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THE OPTIMAL CHOICE OF THE MICROGEOMETRY OF THE SURFACE OF THE SHIP TECHNICAL TOOLS’ CONJUGATION (STT)

The statement of the problem and its relations with the important scientific and practical problems. The search of the technical solutions for the increasing of the reliability of the STT details’ conjugation is a topical issue during the ship systems’ design and utilization. The demanded level of safety and reliability is laid in the creation of the ship units and assemblies, in the process of operation it is possible only to maintain the parameters specified in the design due to proper maintenance and repair, which is associated with time and financial costs.

One of the ways to improve the reliability of the coupling parts STT is to increase their service life by increasing their wear resistance.

Increasing of the wear resistance of the parts is related to the quality and accuracy of their manufacture. After treatment all details have a particular surface roughness, and in many cases, the waviness and microroughness. The presence of these irregularities leads to a discrete nature of contact surfaces. At the same time, the small area of the actual contact causes large contact pressures and deformations, increases the temperature in the contact zone and significantly affects the friction and wear of the interface [2].

The problem of increasing the wear resistance of STT’s details determines the necessity to development and research the new methods of surface hardening, which include the method of deforming cutting (DC). The distribution of micro-hardness in the surface layer formed during DC processing [3] is studied, since one of the factors affecting the wear resistance of friction surfaces is the distribution of microhardness on the friction surface.

In this study, the experimental data characterizing the dependence of the roughness (a) and waviness (b) on the radius of the deforming element at V = 1.08 m/s; S = 0.08 *10-3 m/o; P=98.1 N are obtained. Processed material-steel HVG.

The purpose of this study is to determine the dependence of the surface roughness and waviness of the conjugating parts on the radius of the deforming element

Keywords: the surface's microgeometry, roughness and waviness of the surfaces, conjunction "shaft-bearing", the radius of the deforming element, the radius of curvature of the wave.

Presentation of the main material of the study

Restoring productivity and improving the details' durability has recently become for a variety of industries increasingly important, in particular, during the repair of the ship machinery, especially heavy marine diesel engines. "Sulzer" RD90 can be an example of such engine.

Plunger pair 324-32-151-1SB of a such motor includes a sleeve and a plunger 324-32-153-1 324-32-152-1.

Mating surfaces have high requirements for accuracy and roughness. In particular, for the plunger, the size of the covered surface Ø56 must ensure accuracy of 6 quality and roughness of R_a=0.05. To achieve such precision and roughness the number of treatment-current must be applied: machining - turning, roughing, semi-finishing, finishing and super-finishing.

Finishing processing of such parts of the ship mechanisms, as a rule, is made with the help of the abrasive tools.

At abrasive processing of grain the thinnest shavings of 2-20 microns thickness are removed, and in some cases the shavings are no more than tenths of a micron. A significant number of grains, which are irregular polyhedra with rounded vertices, participate in the work simultaneously. Therefore, the cutting elements work with unfavorable cutting angles. In general, the front angle is negative and the cutting angle is greater than 90°. Due to the fact that the cutting angles are large and the thickness of the cut is small, the specific cutting force reaches a significant value and many times exceeds the specific cutting force in other types of processing [4].

Abrasive tool processing is carried out with high cutting speeds (20 — 40 m/s), exceeding, with high-speed grinding 50-70 m / s. As a result, and as a result of the fact that the processing occurs at large cutting angles, the cutting temperature reaches in some cases 1100-1200° C.

The abrasive tool unlike other cutting tools does not have a continuous blade. On the generatrix of the grinding wheel the grains are placed at some distance from each other, and each grain removes its chips from the processing surface; therefore, the grinding process is essentially a process of scratching. When processing with an abrasive tool the control of the cutting process is somehow more difficult than when processing cutters, milling cutters and similar tools, as it is impossible to change the geometry of the cutting element (grain) of the grinding wheel. In addition, it is necessary for the abrasive machining to choose the right coolant depending on the material to be processed and the characteristics of the grinding wheel. If such treatment is carried out centrally, in the factory, it is necessary to have a special compartment for the preparation and distribution of the coolant.

The process of fine boring compares favorably with the abrasive processing at least by the fact that small particles of grains that are crumbled during grinding do not penetrate into the treated surface. This introduction in the future is the cause of wear of the future details' mating surfaces. Fine boring towards the grinding is more productive and economical-ness of the treatment process.

Given the above, it is at least irrational to use abrasive processing for a plunger pair, for example. After all, all these micro-scratches are, firstly, stress concentrators, and, secondly, they create microchannels, looseness in the working pair. Therefore, the various kinds of leaks appear in the process of the operation, which significantly reduces the durability.

The surface deformation, and, in particular, thin plastic deformation are recently used as a finishing processing of bodies of rotation.

The essence of the process of thin plastic deformation (TPD) in contrast to other methods of metal forming, is concluded in the following - when TPD deformation are subject only to the scallops of micro-roughness (roughness), and the accuracy of the shape and size of the part is achieved in the preliminary operations of fine turning or boring.

To carry out this process, first of all, it is necessary to determine the geometric parameters (size and shape) of the deforming element.

The ideal shape of a the detail machined on a diamond boring machine is a cylinder with a circular cross section.

However, the high-speed parts of the machine (shafts, spindles, gears) are the exciters of vibrations. As a result of these fluctuations between the detail and the tool there are additional relative movements. These relative movements of the detail and the tool affect the macro and microgeometric deviations of the part sizes. It is considered that the relative motion is a harmonic oscillation [1].

The decisive factor affecting the shape of the detail and its size is always the ratio of the frequency of harmonic relative motion to the rotational speed of the part when processing x/n'. To study the relative oscillations, the ratio x/n' is usually expressed as a sum:

$$\frac{x}{n'} = \psi + \psi' \tag{1}$$

where ψ is integer and ψ' is fraction.

It is established [1] that the ratio x/n' characterizes the influence of the spindle unbalance on the deviation of the longitudinal and transverse shape, on the eccentricity and on the size of the part.

Because of this, the wave are formed in the longitudinal and transverse sections (Fig. 1). Their height and length are determined by the flexibility of the MDID system and the elements of the cutting mode.

The increase in cutting speeds and depth leads to the increase in the wave's height, the effect of the feed in this case is weaker. The increase in the flow is somewhat dampens the waves, making them flat.

Thus, knowing the modes of fine boring it is possible to determine the radius of curvature of the waves in the longitudinal and transverse sections of the hole.

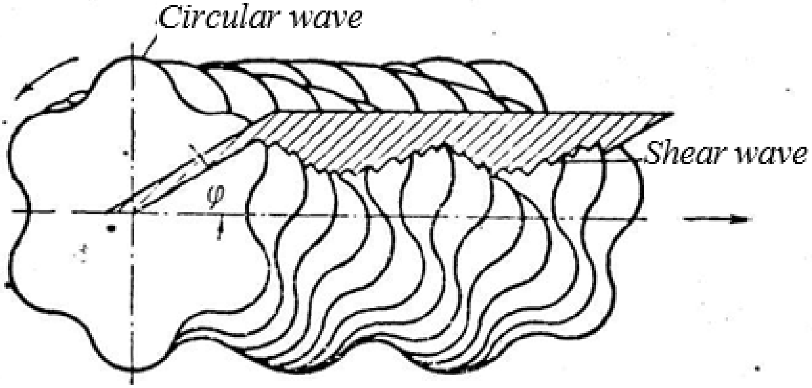

Fig. 1. Transverse and circular waves on the surface of the part.

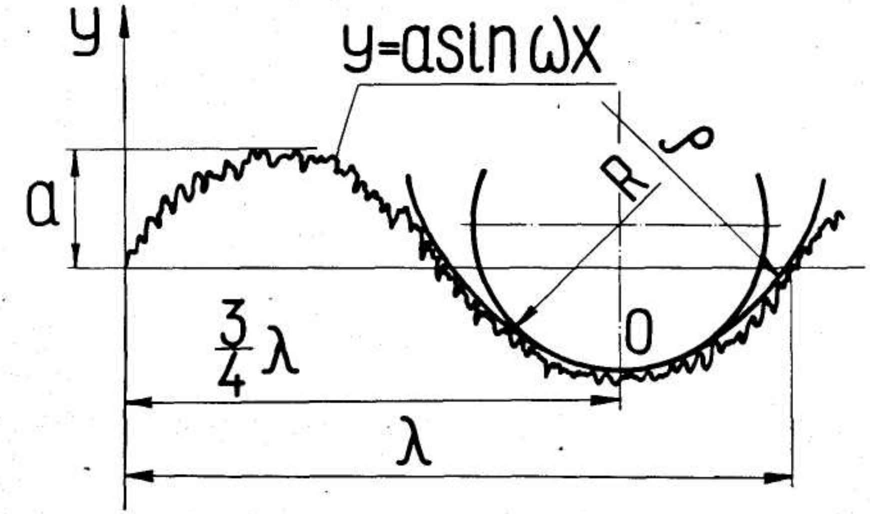

Fig.2. To the calculation of the radius of the deforming element for the crumpling of the longitudinal wave irregularities.

Each roughness of this wave to be plastically deformed, it is necessary that the radius (R) of inventory to be less than the radius of the wave's curvature (ρ), i.e. the condition R≤ ρ has to be always maintained. If this condition is not sustained, the contact of the deforming element with the deepest precision machined surface will not occur and will not be removed scallops irregularities.

We define the curvature of the wave and the radius of the deforming element to crumple the irregularities in the longitudinal direction.

It is known that the surface waviness is a set of periodically repeated irregularities with a relatively large step than the roughness. In general, it can be approximated by an expression:

$$y=a\cdot \sin\omega x$$

where a is the wave amplitude;

ω is a frequency of waves on the perimeter of the longitudinal section.

Use the formula of differential geometry for ρ (Fig.2)

$$|\rho| = \frac{[1+(y')^2]^{\frac{3}{2}}}{y''} \qquad (2)$$

Substitude the value $y=a\cdot sin\omega x$ into the formula (2)

$$\rho = \frac{(1+a^2\omega^2\cos^2\omega x)^{\frac{3}{2}}}{-ax^2\sin\omega x}$$

The smallest value of the curvature's radius ρ is obtained when $\cos\omega x=0$. Therefore:

$$\rho = \frac{1}{a\omega^2}$$

or, taking into account [1] that $\omega = \frac{2\pi}{\lambda}$

$$\rho = \frac{\lambda^2}{4\pi^2 a}; \qquad (3)$$

where λ is the longitudinal wave's length.

Thus, the radius of the deforming element must be less than or, in the extreme case, equal to the value of the expression (3) in order to merge the irregularities of the longitudinal wave)

$$R \le \frac{\lambda^2}{4\pi^2 a} \qquad (4)$$

With fine boring on diamond boring machines 2706 and 2705, as shown in [2], the calculated value of the relative harmonic oscillation's frequency of the system x corresponds to 395 1/s.

The speed depends on the processing speed and is calculated by the formula:

$$n' = \frac{\pi n}{30}$$

where n is the spindle speed, min^{-1}.

When v=1,66 m/s, s=0,08 * 10-^{3} m/o and t=0,1*10-^{3} m

$$n' = \frac{3{,}14 \cdot 530}{30} = 55 c^{-1}$$

The wavelength λ depends on the value of the fractional remainder of the ratio

frequency $\frac{x}{n'}$, i.e.

$$\frac{x}{n'} = \psi + \psi' = \frac{395}{55} = 7 + \frac{1}{6};\ \psi' = \frac{1}{6}$$

Then $\lambda = \frac{1}{\varphi'} = \frac{1}{1/6} = 6;$

That is, the tops of the waves will be from each other through 6 turns (6s).

Substituting the found values into the formula (4), we obtain the numerical value of the radius of the deforming element:

$$R \leq \frac{\lambda^2}{4\pi^2 a} = \frac{(6 \cdot 0{,}08)^2}{4 \cdot 3{,}14 \cdot 0{,}0015} = 3{,}3\,мм = 3{,}3 \cdot 10^{-3}\,м$$

If the ratio of the frequency of harmonic relative motion to the number of revolutions of the spindle is expressed as an integer, the wave after one revolution closes (Fig. 3). In this case, there is no longitudinal wave.

Determine the radius of curvature of the wave and the radius of the deforming element to crumple the irregularities of the circular wave (Fig.Four)

As it is shown on Fig.4 the radius of the deforming element that will fit into the curvature of the circular wave can be determined from the expression

$$R=\frac{b^2+4H^2}{8H}; \tag{5}$$

where b is the half-step of the circular waves;

From ΔAOB (Fig.4) , or $b=2R_0\cdot\sin\frac{\alpha}{2}$, herewith:

R_0 is the radius of a geometrically correct circle;

α is the central angle between the intersection points of a geometrically correct circle and the real surface.

$$H= A_{max} + h;$$

A_{max} is the amplitude of the relative oscillation with respect to the geometrically correct circle;

$$h=D\varepsilon=R_0-R_0;\ h=R_0(1-\cos\frac{\alpha}{2});$$

$$H=A_{max}+h=[A_{max}+R_0(1-\cos\frac{\alpha}{2})]$$

Substituting the values found in the formula (5) and performing the transformation, we obtain:

$$R=R_0+\frac{A_{max}(A_{max}-2R_0\cos\frac{\alpha}{2})}{2[A_{max}+R_0(1-\cos\frac{\alpha}{2})]}$$

Expressing α/2 through the ratio of frequencies x/n' we finally obtain:

$$R=R_0+\frac{A_{max}(A_{max}-2R_0\cos\frac{3n}{2x})}{2[A_{max}+R_0(1-\cos\frac{3n}{2x})]} \tag{6}$$

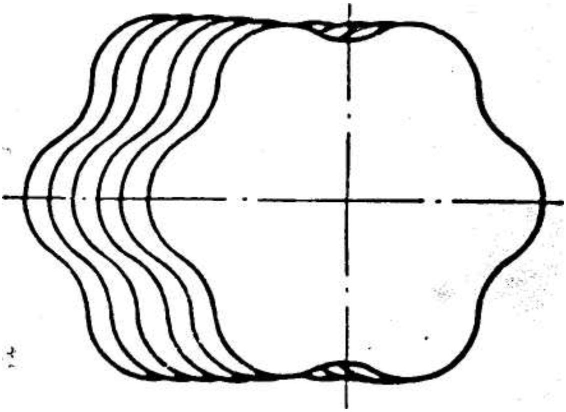

Fig.3 The shape of the hole in the longitudinal and cross sections at the ratio x/n' expressed by an integer.

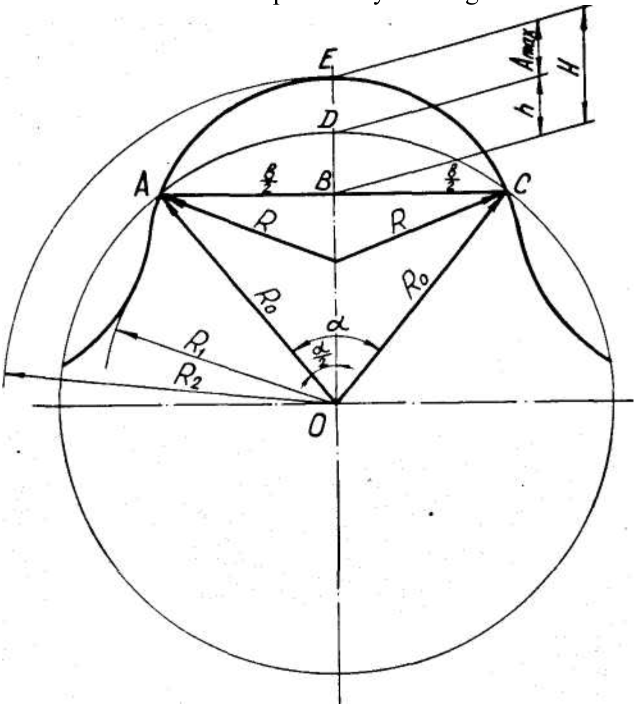

Fig. 4. To the calculation of the radius of the deforming element to crumple the irregularities of the circular wave.

Substituting the numerical values of A_{max}, x, n' for the machining diameter of 0.06 m in the formula (6), we determine the radius of the deforming element to crumple the irregularities in the cross section perpendicular to the axis of the part:

$$R = 30 + \frac{0,01(0,01 - 2 \cdot 30 \cdot 0,9992)}{2[0,01 + 30(1 - 0,9992)]} = 21,2\text{мм} = 0,021\text{м}$$

As it can be seen from the calculation, the radius of the deforming element for crushing irregularities in the transverse section (with a sufficiently large value of A_{max}) is much larger than the radius of the longitudinal wave.

Thus, when crumpling irregularities deforming element, calculated for the longitudinal wave, it is assumed complete crushing, as in this case, the ball, rolling on the wave, deformes the roughness both at the tops and at its depressions. In this case, the surface waviness should be reduced slightly, and its roughness will be minimal.

As the radius of the identer increases, the surface waviness is expected to decrease, since the ball, smoothing the tops of the waves, fills only to some extent the depressions. Therefore, the roughness of the treated surface will be deteriorated due to untreated areas in the cavities of the waves.

The experiments for establishment of the influence of the deforming element's radius on the roughness and undulation of the surface of the joint in the processing of steel HVG on the diamond boring machine 2705 when feeding S = 0.08 *10-3 m/o and speed V=1.56 m/s.

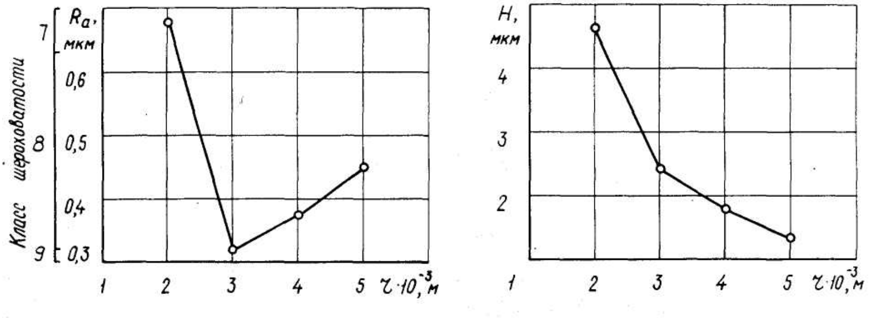

Fig.5. The dependence of the roughness (a) and waviness(b) on the radius of the deforming element V = 1.08 m/s; S = 0.08 *10-3 m/o; P=98.1 N. Processed material-steel HVG.

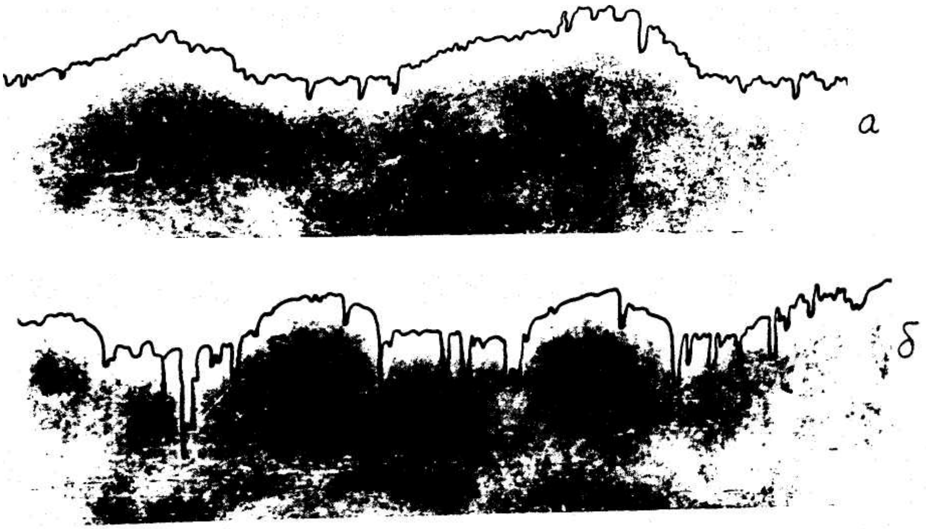

Fig.6. The profilograms of the surfaces of the hole.
a) ironed with $R_{сф}=2,4*10^{-3}$ m
b)ironed with $R_{сф}=3*10^{-3}$ m

The initial surface roughness corresponded to 2.5. According to the research results, the graphs of the dependence of the roughness (a) and waviness (b) on the radius of the deforming element are plotted and presented in figure 5.

From Fig.5 it follows that reducing the radius of the deforming element to $3*10^{-3}$ m leads to a significant reduction in the surface roughness. The ball rolls on the wave, crushing the crests of the humps on the tops and its bottoms (Fig.6). The wave height decreased by 1.3-1.5 times (Fig.6). Increasing the radius of the identer to $5*10^{-3}$ m leads to a deterioration of roughness, so the ball crushes the scallops of irregularities only at the tops of the waves (Fig. 6), while reducing the surface waviness by almost 3 times (Fig. 5).

Conclusions

1. To completely deform the roughness of the original surface, the radius of the deforming element must be less than the radius of the wave's curvature. The value of this radius can be calculated depending on the frequency ratios of the harmonic relative motion to the frequency of rotation of the boring bars during machining.

With respect to the diamond-boring machines of the type 2705 and 2706, the size of the radius is (3÷5,5) $*10^{-3}$.

2. The application of the deforming element with optimal radius allows to consistently obtain in the processing of the surface roughness of holes 0.8÷0.9 at the original roughness in the range of 6.3÷2,5.

3. In the cases where the technical conditions for the part are more stringent requirements for the surface waviness, it is necessary to conduct processing with an increased radius of the deforming element.

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