is migrating towards the object in conformity with kinematics of turning;
- the knife is making oscillation according with direction of turning radial force - F_p;
- the blade is carrying the profile of its hip to the processing object.

By performing showed force interactions elastic displacement any object free point y_1 can be introduced as [5]:

$$y_1 = \left\{ y_0 K_1(\alpha x) + \frac{\Theta_0 K_2(\alpha x)}{\alpha} + \frac{M_0 K_3(\alpha x)}{\alpha^2 EI} + \frac{Q_0 K_4(\alpha x)}{\alpha^3 EI} + \frac{F_0 K_4[\alpha(x-a)]}{\alpha^3 EI} \right\} \cos \omega t, \tag{1}$$

where: K_1, K_2, K_3, K_4 are A. N. Kryłow's bar functions, where:

$$\alpha = \left(\frac{m\omega^2}{EI} \right)^{0,25}$$

Displacement the blade hip y_2 toward acting of F_p force was introduced in form of the harmonic function of the time at the same timescale as extorting force

$$y_2 = y_{20}(x) \cos \omega t. \tag{2}$$

Searching mutual displacement y_i of the object y_{i1} and the blade hip y_{i2}, determining turning irregularities is possible to introduce as:

$$y_i = y_{i1} + y_{i2}. \tag{3}$$

Result of size of the surface roughness irregularities, depicting profilogram, is creating as a result of adding to calculated earlier movement matrix the irregularity matrix $\{h_j\}$ received by putting on y_i displacements the blade hip profile in the basic surface which is approximately possible to describe with the arc of the r_p radius (fig. 1).

Distance between curve y_i and y_{i+1} is choosing equal of feed f = s by turning. Calculations are being carried as follows: ordinates of U_1 and U_2 points put in the centre of the gap are being determined and go out from the irregularity profile a smaller ordinate is being chosen as h_j (fig. 2) [2.3].

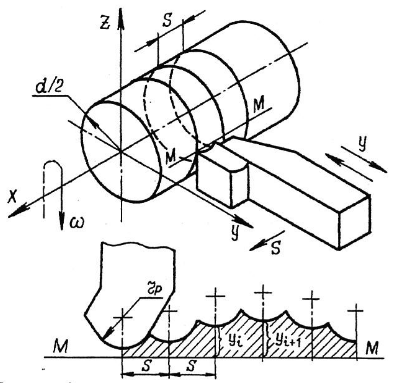

Fig. 1. Diagram showing irregularity at rolling formation, where M_M is a route of the profilogram; y_i and y_{i+1} is a mutual parts and blades movement sizes.

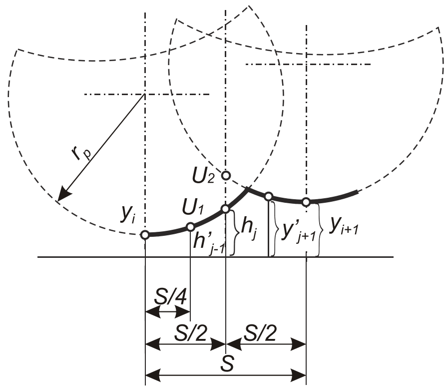

Fig. 2. Scheme of putting the blade profile to modeled profilogram (s=f)

From geometrical deliberations (s = f):

$$h_j = y_i + \left(r_p - \sqrt{r_p^2 - \frac{s^2}{4}} \right) \approx y_i + \frac{s^2}{8r_p}, \;\; h_{j+1} = y_{i+1} + \frac{s^2}{8r_p}, \;\; h_j = h_{j\,\min}, \quad (4)$$

$$h'_{j-1} = y_i + \frac{s^2}{32 r_p}, \;\; h'_{j+1} = y_{i+1} + \frac{s^2}{32 r_p}.$$

The roughness and wavinesses parameters are being calculated using the information from profilogram. Taking random parameters character into consideration micro and macro irregularity, according to physics and technological theory of object irregularity formation, profile parameters are described as averaged sizes, taking their possible exceed into consideration [5].

Analysis of works [1,2,3] is resulting, that possible value deviations of extreme ordinates size to their averages values isn't bigger than the 25%. The instrument accuracy of roughness surface measurements is around of the 10%. Allowing the 25% of the forecast mistake lets us use the deterministic modeling approach which mean, while modeling we can assume that minimal irregularity size can appear. Such surface modeling approach is confirming in experimental researches. Results of technological factors influence on surface roughness parameters examinations were introduced below.

Carried out researches are showing that at durability hip blade period top roughness parameters are increasing to 100%. Basis on experimental researches were received following equation:

$$r_p = r_{p0}\left[1 + m_1 \left(\frac{t_{rob}}{T} \right)^{m_2} \right], \quad (5)$$

where:

r_{p0} - round radius of the blade hip corresponding to the initial durability stage; t_{rob} - blade working time; T - blade durability period; $m_1 = 0{,}6$; $m_2 = 1{,}6$ - coefficient received at steel 45 with the knife with the T15K6 tile turning, speed of machining $v_c = 85$ m/min, feed f = 0,2 mm/rot., machining depth $a_p = 2$ mm.

Specificity of finishing machine processing at the small machining depth is a contact of the blade with the surface received in the previous processing operation, submitting plastic deformation. However the initially deformed area is keeping the elasticity which causes material rising after blades leaving. Taking the specificity of the two objects contact into consideration it is recommended to carry with applying the $HB^{0,5}E^{-1}$ parameter, where HB - hardness softer cooperating material, E – Young module of this material.

At modeling the surface irregularity as a tool trace we need to take into mutual movement the object and tools by machining. Mutual y displacement part and the blade is determined with the size of radial force F_p, according to type of processing parts: stiff or with small stiffness, appropriately with the stiffness of the technological system C_{st} or the stiffness of this part:

$$y = \frac{F_p}{C_{st}}. \tag{6}$$

The technological arrangement stiffness or part stiffness is changing slightly on a small stretch of the tool road, however the F_p component of machining force is changing in the considerably bigger scope.

The radial component of machining force Fp is being calculated with recommended parameters as [4]:

$$F_{p0} = F_{ptab} K, \tag{7}$$

where:

F_{ptab} - value on a board forecast of machining force at chosen machining parameters and machining blades material, K - rate taking the part hardness change.

Radial part of machining force is determined in any future calculations taking the relation into consideration

$$F_{ptab} = 1039 K_{\kappa} a_p^{0,6} f^{0,8} v_c^{-0,3} [N], \tag{8}$$

where: K_κ=0,5 at $\kappa_r = 90^0$.

Carried out researches showed that surface hardness in one part range was taking turns to the 300% and more. Experimental researches of surface hardness changes was carried according to following schema. After considering radial profilograms are taken by touching surfaces along with chosen routes, according to those routes surface hardness measurement was taken, with step equal to feed by turning 0,1-0,2 mm.

A dependence of the K rate on the semi-finished product hardness was received while objects where processing with steel knives equipped with tiles from hard alloys:

$$K = 0{,}1\ HB^{0,4}. \tag{9}$$

We can express the hardness of the part surface layer in the general case as

$$HB = HB_1 \left[1 + \left(\frac{HB_2}{HB_1} - 1 \right) \kappa_1 \right], \tag{10}$$

where: HB_1 i HB_2- appropriately minimum and maximum value of the part hardness; κ_1- random size, from range $0 \le \kappa_1 \le 1$.

While taking equations (7) and (9) value of radial force F_p is determined according to the relation:

$$F_{p0} = 0{,}1 F_{ptab} \left\{ HB_1 \left[1 + \left(\frac{HB_2}{HB_1} - 1 \right) \kappa_1 \right] \right\}^{0,4}. \tag{11}$$

Waste and blunt of tool leads to cutting force increasing which causes object and the tool mutual movement increasing. A result of researches for steel parts processing using carbide knifes complying blade work received the relations:

$$F_p = F_{p0}\left[1 + 0{,}6\left(\frac{t_{rob}}{T}\right)^{1{,}8}\right], \tag{12}$$

where: F_{p0} – radial force sharp blade.

Substituting the expression (12) to the relation (6) lets determine matrixes $\{y_i\}$ of mutual displacement of parts and blades for roughness modeling machining parts.

Results of modeling resilient displacement and roughness characteristics according to the approximate model were introduced on fig. 3. Calculations were being led at parameters: hardness HB_{min}=140, HB_{max}=240, shank weight 8 kg, eccentric weight 0,2 kg, eccentric radius $5\cdot10^{-5}$m, turning object steel type 45, blades with carbide plate T15K6.

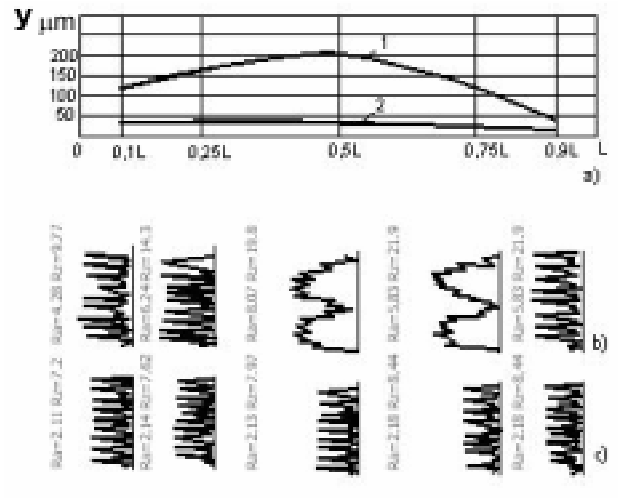

Fig. 3. Relation of elastic strains change in the shaft processed across the length: a) 1-d=10mm curve, L=200mm, f=0,1mm/ob., v_c=3m/s, a_p=1mm, $\kappa_r=45^0$, r_p=0,15mm; curve 2 - d=20mm, L=200mm, f=0,1mm/ob., v_c=3m/s, a_p=2mm, $\kappa_r=45^0$, r_p=0,15mm; b) roughness characteristics change at turning d=10mm shaft; c)roughness characteristics change at turning d=20mm shaft

Analysis of received results lets draw a conclusion that increasing the part diameter two times at the same length leads to decreasing resilient parts displacements (taking the spindle stiffness and eccentric weight practically from 7 to 8 times and roughness parameters in the most dangerous profile along the part 2,5 times into consideration). Mistakes of roughness modeling didn't cross the 20% on average compared with experimental data for the same conditions of turning.

Quoted mathematical models of quality parameters shaping are appropriate for automated designing system modules to designing and optimizing turner's technology. Presented models are minimized and adopted to allow calculations on personal computers. These models are enabling along with simple task – estimation of possibility use one of processing manner elastic-deformers shafts about small stiffness, also more difficult tasks - choice of optimal technology according to objective quality parameters.

In aim of adequacy estimation processed models realized series laboratory and industrial researches. Findings of experimental researches are confirming models analytical calculations, differences aren't exceeding the 40%. Differences in results are caused by models accepted assumptions and mistakes of measurements, especially at the roughness parameters estimation.

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