THE ANALYSIS OF THE JOINT CHARACTERISTICS, BASED ON THE PROCESSING METHODS OF THE CONTACTING SURFACES

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ABSTRACT
The article deals with the problem to ensure the tightness of the mating surfaces of parts for example for example locking group direct – flow gate valve of flush fittings. The mathematical models of the functional characteristics of the joint, such as the density, the volume of the gap, the average thickness of the gap, taking into account the specific characteristics of the flat grinding operation of the sealing face gate. It has been determined empirically depending on the roughness of interfaces tightness, waviness and form errors of conjugating surfaces. It has been established an exceptionally large influence of gate valve sealing surface form on tightness conjugation.

KEYWORDS: *integrity, density, volume of the gap, roughness, waviness, form error, contact area.*

I. INTRODUCTION

Functionalities of machine parts and equipment are carried out, basically with their executive surfaces, reliability and durability of the operation depends, largely, on the processes that occurring in time on the contacts of interface and conjugations. If the nature of the contact at the interface is determined mainly by the geometrical parameters of the contacting surfaces, then the reliability of the processes in the contacts, largely depends on the physico-mechanical properties of the surface layer.
Main characteristics of different variants of the elastic and plastic contact found their analytical expressions in the writings of numerous studies [5,6,7,10-12], including in the Professor I.B Demkina's work [1].
To assess the adequacy of the analytical relationships referred to real contacts, we analyze the definition and assumptions made by the authors in their development of the analytical characteristics of the flat interface.
It is known that the integrity of interfaces forms on the basis of geometrical parameters of the mating surfaces, consisting of roughness, waviness and errors of geometric shapes that is a consequence of mechanical surface treatment of parts, and hence their shape, nature and amount are determined mainly depending on the chosen method of finishing and the characteristics of the technological system. Based on the results of the analyse it was found that in existing studies the influence of form errors functional characteristics of interface did not found adequate lighting, thus defining the contact characteristics depending on the roughness, waviness and error form with the specific characteristics of finishing method of conjugating surfaces is an important task of engineering.
The presented article consists of an introduction, theoretical researches, psychological experiment, experimental researches and final part
Theoretical studies**.** Although convention of the contoured contact surface relative to the actual, based on the fact that reference contour surface within the contact area gives a more realistic picture of the

distribution of material in the joint, we define a mathematical expression based on the contour area taking ino accout the formation of errors of the geometric shapes at a particular method of finishing.
As the original expression we use the formulas proposed by N.B Demkina [1] to calculate the nominal contact area , where contacts waves taking into account the coefficient characterizing the macro ddeviation of the contacting surfaces

$$A'_a \cong 2\pi K_m a_\Sigma \qquad (1)$$

where A'_a the nominal area that contacts waves; K_m coefficient that characterizes macro deviation, a_Σ full convergence due to the deformation of waves and asperities.
Coefficient characterizing the macro deviation of surface shapes, represented by the following formula:

$$K_m \cong \frac{h_1 h_2}{C_m \sqrt{\Delta_{\max_1}\Delta_{\max_2}}}, \qquad (2)$$

Where h_1, h_2 respectively, the length and width of the contact surface detail; $\Delta_{\max 1}, \Delta_{\max 2}$ - maximum deviaton errors of geometric form in the direction according to h_1 и h_2; C_m - coefficient depending on the form of macro deviations. The maximum values of errors of the geometric shape along the length and width of processing at flat grinding the periphry of the circle are defined by [2,3]:
along the width of processing

$$\Delta_{\phi_{вых}} = \frac{i\rho_{cp}\left(1 \pm \frac{V_u}{60V_k}\right)\sqrt{D_{кр} t}S_П \left(\frac{1-q^{\frac{H}{S_П}-1}}{1-q}\right)}{J_{cp}}, \qquad (3)$$

along the length of processing

$$\Delta_{\max_2} = \frac{i\rho_{cp}\left(1 \pm \frac{V_u}{60V_k}\right)\sqrt{D_{rh} t}S_П \left(1-q^{\frac{H-0,5B+r}{S_П}-1}\right)}{(1-q)J_{cp}}. \qquad (4)$$

Where j_{cp}- the average stiffness of the technological system, H/mm; ρ_{cp} average force of micro - cutting with single grain, N;B – the width of the detail in mm, r -radius of the center hole on the ground surface in mm, i - the number of grains actually working on the front band with a width of feed $S_П$; q – coefficient taking into account the penetration of the cutting grains over having sections; H - height of the grinding wheel , mm. V_k - speed of the grindin wheel, V_d – speed of the detail, m/min, t - depth of cut, mm, the sign «+» is accepted at the counter grinding, the sign «-» at the passing.
Including values $\Delta_{\max_1} u \Delta_{\max_2}$ of formula (3) and (4) in formula (2)
we obtain

$$K_m = \frac{h_1 h_2 J_{cp}(1-q)}{C_м i\rho_{cp}\left(1 \pm \frac{V_u}{60V_k}\right)\sqrt{D_{kp} t}S_П \sqrt{\left(1-q^{\frac{H}{S_П}-1}\right)\left(1-q^{\frac{H-0,5B+r}{S_П}}\right)}}. \qquad (5)$$

Writing obtained expression , error forms in the original formula [1], and after making some simplifying, we obtain a nominal area of a flat surface, polished periphery of the circle, which contact waves

$$A'_a \cong \frac{2\pi a_\Sigma h_1 h_2 J_{cp}(1-q)}{C_м i\rho_{cp}\left(1 \pm \frac{V_v}{60V_k}\right)\sqrt{D_{кр} t} S_П \sqrt{\left(1-q^{\frac{H}{S_П}-1}\right)\left(1-q^{\frac{H-0,5B+r}{S_П}}\right)}} \quad . \qquad (6)$$

Where η_0 - relative contour contact of the area.

For the contact of two wavy surfaces $(\gamma_{волн} = 2)$ in work [1] for η_c, is offered the following analytical expression

$$\eta_c = \left(2,94 I J_B^{1/2} q_a / H_{B_{1,2}}^{1/2}\right)^{4/5}, \qquad (8)$$

Where $l = \left[(1 - \mu_1^2)/E_1\right] + \left[(1 - \mu_2^2)/E_2\right]; \quad J_B = R_1 R_2 / (R_1 + R_2);$

E is Young's modues, μ Puasson's coefficient:

$$H_{B_{1,2}} = H_{B_1} + H_{B_2}.$$

These formulas are valid for $A_c \leq 0,5A_n$; H_{B1}, H_{B2} wave height of the mating surfaces; R_1, R_2 - radii instead of A rounding wave crests of the mating surfaces.

Writing the value A_a^1 from formula (6) instead of A in the formula (7) and η_c from (8) we obtain an expression of the contour area for the contact of two wavy surfaces, that have errors of geometrical form.

$$A_c = \frac{2\pi h_1 h_2 J_{cp}(1-q)a_\Sigma}{C_m i\rho_{cp}\left(1 \pm \frac{V_u}{60V_k}\right)\sqrt{D_{кр} t} S_П \sqrt{\left(1-q^{\frac{H}{S_П}-1}\right)\left(1-q^{\frac{H-0,5B+r}{S_П}}\right)}} \times \left[\frac{2,94 I J_B^{1/2} q_a}{H_B^{1/2}}\right]^{4/5} \times$$

$$\times \left[\left(\frac{1,5\pi I^{1/2}}{K_3 H_{\max}^{1/2} b}\right)^{2/(2\nu+1)} \cdot \left(\frac{H_B^{1/2}}{1,66 J_B^{1/2}}\right)^{8/(10\nu+5)} (Iq_a)^{2/(10\nu+5)} + 1,54 H_B^{4/5} I^{2/5} J_B^{1/5} q_a^{2/5}\right] \qquad (9)$$

The recieved formula of contour contact area directly relates to the surfaces polished by the periphery of the circle. Writing the formula complete approach of the surfaces due to the deformation of asperities and waves from applied load from (4.20) [1] in the formula (9) we obtain a clearer view of influence of specific treatment methods on the value of the contour area, respectively through the parameters of roughness and waviness.

With the analytical expression of the contour contact area, considering the error of geometric shapes, peculiar to a particular method of finishing, you can count, and other characteristics of real joint surfaces. Such approach requires to carry out a research on the mechanisms of surface forming on technological primitives, which allows to judge the sealing ability of the surface depending on its size, configuration and location of the sealing zone.

One of the most characteristic properties of the contact characterizing the tightness of the joint is the density of the joint.

By analogy with [1], density of the joint between the contacting surfaces may be defined by the following formula:

$$V = \frac{V_{m_0} - V'_B}{V_{cmo} - \Delta V_{cm}} \quad , \qquad (10)$$

Where V_{m_0} - initial volume of material in the joint with no load; reducing the volume of the material due to the elastic compression; $V_{cm\,o}$ - the initial volume of the joint for the contact of two wavy surfaces; $\Delta V_{cm} -$ reduction reducing the volume of the joint as a result of its deformation under load. The initial volume of the material is presented in the form [1]

$$V_{мо} = V_B + V_ш \quad ,$$

Where $V_B -$ volume occupied by the waves; $V_ш$ - volume microprotrusions forming roughness. Given that contacting roughness and waves occurs within a conditional nominal area unlike [1] , the payment of the initial volume of the material we carry out within conditional nominal area A_0'.

For two wavy surfaces

$$V_{m_0} = A_o'\left\{\frac{H_{B_1}+H_{B_2}}{2} + \left[1-\left(\frac{1}{2b_1}\right)^{\frac{1}{V_1}}\right]H_{\max_1} + \left[\left(1-\frac{1}{2b_2}\right)^{\frac{1}{V_2}}\right]H_{\max_2}\right\} \quad . \tag{11}$$

Instead of writing A'_0 its value from the formula (6), given the geometric shape errors of the contacting surfaces, we obtain

$$V_{m_0} = \left\{\frac{H_{B_1}+H_{B_2}}{2} + \left[1-\left(\frac{1}{2b_1}\right)^{\frac{1}{V_1}}\right]H_{\max_1} + \left[\left(1-\frac{1}{2b_2}\right)^{\frac{1}{V_2}}\right]H_{\max_2}\right\}\times \tag{12}$$

$$\times\frac{2\pi a_\Sigma h_1 h_2 J_{cp}(1-q)}{C_м i\rho_{cp}\left(1\pm\frac{V_v}{60V_k}\right)\sqrt{D_{кр}tS_П\sqrt{\left(1-q^{\frac{H}{S_П}-1}\right)\left(1-q^{\frac{H-0,5B+r}{S_П}}\right)}}}$$

$H_{B_1}; H_{B_2}; H_{\max_1}; H_{\max_2} -$ respectively, wave height and the maximum height of the micro roughness of the contacting surfaces; $b_1; b_2; v_1; v_2$ - coefficients of abutting curve contacting surfaces.

The calculation of the initial volume for the contact of two wavy surfaces in the presence of macro deviations it should be better to take into account the volume of the gap from macro deviations.

Thus, the initial volume of the joint for two wavy surfaces will have the following formula

$$V_{cm.o} = (H_{B_1}+H_{B_2}+H_{mav_1}+H_{\max_2})\frac{2\pi a_\Sigma h_1 h_2 J_{cp}(1-q)}{C_м i\rho_{cp}\left(1\pm\frac{V_v}{60V_k}\right)\sqrt{D_{кр}tS_П\sqrt{\left(1-q^{\frac{H}{S_П}-1}\right)\left(1-q^{\frac{H-0,5B+r}{S_П}}\right)}}} \; .$$

(13) Studies [1] showed that the decrease in the volume of the material in the joint due do the elastic deformation of the asperities is little and it can not be taken into account in the calculations. Thus, the volume reducing of the material in the joint, due to the elastic deformation of the waves, for the contact of two wavy surfaces based on the results of [1] at conditional nominal area will have the following formula

$$V_B' = \frac{2\pi a_\Sigma h_1 h_2 J_{cp}(1-q)a_B^3}{C_м i\rho_{cp}\left(1\pm\frac{V_v}{60V_k}\right)\sqrt{D_{кр}tS_П\sqrt{\left(1-q^{\frac{H}{S_П}-1}\right)\left(1-q^{\frac{H-0,5B+r}{S_П}}\right)}}\,3\left(H_{B_1}+H_{B_2}\right)^2} \quad , \tag{14}$$

Where a_B - convergence due to the deformation of the waves. The reducing the volume of the joint as a result of its deformation under load, at conditional nominal area is represented in the form

$$\Delta V_{cm} = \frac{2\pi a_{\Sigma} h_1 h_2 J_{cp}(1-q)a\sum}{C_{м} i \rho_{cp}\left(1 \pm \frac{V_v}{60V_k}\right)\sqrt{D_{кр} t} S_{П} \sqrt{\left(1-q^{\frac{H}{S_П}-1}\right)\left(1-q^{\frac{H-0,5B+r}{S_П}}\right)}} , \qquad (15)$$

Where $a\sum$ - convergence due to the deformation micropoints and waves.

Entering the expression (10) values of V_{m_0} ; $V_{cm\,o}$; $V_B{}' u$ ΔV_{cm} respectively from formulas (12), (13) (14) and (15) we obtain an expression of the joint density for the contact of two wavy surfaces.

$$\Lambda = \frac{0,5(H_B + H_B) + C_{M1} H_{Max1} + C_{M2} H_{Max2} - a_B^3 a_B^3 / 3(H_{B1} + H_{B2})^2}{H_{B1} + H_{B2} + H_{\max 1} + H_{\max 2} - a\sum} \qquad (16)$$

Where $C_{M1} = 1 - \left(1/2b_1)^{1/\nu_1}\right)$ and $C_{M2} = 1 - \left(1/2b_2)^{1/\nu_2}\right)$.

Substituting the value of (4.10) and (4.20) and (4.28) [1] in the formula (16) we obtain the expression

for the joint density , taking into account macro deviations for the contact of two wavy surfaces.

$$\Lambda = \frac{0,5H_B + (C_{M1} + C_{M2})H_{Max} - 12 H_B^{2/5} I^{6/5} J_B^{3/5} q_a^{6/5}}{H_{B1} + H_{\max} - \chi^2 - 1,54 H_B^{4/5} I^{2/5} J_B^{1/5} q_a^{2/5}}, \qquad (17)$$

где $\chi^2 = \left(\frac{1,5\pi I^{1/2} H_{\max}^{\nu}}{K_3 b}\right)^{\frac{2}{(2\nu+1)}} \left(\frac{H_B^{1/2}}{1,66 J_B^{1/2}}\right)^{\frac{8}{10\nu+5}} (Jq_a)^{\frac{2}{10\nu+5}}; H_B = H_{B1} + H_{B2} u H_{\max 1} + H_{\max 2}$

Analysis of the obtained formula shows that the density of interface increases with increasing load and decreases with increasing height of asperities, waviness and macro value deviations and a modulus of elasticity of the contacting materials. Exclusively large impact on the joint density provides the value of the form errors. Another significant feature of the joint for evaluating the tightness is the volume of the gap. The volume of the gap between the contacting surfaces having roughness and waviness appear in the following form [1]

$$V = V_{cm_0} - \Delta V_{cm} - V_{m_0} \quad . \qquad (18)$$

Including values from the formulas (13), (14) and (15) into (18) we obtain

$$V_з = (H_{B_{11}} + H_{B_2} H_{\max_1} + H_{\max_2}) A_0' - A_0 a_{\Sigma} - (H_{B_1} + H_{B_2}) A_0 / 2 - \left[1 - \left(\frac{1}{2b_1}\right)^{1/\nu_1}\right] H_{\max_1} A_0' \times$$

$$\times \left[1 - \left(\frac{1}{2b_2}\right)^{1/\nu_2}\right] H_{\max_2} A_0'. \qquad (19)$$

The volume of the gap contact of the joint surfaces , processed by various machining methods we get

by a more detailed description of their components

$$V_з = A_0'\left[\frac{H_{B_1}+H_{B_2}}{2} - a\sum + H_{\max_1}\left(\frac{1}{2b_1}\right)^{1/\nu_1} + H_{\max_2}\left(\frac{1}{2b_2}\right)^{1/\nu_2}\right] \quad . \qquad (20)$$

Writing together A_0 , the value of the nominal contact area , in which there is contact waves, i.e. A_0' , we obtain an expression of the gap volume during the contacting of two wavy surfaces taking into account the geometric shape errors.

(21)

The volume value of the gap from the point of view of evaluating the conjugation tightness, does not give enough visual presentation, as it depends on the dimensions of the contacting surfaces, expressed by the nominal area of the contact. From the point of view of joint tightness it is appropriate to

$$V_з = \left[\frac{H_{B_1}+H_{B_2}}{2} - a\sum + H_{\max_1}\left(\frac{1}{2b_1}\right)^{1/\nu_1} + H_{\max_2}\left(\frac{1}{2b_2}\right)^{1/\nu_2}\right]\frac{2\pi a\sum h_1 h_2 J_{cp}(1-q)}{C_M i\rho_{ch}\left(1 \pm \frac{V_k}{60V_u}\right)\sqrt{DtS_П}\sqrt{\left(1-q^{\frac{H}{S_П}-1}\right)\left(1-q^{\frac{H-0,5B+r}{S_П}}\right)}}$$

determine the mean thickness of the gap that, it is possible to divide the nominal volume of the gap into the nominal area of the contact.

$$h = \frac{A_0'}{A_0}\left[0,5H_B + H_{\min} - \Delta_{\max} - 0,5H_{\max}(C_{m_1} + C_{m_2})\right] + \Delta_{\max} - a_\Sigma \quad . \qquad (22)$$

The resulting formula is specific for the contact surfaces treated by the same method of treatment, under the same conditions and parameters of technological operations. Analysis of formula (21) shows that, the errors of the geometric forms of the conjugate surfaces have a significant impact on the volume of the gap joint. Thus except for the main parameters of the micro and macro surface deviation, the nominal pressure and material properties it has been also taken into account the effect of surface treatment methods. The characteristics of the grinding circle and cutting conditions based on the fact that each method of finishing treatment has the specific characteristic of the micro and macro deviation. The surface that is smoothed even by the same method, and at various configurations of treated surfaces has the different properties of the contact.

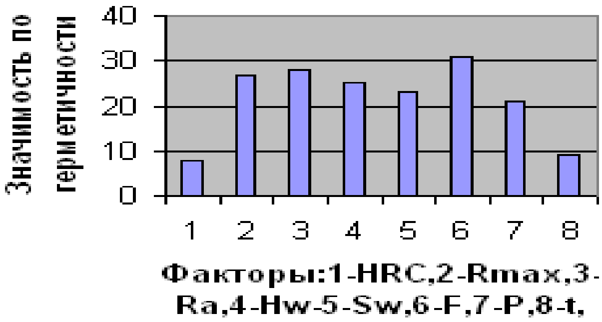
II. EXPERIMENTAL RESEARCHES

To confirm the adequacy of the theoretical investigation results the experimental studies have been carried out by the method of mathematical experiment planning with aim of determining the most significant factors affecting the tightness of the joint, was based on a psychological experiment. On the basis of concordance of researchers' opinions - experts, by plotting the abscissa factors by the axis, having the influence on the joint tightness, by the ordinate axis corresponding rank sums is constructed average ranks diagram (pic.1). The studied parameters of the experiment was the joint tightness expressed by the value of the medium working leakage $y\ мм^3/мин$. Based on the experimental studies by the second order planning it has been obtained the empirical model of the flat joint tightness, metal-metal.

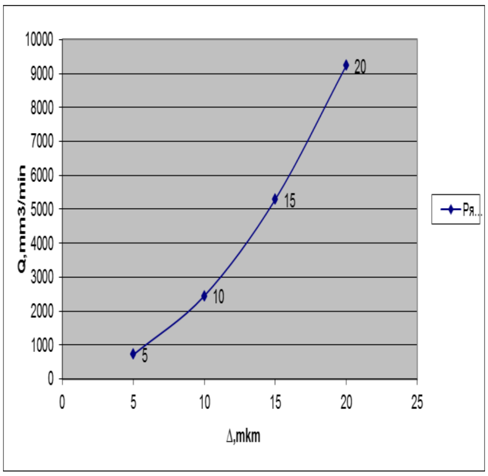
$$Y = 83{,}1 - 3{,}2R_a + 8{,}5\Delta + 0{,}05P + 10{,}8R_a\Delta + 22{,}1\Delta^2 \quad . \qquad (23)$$

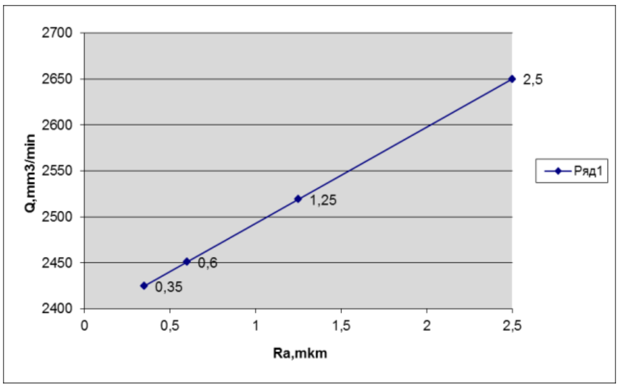
Where p – is the pressure of medium working , Ra – the average arithmetic deviation of microasperities, um, Δ^2 - for errors um.

The analysis of the empirical model of the flat joint tightness metal-metal and graphics , constructed on the basis of its showed that the results of the experiments conducted on the basis of mathematical planning consistent with the results.

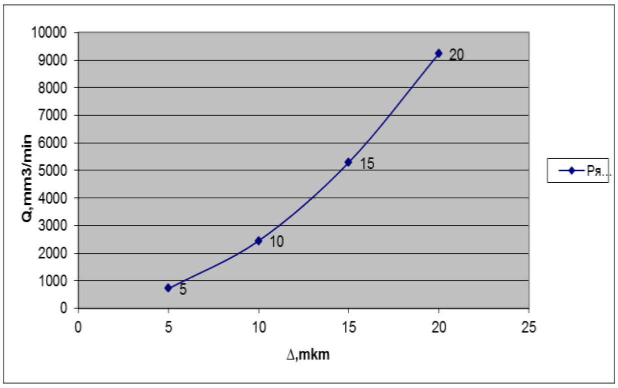


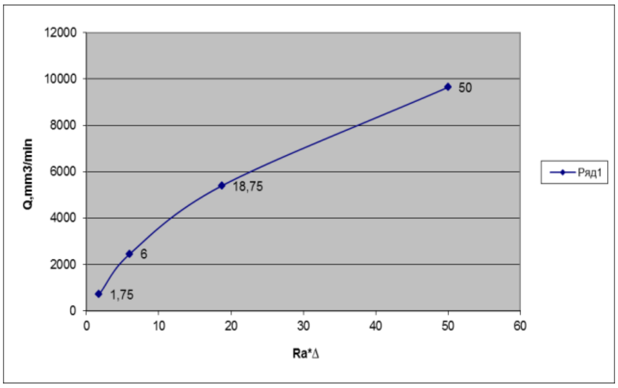
Pic.1. The ranking factors for raising the impact on the conjugation tightness .





a) **b)**





v) d)

The graphic depending tightness of the flat joint the geometrical parameters of surfaces and the pressure of the working medium a) on the error forms; b) on the roughness - R a ; v) on the pressure Q ; q) from the joint effect of roughness and form error.

III. CONCLUSION

1. It has been established the analytical relationship between the contact of the joint density, volume and the average thickness of the gap and the geometrical parameters of the mating surfaces of gate valve and saddle of direct – flow damper.The analysis shows that impermeability of gate valve locking unit increases with the load, and decreases with increasing the roughness, waviness, and geometric shape error of detail conjugating surface . The exceptionally large impact on the value of the joint density provides the value of geometric error forms of gate valve sealing surface.
2. The exactness of contact zone geometric shape of gate valve sealing surface has an extremely large influence impermeability of locking unit. From this point of view at final grinding of gate valve sealing surface should be paid special attention to the forming mechanism of geometrical parameters of surface in technological primitive zone of mouth.
3. On the basis of experimental studies by the second order planning it has been obtained the empirical model of impermeability of direct – flow valve locking unit .
4. The results of experiments confirmed that, the adequacy of received theoretical models of joint density and average thickness of the gap at contacting of grinded surfaces.

The nature of the influence of geometrical parameters of the mating polished surfaces: roughness, form errors and the pressure of the working fluid on the conjugation tightness is identical , i.e with increasing the values of these leakage parameters are increasing. The sizes of the leakage besides the linear effects of the roughness R a , form errors Δ - and the pressure P , the influence and the interaction effects of roughness - $R_a\Delta$
and the effect of the form error in the quadratic term Δ^2 .

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