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V.STUPNYTSKYY, PhD, National University “Lviv Polytechnic”

A GENERALIZED EXAMPLE OF STRUCTURAL AND PARAMETRIC OPTIMIZATION OF FUNCTIONALLY-ORIENTED PROCESS

The example of structural and parametric optimization of the functionally-oriented technological process machining of mold’s parts is described in the article. The most essential criteria of optimization are wearproofness, fatigue strength, contact stiffness and corrosion resistance of production. In the article the brought methodology over of researches and algorithm of optimization.

Keywords: functionally-oriented technological process, optimization, wear resistance, residual stress, contact stiffness, corrosion resistance, coefficient of friction, CAF- system

Introduction. The systems approach to technological ensure efficiency components based on the one hand, the evaluation of parts quality indicators that characterize their geometric shape, surface layer microstructure and its physical and mechanical properties (including residual) based on technological factors and other hand, the forecasting measure parts properties (wear resistance, the contact stiffness, corrosion resistance, etc.) depending on their quality. Obviously, providing only some local indicators of quality products not guarantee optimal measure properties of the product as a whole. It is therefore necessary to design functional- oriented process, based on the analysis of a set of interrelated operational measures of the product.

Manufacture of various parts of dies and molds is extremely difficult in modern engineering. This is due to their high accuracy, low roughness of the functional surfaces, significant temperature changes during operation (to 500-700°C), difficult workability of these parts material, high frequency and intensity of cyclic and alternating loads more. Particular attention to the operation of molds are ejectorP. As described in [1] statistics bounce functional parts and assemblies molds, pushing the system accounts for 25-30 % of all failures at work and breakdowns of these productP. This is due to high-frequency complex thermodynamic operating conditions ejector, cooling problems, combined with their non-rigid structure (ratio of length to diameter in the range of 15-20), the requirements of superdense mobile connection tightness, wear resistance, fatigue strength and high manufacturing quality (precision size - 5-7 ISO accuracy degree, functional surface roughness - 0.2-0.8 microns, etc.). The working surface of the mold insert with ejector form a joint that can roll over. During this period numb molten metal, forming fin on the casting surface. Therefore, the gap between the ejector and the hole in the ear performed within 0,08-0,1 mm. On the other side, this gap should be the maximum, it depends on the use of materials for inserts and ejector fabrication, casting material, temperature, pouring temperature heating molds, liquid metal flow rate, specific pressure on the walls of the working cavity and other factors [2].

In this example ejector is made from the high-alloy low-carbon steel 316L. This design element is subject to intense wear and alternating power and thermal loads during operation, which combined to cause loss of use of molds in general. Therefore, the most important measure properties ejector is wear resistance, contact stiffness, fatigue strength and corrosion resistance. The above measure properties depend strongly from parameters such as surface layer microstructure, functional surfaces microhardness (hardness of the surface layer), character and depth of the residual stress and deformation.

Measure as a working surface formed mainly at the final stage of the process manufacturing ejector comprising finish turning and smoothing diamond shapeP. It is the final stage of manufacturing ejector investigated in part in this example. Principles of functional and process -oriented indicators formation of a product intended to for given values of quality parameters of the finished part, known range of values of the original piece and given information about their transformation, technological heredity and mutual influence in the formation of functional surfaces to develop the most efficient technological process to ensure the optimal combination of product quality parameters

Main part. Consider the implementation of 2 version workflow handling most accurate cylindrical surface on finish operation.

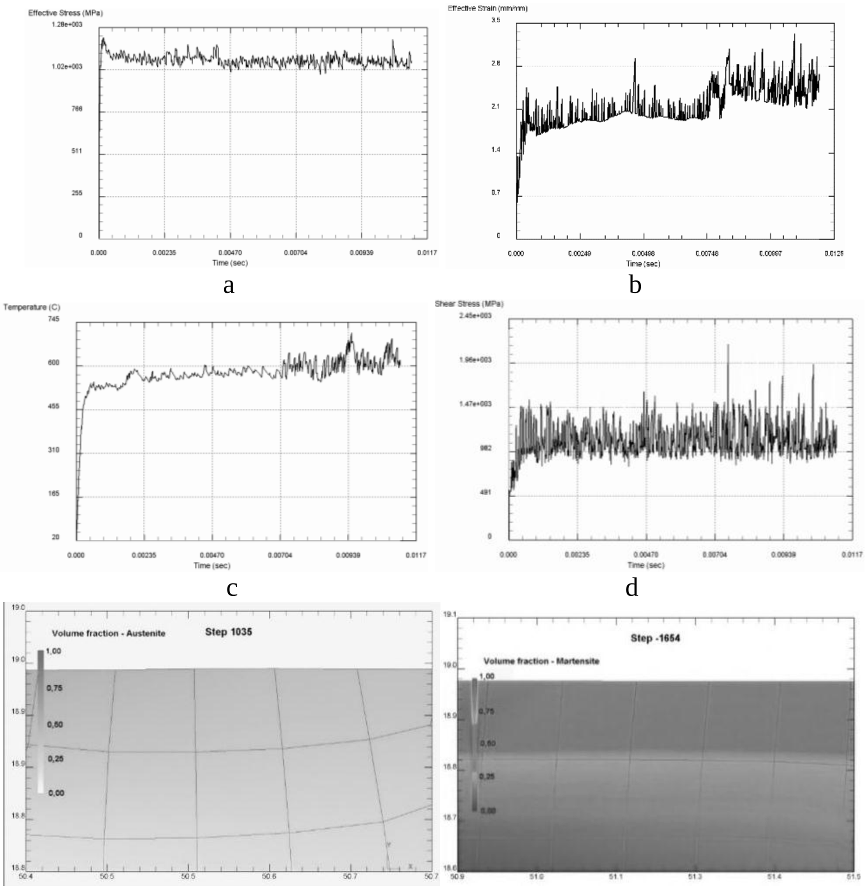
– 1-st variant. Finish grinding by the abrasive wheel.

– 2-nd variant. Fine turning tool with synthetic polycrystalline diamond - carbonado (as an example, suggested the use of PCD universal mark - CTM302 ElementSix [3]).

To determine the basic measure criteria functionally-oriented technological process mold ejector machining, it is necessary to analyze the mechanisms of formation parameters durability, fatigue strength, corrosion resistance and so on. To do this, CAF system simulation rheological model of formation of base surfaces ejector and identify indicators of stress- strain state (including residual) parameters mikrotopolohiyi surface and its structural and phase state as a result of cutting [4,5].

Featured [6] geometrical parameters for sharpening cutters with PCD γ = 15-20°, α = 10-12°, r = 0,3-0,5 mm. Tools with circles sharpen PCD ACB 100/80-50/40 TO2 50% with the use of lubricoolant containing water as coolant soda solution. After bringing sharpening is performed by iron discs, overact diamond powder ACM 40/28-28/20. The model implemented within the system Deform-2D, use: type of modeling - Lagrangian Incremental (Lagrangian Analysis) with gradient mesh (ratio - 0.1 mm); shows the geometry of the object modeling - Plane Strain; object type modeling: workpiece - Elasto-Plastic; tool - Rigid; iterative method for solving problems - Newton-Raphson; condition of convergence calculation - Conjugate-Gradient Solver (combined gradient method); condition yield stress - Generalized Johnson & Cook Model; criterion destruction - Normalized C & L Fracture; model of structural phase machinings - Avrami model.

Results of simulation of rheological modeling are shown in Figure 1.



a b

c d

i f

Fig.1–Results of the rheological modeling machining mold's ejector by tool with synthetic polycrystalline diamond CTM302. a - effective stress; b – effective strain; c - temperature in the cutting zone; d – shear stress; i-f - picture structure and phase state of the surface after machining.

Microprofile finish surface, which determines the value of its roughness, formed by vector addition of three components: the microscopic height derived as a result of copying the cutting wedge tool considering its kinematic characteristics of motion (Δ_1), microscopic height, which is determined by fluctuations in the elements of the cutting tool (Δ_2) and the component profile roughness caused by plastic deformation in the contact zone of tool and workpiece (Δ_3).

Geometric-kinematic component of roughness Δ_1 under the conditions: $\varphi > \arcsin\left({}^{S}\!/_{2r}\right)$ i $\varphi_1 \geq \arcsin\left({}^{S}\!/_{2r}\right)$ after transformation in Chebyshev equation [7]:

$$\Delta_1 = \frac{S^2}{8r} = \frac{0{,}05^2}{8 \cdot 0{,}5} = 0{,}000625 \; mm = 0{,}625 \; mic \qquad (15)$$

Method of determining the microscopic of roughness height, which is determined by fluctuations elements of the cutting tool (Δ_2) is written in [8]. Moreover, the nonlinear dynamic model of self-oscillation technology system allows for regenerative mechanism of excitation of vibrations when moving the tool along the workpiece surface formed by the previous machining (Ra_{i-1}=5 microns). In the model the cutting force depends on the geometrical parameters of the tool and mechanical properties of orthogonal cutting:

$$\begin{cases} M\ddot{x} + K_X \dot{x} + C_X x = \tau_{xy} \cdot S_i \times \\ \times \left(b_1 + \dfrac{S_{i-1}^2}{16r}\left(1 + sin\left(\dfrac{2\pi x}{S_{i-1}} - \dfrac{\pi}{2}\right)\right)\right) \dfrac{cos(\eta - \gamma)}{sin\beta \cdot cos(\beta + \eta - \gamma)} \\ M\ddot{y} + K_Y \dot{y} + C_X y = \tau_{xy} \cdot S_i \times \\ \times \left(b_1 + \dfrac{S_{i-1}^2}{16r}\left(1 + sin\left(\dfrac{2\pi x}{S_{i-1}} - \dfrac{\pi}{2}\right)\right)\right) \cdot \dfrac{sin(\eta - \gamma)}{sin\beta \cdot cos(\beta + \eta - \gamma)} \end{cases} \qquad (16)$$

Surface microrelief in the transverse direction is modeled by imposing an array of tool motion profile in terms of its summit, which describes an arc with radius R. In this case [9]

$$\Delta_2 = 2A_{max} - H_B = 2 \cdot 0{,}00027 - 0{,}00015 = 0{,}00039 \; мм = 0{,}4 \; мкм \qquad (17)$$

where $A_{max} = \dfrac{\chi}{\sqrt{(J^p + \chi - mp^2\omega^2)^2 + \mu_{mp}^2 p^2 \omega^2}} H_в$ - maximum amplitude of oscillation tool, determined in solving the differential equations of the tool motion; J^p - radial stiffness of the technological system, N/mm; (χ - coefficient depending on the specific machining conditions; m - reduced mass of the moving system, kg; $\omega = \dfrac{\pi n}{30} = 167{,}5$ rad - cyclic frequency of the main motion; $H_{в\_i-1} = \dfrac{Ra_{i-1}}{2} = 0{,}0025 \; мм$ - amplitude of surface irregularities resulting from implementation of previous technological machining.

It is the top of the tool in this technological machining step:

$$H_{в\_i} = R - (R - r)\cos\frac{\psi}{2} - \sqrt{r^2 - \left((R - r)\sin\frac{\psi}{2}\right)^2} =$$

$$= 0{,}85 - (0{,}85 - 0{,}5)\cos\frac{0{,}143}{2} - \qquad (18)$$

$$- \sqrt{0{,}5^2 - \left((0{,}85 - 0{,}5)\sin\frac{0{,}143}{2}\right)^2} = 0{,}00015 \; мм$$

Where central angle tips:

$$\psi=\arccos\left(1-\frac{S^2}{2\left(R-r\right)^2}\right)=\arccos\left(1-\frac{0{,}05^2}{2\left(0{,}85-0{,}5\right)^2}\right)=0{,}143\ \textit{рад} \tag{19}$$

Component profile roughness caused by plastic deformation in the contact zone of tool and workpiece Δ_3 determined from the [7] under the conditions: $\varphi>\arcsin\left({}^{S}\!/_{2r}\right)$ and $\varphi_1\geq\arcsin\left({}^{S}\!/_{2r}\right)$:

$$\Delta_3=\frac{\left(1-\frac{\tau_{xy}}{\sqrt{\tau_{xy}^2+\bar{\sigma}^2}}\right)\cdot\left(2S_i+\frac{r}{2}\cdot\left(1-\frac{\tau_{xy}}{\sqrt{\tau_{xy}^2+\bar{\sigma}^2}}\right)\right)}{64}=$$

$$\frac{\left(1-\frac{992}{\sqrt{992^2+1099^2}}\right)\cdot\left(2\cdot 0{,}05+\frac{0{,}5}{2}\cdot\left(1-\frac{992}{\sqrt{992^2+1099^2}}\right)\right)}{64}=0{,}0001\ \textit{мм}$$

where τ_{xy} - dynamic shear stress, MPa; $\bar{\sigma}$ - effective mean stress, MPa.

So, in this case the average value of the roughness derived as a result of copying the cutting wedge tool considering its kinematic characteristics of motion (Δ_1) constitute 55,5%, microscopic height, which is determined by fluctuations elements of the cutting tool (Δ_2) – 34,7% and the component profile roughness caused by plastic deformation in the contact zone of tool and workpiece (Δ_3) - 9,8%, respectively. Thus, the result $Ra=0{,}625+0{,}39+0{,}13=1{,}125\ mic$ corresponding specifications drawings (set $Ra=1{,}25\ mic$).

In Fig.2 is shown the picture of residual stresses rheological modeling as a result of finishing lathe machining mold’s ejector tool with synthetic polycrystalline diamond CTM302. These stresses exponential decrease as a result of thermodynamic relaxation with increasing distance from the top of the cutting wedge along the machined surface. The depth of plastic deformation is based on solving of the Prandtl problem [7].

The curve of residual stresses I type (Fig.2) shows an interference pattern manifestation fluktatsiynyh stretching (temperature and friction) and compressive (force) loadP. Average values the of residual stresses in the zone of thermal stabilization (at about 100°C) will be approximately 170 MPa for machining the workpiece ejector manufactured from steel 316L by tool with synthetic polycrystalline diamond CTM302.

Steel 316L has high viscosity due to the low carbon content. In the annealed steel contains about 12% soluble carbide M6P. Hardening steel in oil at a temperature of 1050 - 1100°C dissolved in austenite is about 7 % of carbides, enriching it with carbon, tungsten and chromium.

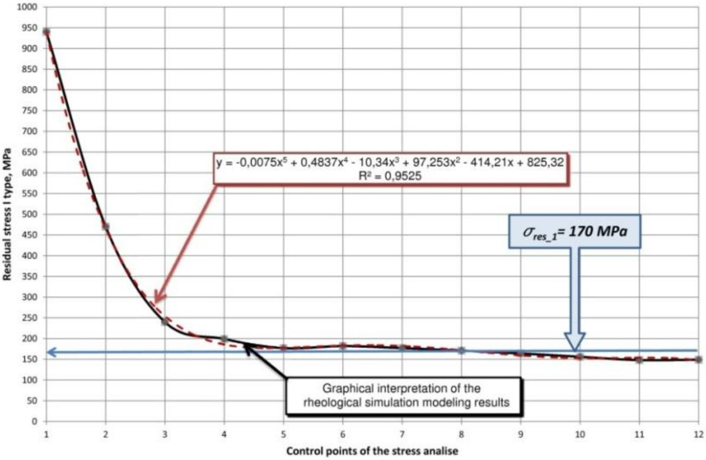


Fig.2 – Graphical dependence of residual stresses I type, resulting in rheological modeling technology finishing lathe mold's ejector machining by tool with synthetic polycrystalline diamond CTM302

After quenching structure consists of alloyed martensite, 5% excess carbides and a small amount of residual austenite, HRC 48-50. After tempering at 600 - 620°C structure consists of troostyta and 5% excess carbides, HRC 38-44. Carbide M6S coagulates only at temperatures above 600°C that provides high red hardness and heat resistance. Thus, if the machining of hardened steel 316L parts a martensitic structure in the surface layer, there will be a of martensite-austenite or martensite-troostite structure, then treated will create conditions of residual tensile stress since $1-\frac{\rho_1}{\rho_2}>0$.

Structural volume austenitic phase ζ_A was determined from the joint modeling of thermal fields and structural phase machinings using the Avrami equation [10]:

$$\zeta_A = 1 - exp\left\{-k\cdot\tau^n\right\} \qquad (20)$$

where ζ_A - volume fraction of austenite phase formed by machining; k and n - kinetic parameters calculation which takes place from the kinetic diagrams of austenite decomposition [11]; τ - cutting time.

Thus, the modeled stress-strain and thermodynamic state of the cutting area and with empirical coefficients $\psi_1, \psi_2, \psi_{31}, \psi_{32}, \psi_4$ [12], you can make a simulation of residual stresses II type in the environment Deform HT 2. We can use the coefficients in Maggie equation:

$$\zeta_M = 1 - exp\left\{0{,}025T - 0{,}002315\sigma_m - 0{,}003314\bar{\sigma} - 5{,}35\right\} \qquad (21)$$

Average values of density ρ_Σ formed by the impact force and thermodynamic factors finish cutting of the polyphase structure is equivalent density ρ_i different phases according to their percentage ζ_i. That is:

$$\sigma_\phi(l) = E_M\left(1 - \frac{\rho_M \cdot \zeta_M(l) + \rho_\Pi \cdot [1 - \zeta_M(l)]}{\rho_\Pi}\right) \qquad (22)$$

where $\sigma_\phi(l)$ - the value of residual stress II type of depth l (mic) of their occurrence on the treated surface; E_M = 224 - Young's modulus of 314L steel, GPa

According to the results of rheological analysis (Fig.1) on the workpiece surface the volume phase is ζ_M =0,45…0,47 (45-47%), denying the formation of "white layer". According to the calculations (12) ζ_M = 0,395 (39,5%):

$$\zeta_M = 1 - exp\{0{,}025 \cdot 330 - 0{,}002315 \cdot 620 - 0{,}003314 \cdot 594 - 5{,}35\} = 0{,}395$$

The error of simulation and design value does not exceed in this case 12,5%, which is quite receptive to confirm the adequacy of modeling.

Thus, the value of residual stress II type is just $\sigma_{r\_2} \approx 5{,}5$ MPa. This is primarily due to the low temperature in the cutting zone, which does not contribute to the phase transformation and, consequently, does not produce significant II type residual stresseP.

Degree libel can be calculated by the prof.Silin empirical equation [13]:

$$N = 40h_з T^{-0,72} = 40 \cdot 0{,}12 \cdot 580^{-0,72} = 0{,}049 \qquad (23)$$

where $h_з$ = 0.12 mm - depth of the strain hardening, determined by the results of rheological modeling of technological machining, mm (Fig.1); T=580°C - the temperature in the cutting zone when working tool with synthetic polycrystalline diamond CTM302 (S = 0,05 mm; t = 0,12 mm; V = 50,2 m/min).

The value of the degree of work hardening in the case the finishing lathe machining ejector by tool with synthetic polycrystalline diamond CTM302 not relatively large, becous depth of cut is small (t = 0,12 mm) and temperature in the cutting area is relatively low ($T \approx 580^o C$). According to experimental results [13] for grinding stainless steel 316L importance degree defamation is $N = 0{,}5...0{,}6$ which having a significant negative impact on the operating conditions of molds partP.

According defined in [14] algorithm structural and parametric optimization of functionally -oriented process ejector machining, should be implemented step of calculating local criteria - the wear of functional surfaces in terms of the potential operation of the product, depending on the variable structure parameters and functional- oriented process of forming most loaded surfaces of the product. It is important to formulate the initial conditions for the subsequent calculation: A fully conjugated wear two bodies in a stationary (steady) mode of dry friction or boundary; subject to wear ejector mold: the body - hard and rough; coupled guide bushing is taken as smooth and deformed counterbody; rated pressure, speed and temperature sliding friction constant in time and uniformly distributed over the contact surface.

Table. 1– Comparative table of analytical and experimental studies results of finish machining mold’s ejector

<table>
<tr><td colspan="2"></td><td>The results of analytical studies in the system Deform2D</td><td colspan="2">Of average results of experimental and industrial research ("Interterm Ltd")</td></tr>
<tr><td colspan="2">Parameters</td><td colspan="2">Finishing lathe cutting tool with synthetic polycrystalline diamond CTM302 (machining rates: S = 0,05 mm; t = 0,12 mm; V = 50,2 m/min)</td><td>DIA diamond grinding around 125/100 M5-2 (machining rates V_c = 31 m/s, t = 0,01 mm, S_n = 6 m/min)</td></tr>
<tr><td rowspan="13">Microprofile finish surface</td><td>Ra, mic</td><td>1,125</td><td>1,29</td><td>1,22</td></tr>
<tr><td>Δ_1, mic</td><td>0,625</td><td colspan="2" rowspan="3">-</td></tr>
<tr><td>Δ_2, mic</td><td>0,39</td></tr>
<tr><td>Δ_3, mic</td><td>0,13</td></tr>
<tr><td>Rpk, mic</td><td>0,30</td><td>0,28</td><td>0,43</td></tr>
<tr><td>Rk, mic</td><td>0,75</td><td>0,84</td><td>0,61</td></tr>
<tr><td>Rvk, mic</td><td>0,12</td><td>0,17</td><td>0,18</td></tr>
<tr><td>Rmax</td><td>-</td><td>2,0</td><td>2,2</td></tr>
<tr><td>r</td><td>-</td><td>35</td><td>20</td></tr>
<tr><td>b</td><td>-</td><td>2,0</td><td>1,29</td></tr>
<tr><td>ν</td><td>-</td><td>1,7</td><td>1,9</td></tr>
<tr><td>$\Delta = \frac{R\max}{rb^{1/\nu}}$</td><td>-</td><td>0,024</td><td>0,096</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td>dual
stres</td><td>$\pm\sigma_{r\_1}$, MPa</td><td>+170</td><td colspan="2">-</td></tr>
</table>

Mark "+" implies on the treated surface of the workpiece residual stresses of compression, and the mark "-" - tensile residual stresses

Sequel tabl. 1

	$\pm\sigma_{r\_2}$, MPa	-5		
	$\pm\sigma_{r\_\Sigma}$, MPa	+165	+143	-130
Residual deformation	Depth of hardening $h_{з}$, mm	0,12	-	-
	Level of hardening, N	0,049	0,06	0,5

In terms of elastic contact intensity of wear depends on the topology mikroheometrychnyh characteristics conjugate surfaces (b, ν, Rvk, Rpk, Rk, Rmax, tm), mechanical properties ($\sigma_т$, $\sigma_в$, $\sigma_{0,2}$, E, μ), coefficient of friction f, fatigue characteristics and pressures t: nominal - Pa and contour - Pc.

λ - Coefficient taking into account the influence of surface residual stresses on wear intensity (provided that the limit of fatigue strength for steel 316L - $\sigma_в$=1530 MPa; t_y=3- coefficient of friction fatigue in elastic contact surfaces is given:

- for turning

$$\lambda_1 = \left(\frac{1530-143}{1530}\right)^3 = 0,75 \tag{24}$$

- for grinding

$$\lambda_2 = \left(\frac{1530-(-130)}{1530}\right)^3 = 1,27 \tag{25}$$

The intensity of wear on the product under given conditions of operation in the case of the second option and process of manufacturing this product, we can write [15]

$$I_{hi} = \frac{0,6\left(1-\mu^2\right)\cdot P_a \cdot \lambda_i}{\sqrt{\nu_i}\left(\nu_i^2-1\right)\cdot K_2 \cdot E \cdot n} \tag{26}$$

Then a relative measure of durability $K\left(I_h\right)$, that characterizes the change in the wear rate depending on the state of functional surfaces arising from the implementation of different variants of structures and process parameters is given by:

$$K\left(I_h\right)=\frac{I_{h1}}{I_{h2}}=\frac{\left[\dfrac{0,6\left(1-\mu^2\right)\cdot P_a\cdot\lambda_1}{\sqrt{\nu_1}\left(\nu_1^2-1\right)\cdot K_2\cdot E\cdot n}\right]}{\left[\dfrac{0,6\left(1-\mu^2\right)\cdot P_a\cdot\lambda_2}{\sqrt{\nu_2}\left(\nu_2^2-1\right)\cdot K_2\cdot E\cdot n}\right]}=\frac{\sqrt{\nu_2}\left(\nu_2^2-1\right)\cdot\lambda_1}{\sqrt{\nu_1}\left(\nu_1^2-1\right)\cdot\lambda_2} \qquad (27)$$

where ν_i - parameter curve fitting step.

Comparing finishing lathe machining ejector by the tool with synthetic polycrystalline diamond CTM302 (cutting conditions: S = 0,05 mm; t = 0,12 mm; V = 50,2 m/min) and its grinding by the diamond wheels DIA 125/100 M5-2 (cutting conditions Vc = 31 m/sec, t = 0,01 mm, Sn = 6 m/min), we obtain a relative measure of durability $K\left(I_h\right)$:

$$K\left(I_h\right)=\frac{I_{h1}}{I_{h2}}==\frac{\sqrt{1,9}\left(1,9^2-1\right)\cdot 0,75}{\sqrt{1,7}\left(1,7^2-1\right)\cdot 1,27}=0,86$$

That is, as a result of changes in the structure of the process of finishing machining ejector wear functional surface increases about 14% due to changes in the prevailing surface microstructure and changes in the nature and nominal values of residual stresseP.

Among the important measure factors of the ejector should be noted relative measure of fatigue strength. As stated in [14], the overall impact to the safety factor in fatigue strength with a number of design and technological factors: effective stress concentration factor $\left(n_{\textit{в}K}\right)$; coefficient of influence of geometrical dimensions of the parts $\left(n_{\textit{в}D}\right)$; influence of surface hardening coefficient $\left(n_{\textit{в}V}\right)$; coefficient of influence of surface roughness $\left(n_{\textit{в}R}\right)$ and coefficient of influence of residual deformations resulting from machining parts $\left(n_{\textit{в}Z}\right)$. Moreover, only the last 2 figures depend on the quality of the surface layer of formation which is a consequence of the structure and parameters of the process of its machining.

Factor influence surface roughness functional ejector if it is a finishing lathe cutting tool with synthetic polycrystalline diamond CTM302 can be defined by the Stepnov equation [16]

$$n_{\textit{в}R\_1}=1-0,22\cdot\lg R_{\max}\cdot\left(\lg\left(\frac{\sigma_{\textit{в}}}{20}\right)-1\right)=1-0,22\cdot\lg 2,0\cdot\left(\lg\left(\frac{1530}{20}\right)-1\right)=0,94$$

Similarly, this coefficient for the case of grinding ejector is:

$$n_{\textit{в}R\_2}=1-0,22\cdot\lg R_{\max}\cdot\left(\lg\left(\frac{\sigma_{\textit{в}}}{20}\right)-1\right)=1-0,22\cdot\lg 2,2\cdot\left(\lg\left(\frac{1530}{20}\right)-1\right)=0,93$$

Factor influence functional surface residual stress $n_{вZ}$ in case of the finishing by lathe cutting tool with synthetic polycrystalline diamond CTM302 is determined by the interference dominance residual stresses first and second type for compression $\sigma_{вI}^{+}, \sigma_{вII}^{+}$ and tension $\sigma_{вI}^{-}, \sigma_{вII}^{-}$

$$n_{вZ\_1} = \frac{\sigma_{-1} + \left(\sigma_{вI}^{+} + \sigma_{вII}^{+}\right)}{\sigma_{-1}} = \frac{780 + 143}{780} = 1{,}18$$

where σ_{-1} = 780 MPa - tensile strength of the material when tested in tension-compression cycle for outzero load, which is typical for ejector working [17].

When grinding ejector mold by the around diamond DIA 125/100 M5-2:

$$n_{вZ\_2} = \frac{\sigma_{-1} - \left(\sigma_{вI}^{-} + \sigma_{вII}^{-}\right)}{\sigma_{-1}} = \frac{780 - 130}{780} = 0{,}83$$

The other coefficients do not depend on the quality of the surface layer and therefore will not be important for structural and parametric optimization process machining ejector for functionally-oriented criteria.

Then a relative measure of fatigue strength $K\left(n_{-1}\right)$, which characterizes the change in fatigue strength safety factor depending on the state of functional surfaces arising from the implementation of different variants of structures and process parameters is given by:

$$K\left(n_{-1}\right) = \frac{n_{-1\_1}}{n_{-1\_2}} = \frac{n_{\mathrm{вR}\_1} \cdot n_{вZ\_1}}{n_{\mathrm{вR}\_2} \cdot n_{вZ\_2}} = \frac{0{,}94 \cdot 1{,}18}{0{,}93 \cdot 0{,}83} = 1{,}43 \tag{28}$$

That is, as a result of changes in the structure of the process of finishing machining ejector surface functional fatigue strength increases about 43% due to changes in the prevailing surface microstructure and changes in the nature and nominal values of residual stresseP.

Measure of corrosion resistance in a volume equivalent τ_m determined taking into account the fact that the decrease in mass per unit area to be permissible value $\Delta m = (Rpk_{ekv} + Rk_{ekv}) \cdot l \cdot k_o \cdot \ln\left(\frac{t}{\tau} + 1\right)$. In this case, approximate interaction of rough surfaces in the form of a spherical contact surface and a planar plastic half-space by the Ishlinsky method [18]. Then a relative measure of the speed of fretting corrosion $K\left(\tau\right)$ is given as:

$$K\left(\tau\right) = \frac{\tau_{\mathrm{m}\_1}}{\tau_{\mathrm{m}\_2}} = \frac{\Delta m_1}{\Delta m_2} = \frac{(Rpk_1 + Rk_1) \cdot l \cdot k_o \cdot \ln\left(\frac{t}{\tau} + 1\right)}{(Rpk_2 + Rk_2) \cdot l \cdot k_o \cdot \ln\left(\frac{t}{\tau} + 1\right)} = \tag{29}$$

$$= \frac{(Rpk_1 + Rk_1)}{(Rpk_2 + Rk_2)} = \frac{0{,}28 + 0{,}84}{0{,}43 + 0{,}61} = 1{,}07$$

That is, as a result of changes in the structure of the process of finishing machining ejector intensity fretinh corrosion-functional surface increases about 7% due to changes in the prevailing surface.

As one of the most important criteria of efficiency of mobile connections is adherence to fluid friction between surfaces conjugated components by providing a minimum thickness of liquid friction in the contact zone, relative rate coefficient of reliability of mechanical systems in liquid contact mode $K(S)$ is given:

$$K(S)=\frac{h_{\min\_1}}{h_{\min\_2}}=\frac{k_S\cdot Rvk_1}{k_S\cdot Rvk_2}=\frac{Rvk_1}{Rvk_2}==\frac{0,17}{0,18}=0,94 \qquad (30)$$

Tribological quality conjugations by the energy losses due to friction in the conjugate surfaces of machine partP. The relative index $K(f)$, that characterizes the change from the coefficient of friction in the conjugated tribological pair depending on the state of functional surfaces arising from the implementation of different variants of structures and process parameters is given:

$$K(f)=\frac{f_1}{f_2}=\frac{\sqrt{\dfrac{R\max_1}{rb_1^{1/\nu_1}}}}{\sqrt{\dfrac{R\max_1}{rb_1^{1/\nu_1}}}}=\sqrt{\frac{\Delta_1}{\Delta_2}}=\sqrt{\frac{0,024}{0,096}}=0,5 \qquad (31)$$

Calculation non-standardize local criteria optimization qualimetric indicators for finishing lathe machining functional surface ejector by the tool with synthetic polycrystalline diamond CTM302 for this example is in relative terms durability Q1 = 0,28; safety factor for fatigue strength Q2 = 0,30; the parameter tribotechnical as conjugations Q3 = 0,10; parameter for corrosion resistance Q4 = -0,14; safety factor for liquid contact Q5 = -0,17. Finally, a generic optimization criterion, determined by the method [14] is $F_1=0,383$. As in this example compared only 2 options of technological processes, generalized optimization criterion for the case of functional surface grinding ejector around diamond DIA 125/100 M5-2, the amount accordingly $F_2=-0,383$.

Conclusion. Thus, the variant of finishing lathe machining functional surface mold's ejector by the tool with synthetic polycrystalline diamond CTM302 compared to grinding diamond wheels DIA 125/100 M5-2 is more optimal for qualimetric integral indicator system characterizes wear resistance, fatigue strength, quality of the tribotechnical conjugations, corrosion resistance and ensure the option of carrying capacity lubricant layer and is obtained as a result of the formation process of forming microstructure surface layer, residual stresses and strainP.

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Г.Л. ХАВИН, канд. техн. наук, доц. НТУ «ХПИ»

ТРЕЩЕНООБРАЗОВАНИЕ ПРИ СВЕРЛЕНИИ ПОЛИМЕРНЫХ КОМПОЗИЦИОННЫХ МАТЕРИАЛОВ

Рассмотрена задача определения величины и глубины залегания трещины расслоения при сверлении полимерных многослойных композитов. Учитывая анизатропию свойств материала, предполагается, что трещина расслоения имеет эллиптическую форму, и значение большей оси трактуется как максимальная длина трещины. Используя эмпирическое представление фактора расслоения, как функции режимных параметров обработки, представлена модель локального расслоения. Полученное соотношение связывает глубину появления максимальной трещины расслаивания и значение ее длины. Представлены количественные зависимости длины трещины от частоты вращения и подачи.

Ключевые слова: трещина расслоения, фактор расслаивания, полимерные композиты.

Вступление. При сверлении полимерных многослойных композитов, как и других конструкционных материалов, возникают дефекты, ухудшающие качество обработанной поверхности. Эти дефекты в основном связаны с начальным контактом инструмента и его выходом из заготовки. Разрушение при сверлении было классифицировано многими авторами [1-5], которые выделили следующие явления: разрыв волокон армирования, межслойная трещина, расщепление вдоль волокон, растрескивание и выкрашивание, нарушение адгезионной связи волокно – связующее и термическое разрушение. Эти факторы были рассмотрены и проанализированы в работах [6-8].

Наиболее опасным дефектом считается расслаивание между соседними слоями армирования вдоль его направления. Основной причиной появления расслаивания при сверлении многослойных композитов является высокое значение действующей осевой силы, величина которой в основном определяется подачей. Кроме того существенную роль играет также неправильный выбор режущего инструмента и степень его изношенности. Для уменьшения расслаивания известно несколько приемов, например,