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Research paper

Information model of registration and analysis of technological factors arising during final processing of products of transport pipeline systems

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Abstract

One of the most important technological characteristics of the rubbing surfaces of the shut-off part of the pipe fittings (PF) of the transport pipeline systems (TPS) is their waviness, which is characterized by the deviation of the step of the wave to the height of the micro-roughness. The nature of the waviness is associated with oscillations of the working bodies of the executive devices of the technological equipment in the production process of manufacturing or repairing precision pairs of PF. The waviness of the rubbing surfaces of the PF shut-off part, as well as the high accuracy of their processing, is achieved by increasing the kinematic stiffness of the process equipment, as well as improving the methods and means for the precise processing of the PF precision pairs.

Keywords: *Information model, finish processing, precision pairs, lapping tool, roughness, pipe fittings, transport pipeline systems.*

1. Introduction

Lapping processing is one of the finishing and most costly operations in the production process of manufacturing or repairing the PF precision pairs. It is a mechanical and chemical process of removing the allowance from the workpiece by massive dynamic exposure of the abrasive grains (AG) to the metal being processed in combination with the chemically and surface-active substances located on the surface of the lapping tool. In this case, the AG placement on the surface of the lapping tool can be in a free, semi-secured or fixed state [4, 6].

2. Page style

It has been experimentally established that in the process of performing a fine-tuning operation in the production process of processing the PF precision pairs the AG can occupy different spatial positions, emerging then on the working surface of the lapping tool. Therefore, the AG can occupy the limiting values of the layer thickness of the abrasive-refining mixture (ARM) in accordance with its linear dimensions (grain size) [2].
Probabilistic analysis of the AG positions in space shows that with its uniform angular turn (Fig. 1), different parts of the AG surface have different probability of touching the surface of I–I. Therefore, sites 5–6 have a greater surface tension than those 1–2 located at the smaller semi-axis of the ellipse.
Having determined the length of these sections, having found among them the general meaning and angle $\overline{\beta}$ corresponding to it, it is possible to find the average probabilistic conditional coordinates of the points of contact:

for an ellipse with axes l and b

$$\overline{\beta}_1 = 55^0 - 10K_b ; \tag{1}$$

for an ellipse with axes b and h

$$\overline{\beta}_2 = 55^0 - 10K_b . \tag{2}$$

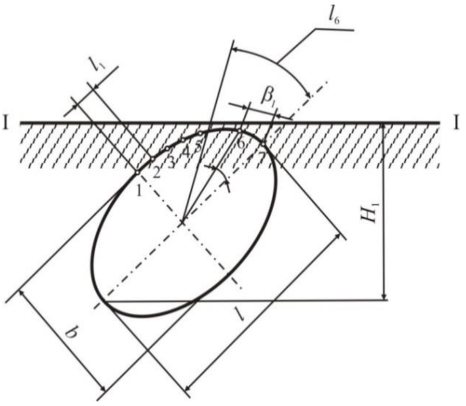

Fig. 1: Variants of the AG touching with the working surface of the lapping tool.

From the consideration of the geometric dependences of the ellipse in accordance with the possible position of the AG under certain angles $\overline{\beta}_1$ and $\overline{\beta}_2$ it is not difficult to find the probable thicknesses of the ARM layer occupied by this grain (ellipses):
for an ellipse with axes l and b

$$H_1 = b\left(K_b \frac{1}{\sqrt{1+K_b^2 tg\bar{b}_1}} + \frac{K_b^2 tg\bar{b}_1}{\sqrt{K_b^2 + tg\bar{b}_1}} \right) \times \sin arctg\left(\frac{1}{K_b^2 tg\bar{b}_1} \right); \quad (3)$$

for an ellipse with axes b and h

$$H_2 = b\left(K_b \frac{1}{\sqrt{1+K_h^2 tg\bar{b}_2}} + \frac{K_h^2 tg\bar{b}_2}{\sqrt{K_h^2 + tg\bar{b}_2}} \right) \times \sin arctg\left(\frac{1}{K_h^2 tg\bar{b}_2} \right). \quad (4)$$

For all AG, the average probability thickness in the ARM is defined as the average between these two values:

$$H = \frac{H_1 + H_2}{2}. \quad (5)$$

Thus, the distance between the AG and their amount per unit of the working surface of the lapping tool is an important characteristic and it largely determines the cutting power of the tool [7]. As the analysis shows, the solution of this problem becomes more reliable in the case of the introduction and account of the magnitude of the critical depth of the seal, from which its alignment occurs under the action of the cutting force. As can be seen from Fig. 2, the output-contact of the AG in the approach of its center to the working surface is a value $H/2$, therefore, the greater the pressure of the lapping tool on the surface to be treated, the faster the output occurs, and consequently, the processing efficiency increases.

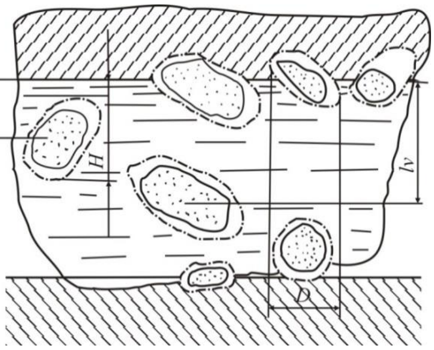

Fig. 2: The average probabilistic position of the AG in the near-surface layers of the workpiece of the lapping tool or the matched surfaces of the PF.

It is theoretically possible to prove that the differentiated level of pressures in the layer of incompressible ARM in the process of lapping the PF precision pairs is of the form [7]:

$$\begin{aligned} &\frac{\partial}{\partial x}\left(h^3 \frac{\rho}{\mu} \frac{\partial \rho}{\partial x} \right) + \frac{\partial}{\partial y}\left(h^3 \frac{\rho}{\mu} \frac{\partial \rho}{\partial y} \right) = \\ &= 12\rho \nu_2 + 6\frac{\partial}{\partial x}\left(\rho \nu_x h \right) + 6\frac{\partial}{\partial y}\left(\rho \nu_y h \right) + 12h\frac{\partial p}{\partial t}, \end{aligned} \quad (6)$$

where h is the thickness of the ARM layer in the section under consideration; μ is the coefficient of dynamic viscosity of the ARM; ρ is the consistency of the mixture; ν_x, v_y, v_2 are the components of the velocity of motion of one surface relative to another in the direction of the corresponding coordinate axes.
Use the same symbol into a definition over the entire article. Use correct symbols for physical or technical terms. (Example: ε_0 and not ε0 for permittivity). Do not repeat definitions over the article. Refer to already defined symbols, equations, theorems by using the cross reference number (Example: As pointed in (1) the…).
The thickness of the ARM is determined from the equation

$$h = \gamma_f - \gamma \cos\gamma - e\cos\left(180^0 - \varphi \right), \quad (7)$$

where γ, γ_f are the radius of the workpiece and the surface of the friction; e is non-roundness of the workpiece.
If we take into account that the angle γ is very small, then one can accept $\gamma_{\text{п}} - \gamma\left(\cos\gamma \right) = \sigma$, where σ is the radial clearance in the system (tool-detail).
Then

$$h = \sigma\left(1 - \varepsilon\cos\varphi \right), \quad (8)$$

where ε is the relative eccentricity, $\varepsilon = e/\sigma$.
The maximum value $h_{\min}$ of the thickness of the ARM lubricant layer is taken at $\varphi = 180^0$

$$h_{\min} = \sigma\left(1 - \varepsilon \right). \quad (9)$$

The thickness of the layer of the main technological material h_t in a section with a coordinate $\varphi_{\text{т}}$ in which the pressure p reaches the maximum

$$h_t = \sigma\left(1 + \varepsilon\cos\varphi_{\text{т}} \right). \quad (10)$$

The equation allows determining the working capacity of the process material layer. For intra lapping machines with horizontal spindle arrangement after integration, we obtain:

$$\frac{\partial \rho}{\partial x} = 6\mu v_x \frac{h - h_{\text{т}}}{h^3}. \quad (11)$$

The pressure P_v in the section of the lubricant layer, located at an angle φ to the line of the center of the lapping tool and the workpiece, is found in the polar coordinates by integrating within the appropriate range:

$$P_\varphi = 6\frac{\mu\omega}{\psi^2}\int_{\varphi_1}^{\varphi} \frac{\varepsilon\left(\cos\varphi - \cos\varphi_{\text{т}} \right)}{\left(1 + \varepsilon\cos\varphi \right)} d\varphi, \quad (12)$$

where ω is the angular frequency of the rotation of the lapping tool; φ is the angle defining the beginning of the diagram of the pressure; ε is relative radial clearance.
The elemental force dP of normal pressure on the site dS with a coordinate φ is equal

$$dP = \rho_\varphi dS = \rho_\varphi \gamma L d\varphi, \quad (13)$$

where L is the working length of the lapping tool.
The bearing power of the ARM lubricant layer of the lapping tool is expressed as an equalizing p diagram of internal pressure, which balances the external pressure of the lapping tool. From (12) and (13) we obtain

$$p = \frac{3\mu\omega}{\psi^2} ld \int_{\varphi_1}^{\varphi_2} \cos\left[\pi - \left(\varphi + \varphi_2 \right) \right] d\varphi \int_{\varphi_1}^{\varphi_2} \frac{\varepsilon\left(\cos\varphi - \varphi_{\text{т}} \right)}{\left(1 + \varepsilon\cos\varphi \right)^3} d\varphi, \quad (14)$$

where d is the diameter of the lapping tool; $\varphi_{\text{т}}$ is the angle determining the position of the line of centers of the lapping tool and the workpiece relative to the external load line action; φ_ε is the angle defining the end of the diagram of the specific pressures of the lubricating layer of the ARM.
Expression (14) is reduced to the following form:

$$P = \frac{\mu\omega}{\psi^2} ld\phi_p, \quad (15)$$

where ϕ_p is the dimensionless coefficient of bearing power.

$$\phi_p = 3\int_{\varphi_1}^{\varphi_2} \cos\left[\pi - \left(\varphi + \varphi_a\right)\right] d\varphi \int_{\varphi_1}^{\varphi_2} \frac{\varepsilon\left(\cos\varphi - \varphi_{\text{т}}\right)}{\left(1+\varepsilon\cos\varphi\right)^3} d\varphi \,. \tag{16}$$

The values of the coefficient ϕ_p, depending on the angle of coverage φ_1, φ_2 and various sizes ratios, are given in [5, 8]. The main dependencies of the hydrodynamic theory of lubrication are used to determine the loss of power to overcome the resistance of the rotation of the lapping tool N during the process of abrasive precision-lapping machining and the flow of the ARM G_{CM} :

$$N = \frac{\mu\omega}{2\psi} l d^2 \phi_{\text{т}} \,, \tag{17}$$

where $\phi_{\text{т}}$ is the dimensionless coefficient of rotational resistance of the lapping tool.

The quantity of the ARM necessary for maintenance of normal working capacity and course of the process of cutting,

$$G_{CM} = \frac{1}{2}\psi l d^2 q \,, \tag{18}$$

where q is the dimensionless flow rate of the ARM.

The temperature of the working medium during abrasive pretreatment is determined by some assumptions based on the solution of the equation of thermal balance:

$$Q = Q_1 + Q_2 + Q_3 + Q_4 \,, \tag{19}$$

where Q is heat formation in the cutting zone; Q_1, Q_2, Q_3, Q_4 is the heat that is given by the lapping tool.

For occasions of providing high tightness of the locking PF, only abrasive finishing and lapping machining is a technologically feasible method [1, 3], which allows getting the surface roughness up to $R = 0{,}1/0{,}025$ μm and a deviation from the required geometric shape of the treated flat, cylindrical and spherical surfaces within 1,0/3,0 μm. The technological advantage of mechanical abrasive finishing and lapping machining is also that, in one technological operation, it is possible, first, to perform a rough processing – the picking up of the allowance – and then the finishing final processing, at which the desired shape and accuracy of the dimensions of the surface to be processed are achieved.

The condition of the surface layer of the shut-off PF is determined by a number of factors of the abrasive finishing and lapping process, which can be divided into several groups.

The factors determining the technological characteristics of the process, that is, its conditions and regimes: the nature of the abrasive and the nonabrasive part of the abrasive-finishing mixture, the materials of the lapping tool and the detail, the state of their surface layers, the grain, the consistency, the pressure, the hardness of the materials of lapping tool and the detail.

The factors characterizing the kinematic characteristics of the process are the ratio of the angular velocities and linear dimensions of the links of velocity variation and the acceleration of the relative motion of the detail by the lapping tool.

The factors determining the dynamic characteristics of the process are the average value and the law of the change in the interaction force of the detail through the abrasive interlayer with the lapping, as well as the amplitude-frequency characteristics of the process, which depend on the magnitudes and interaction of the technological and kinematic factors, in particular, the velocity pressure and their laws change along the trajectory of the relative motion of the elementary areas of the lapping tool-part.

The factors determining the geometric characteristics – the accuracy of the shape of the working surface of the lapping and parts, the shape of the grooves for the supply of abrasive suspension, the relative location of the axes of the lapping, separators and parts affecting the quantities and laws of distribution (change) of some technological and kinematic factors.

The scale factor-ratio of the linear dimensions of the surfaces to be treated or their individual sections and lapping.

Many of these factors are random variables, therefore the quantitative and qualitative indices of the abrasive finishing-lapping process are variable in time, depending on the random combination of the dominant factors in the process of the treated surface. After the finishing-lapping treatment, the quality parameters of the process, as a rule, can be higher than after fine grinding, superfinishing and honing. Attention is drawn to the fact that without knowledge of the probabilistic position of the AG on the lapping, it is impossible to solve the problems of technological heredity and wear resistance of the PF precision pairs.

The abrasive wear of precision pairs of the PF cut-off part, which is evaluated by the wear resistance of the mating parts, according to the classification of types of machine defects [2], should be given due importance in production and repair. Mainly, abrasive wear during the PF operation is a fact of technological heredity that influences the strategy of ensuring the operational reliability of the TPS structural elements.

Using the theoretical studies of the rational solution of finishing and lapping technology in the PF manufacture and repair, it is possible to predict the reliability and durability of the operation of high-precision products under the influence of technological heredity. So, the AG strength is decisive in the formation of service life of pipe fittings [7]. The initial values of these parameters are fixed by measuring and calculating. So, with reference to the roughness of the surface of the PF cut-off part, it is necessary to know the dependence of the measurement of the parameters in time.

In the analytical solution of the problem, assumptions can be made that provide for the action or absence of individual factors. Such may be vibrations, changes in the rigidity of the working parts of the machine tool, the influence of temperature deformations etc. A certain dependence of the type can serve as a model for changing the roughness:

$$R_z\left(\tau\right) = R_{z0} \pm C e^{-a\tau} \,, \tag{20}$$

where $R_z\left(\tau\right)$ is the roughness value of the PF pairs precision after abrasive finishing-lapping treatment during time τ ; R_{z0} is the amount of roughness before processing; C is kinematic constant of the grinding machine; a is the correction factor.

The coefficients in this equation should reflect the technological heredity influence on the change of roughness with time, and, hence, the geometric accuracy of the mating surfaces will vary (Fig. 1). All this ultimately reduces the operational reliability of the PF TPS.

3. Conclusion

The finishing-lapping machining is one of the finishing operations in the production process of manufacturing or repair of the PF precision pairs and is a mechanical-chemical process of removing the allowance from the workpiece to be processed by means of the mass dynamic impact of abrasive grains on the metal being treated in combination with chemical and surface active substances that are located on the surface of the lapping tool.

During the execution of the finishing-lapping operation in the production process of the PF precision pairs processing, the abrasive grain may occupy various spatial positions.

The distances between the abrasive grains and their number per unit of the working surface of the lapping too is an important characteristic and in many respects determining factor of the cutting ability of the lapping tool.

The greater the pressure of the lapping tools on the machined surface, the faster the output, and, consequently, the processing capacity increases.

The technological advantage of mechanical abrasive finishing-lapping processing is that in one operation it is possible to perform both roughing and finishing, in which the required shape and precision of the machined surface size of the PF precision pairs are achieved.

The carried out theoretical researches make it possible to predict reliability and durability of functioning of PF TPS by means of rational decisions of realization of technological process of finishing-lapping work under the influence of technological heredity.

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