Study of microrelief forming technology on sliding bearings for oil and gas centrifugal units

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Abstract. The present paper is dedicated to improving the quality, reliability and operational characteristics of machines that is a major challenge for modern oil and gas engineering. Improving the quality of machines, increasing their reliability and durability is inextricably linked with the issue of enhancing the parts surface quality as virtually all operational parts properties are determined by certain geometric and physical-chemical parameters of their working surfaces. In particular, there is a known way to increase the reliability of supports of centrifugal units when sliding bearing supports with a regular microrelief are used. In particular, there is a known way to increase the reliability of bearings of centrifugal units when sliding bearing bearings with a regular microrelief are used. When researching the planetary rotary turning the tool is given additional movement - planetary rotation, it is found out that the complicated movement of planetary rotary turning provides an emerging various regular microreliefs on the surface of the parts that can be effectively applied to sliding bearings. The article focuses on the study of the kinematics of this relief by planetary cutting tools.

1. Introduction

It is known that in the oil and gas complex rolling bearings are widely used as supports for the shafts of centrifugal units. However, this type of bearing supports has high requirements to the perceived loadings, the lack of shock and vibration impacts. In addition, rolling bearings, even with minor defects, can themselves be a source of vibration that results in rapid wear of the rotating parts of units, increased noise and low levels of productivity. Rolling bearings require frequent maintenance and constant monitoring of vibration levels [1], [2]. Bearings must be replaced after disassembling the unit; installation of repaired rolling bearings is often prohibited.

The listed shortcomings of rolling bearing supports represent important opportunities for the use of sliding bearings which were widely used in many branches of modern mechanical engineering due to the simplicity of design and durability during proper operation. Sliding bearings can be applied at high rotating speeds and considerable loadings, they can effectively work in aggressive environments, have small sensitivity to shock loads [3].

One of the main disadvantages of this type of support is the increased wear of the antifriction layer when starting or stopping the shaft of a centrifugal unit. In this case, boundary friction takes place along the antifriction layer of the bearing support. One way to avoid or reduce the impact of boundary friction in the sliding bearing is to use a relief on the working surfaces of the bearing.

2. Sliding bearings with a relief

When starting and stopping the rotation of the centrifugal unit shaft the presence of a relief and oil in it allows liquid friction to be provided at practically any speed in the contact areas of the shaft and the surface of the bearing shell which increases the durability of the sliding bearing supports.

It is also worth noting that due to the hydrodynamic turbulence of the oil which can lead to shaft vibrations the standard sliding bearings are made with a small radial clearance. This increases the heat generated in the lubricating film, adversely affecting both the lubricant due to an increase in its viscosity and, as a consequence, a decrease in the bearing strength as well as an increase in the bearing wear. Moreover, the relief forming a kind of lubricating grooves contributes to the heat exchange intensification in the bearing [4]. Thus, textured surfaces with regular microrelief are an effective means of lubrication control [5].

It is obvious that the relief on the sliding bearings can also be formed during the repair of old supports.

Analysis of the sources [6], [7], [8] revealed the following main features of the developed designs of bearings with relief:

- hydrodynamics of the lubricant behavior in the formed reliefs is quite complicated for description and control;
- in geometry of the formed reliefs there are sharp edges including those determined by the methods of applying the relief, which contribute to the formation of turbulence in the lubricant that adversely affect the lubricant film;
- insufficient attention is paid to the technology of applying relief on the friction surface of the bearing; therefore, some promising designs are almost impossible to implement.

Based on the foregoing, the method for applying a microrelief to the working surface of the bearing using a rotation module was proposed [9].

3. Rotary modules for processing the parts of the oil and gas complex

The rotary module is a cutter with a cutting part in the form of a rotation body, which works on the principle of rolling

A feature of such cutters is the movement of the working blade parallel to itself, which is carried out by free rotation of a round cutter around its geometric axis in interaction with the workpiece (figure 1). The rotation axis of the cutter is inclined at an angle φ_y to the plane of supplying and at an angle β_y to the plane perpendicular to an axis of a workpiece.

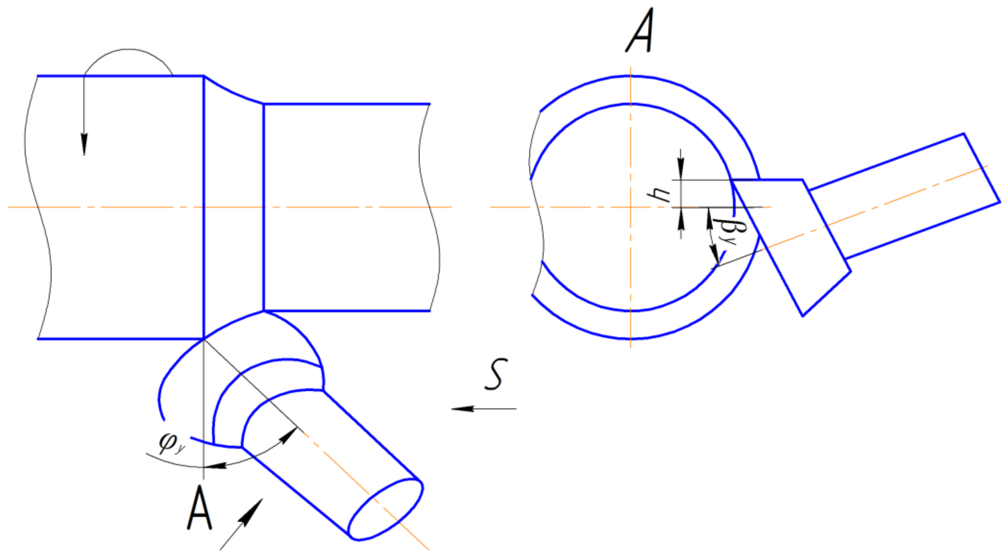

Figure 1. Pattern of workpiece processing with a rotary cutter.

The practice relating to mechanical-engineering shows that rotary cutting modules have significant predominant differences in productivity, temperature and power conditions of the forming process while ensuring the required quality of processing [10], [11].

One of the promising areas for enhancing the characteristics of spindle assemblies is the use of hydrostatic supports instead of conventional rolling and sliding bearings supports which allow stabilizing surface parameters [12], [13]. The use of hydrostatic bearings supports in the spindle assemblies of rotary cutters will reduce dynamic loads in the cutting zone due to the damping properties of the lubricating layer, improve heat removal from the cutting zone, and improve the quality of the processed surfaces of machine components.

When processing machine components with the rotary cutters, the authors experimentally obtained a cellular microrelief that does not have sharp edges, and, consequently, swirls of the lubricant layer, it is obvious that this type of relief would be suitable for use in the sliding bearing. But for high-quality control of the parameters of the bearing microrelief it is necessary to set exact kinematic dependences to obtain it.

4. Study of the kinematics of obtaining microrelief

When studying various processing methods and comparing their capabilities, it is first necessary to know the dependence of the cut parameters (chip thickness *a* and chip width *b*) on the cutting modes, feeding, removed allowance, etc.

The cutting surface during planetary turning by rotary cutters is considered to be a cylindrical surface, the normals to this surface pass through the point of sleeve rotation. As a result of this, the average thickness of a cut a_{av} is measured in a plane perpendicular to the axes of the tool and the sleeve.

To derive the formula for finding average thickness of a cut we consider the pattern of removing of chip (figure 2) in this plane (figure 2).

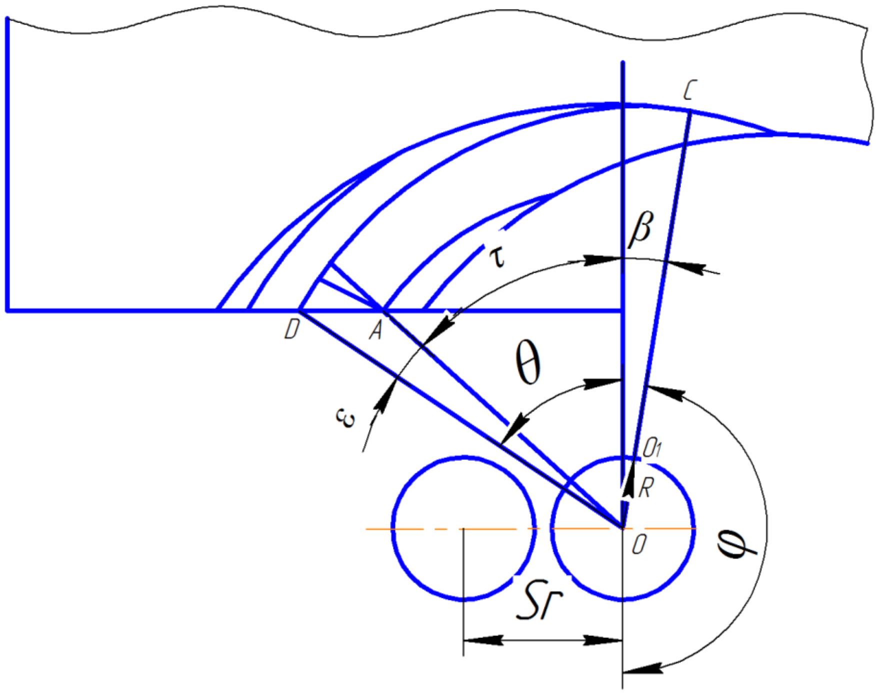

Figure 2. Calculated pattern for determining thickness of the cut layer.

When tool-center point is in O_1, the rotary cutter enters the part at the point C and exits at the point A, located on the radius circle $R+r$, where R – planetary motion radius, and r – rolling radius. Since the value of R is negligible, we carry out some simplifications and consider that the line connecting the center of planetary motion and the output points of the rotary cutter is equal to $R+r$.

The rotation time of the tool and the sleeve is different, during the rotation of the tool by an angle of 2π the sleeve rotates by an angle $\varepsilon = 2\pi / i$, which corresponds to the movement of the tool from point A to point D.

The average thickness of the layer is determined from the condition

$$a_{av} = F / m, \tag{1}$$

where F – the area of a cut; $m = b$ – length of the forming surface of cutting (chip width).

The area of a cut is determined by the known technology factors

$$F = S_r \cdot t, \tag{2}$$

where S_r – cutter feed; t – cutting depth.

The length of the forming surface is radius circular arc length $R+r$

$$m = b = \frac{(R+r)\cdot 2\pi \cdot \theta_{\max}}{360}, \tag{3}$$

where θ_{max} – angle of contact.

The contact angle is maximum at a roller rotation angle $\lambda = 180^{\circ}$.

Substituting the values F and m in the formula (1) we find the average thickness of the cut

$$a_{av} = S_r \cdot t \cdot 360 / 2\pi \cdot \theta_{\max}(R+r). \tag{4}$$

Dependencies (1) and (4) allow us to see the influence of various technological factors and design parameters on the thickness of the cut. Figure 3 graphically shows the change in the thickness of the cut on the sleeve feed for different radii planetary motion R. The data for constructing a graphical dependence are presented in table 1.

Table 1. Parameters for constructing the dependence of the feed on the thickness of the cut layer.

Parameter	*r, mm*	*θ*, °	*t, mm*
Value	5	60	0.8

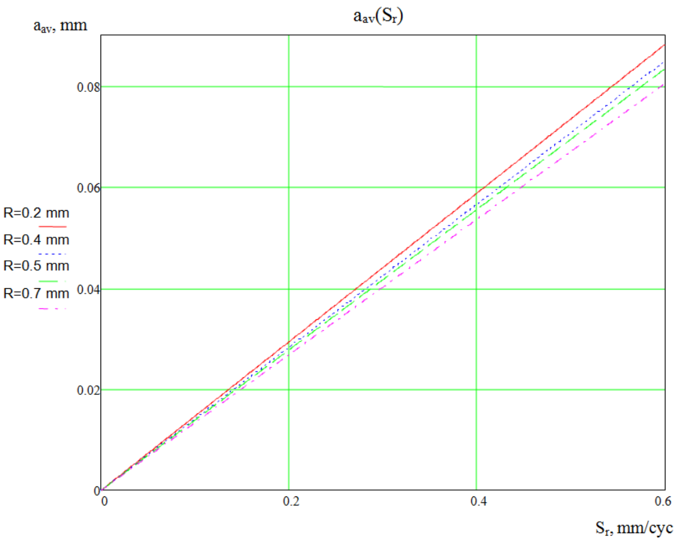

Figure 3. The effect of tool feed on the average thickness of the cut layer.

The graph in figure 3 clearly shows how using the obtained dependence (4), the geometrical parameters of the obtained microrelief can be selected and controlled by the kinematics of the tool feed.

Nonetheless, it is clear that further studies of rotary modules are necessary for the formation of the microrelief on the surfaces of sliding bearing supports, in particular, the study of the power parameters of the cutting process and the geometric parameters of the tool.

5. Conclusion

The prerequisites for the development of sliding bearing supports for the oil and gas industry centrifugal machines are identified. A promising development way was found to increase the reliability of sliding bearing supports. It consists in using the relief on the working surface of the bearing. It provides the presence of an additional volume of lubricant in the contact area of the sliding surfaces, which reduces wear at the time of starting up the equipment. In the experimental tests of rotary modules it was found that with their help it is possible to create a cellular relief that can be effective for sliding bearing supports in terms of the hydrodynamics posed by it and its other properties. The kinematics of the rotary module for understanding the process and the quality control of the microrelief creation on the bearing surface was investigated.

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