Choice of finishing and strengthening treatment method for cycloidal screw surfaces for multi-product production conditions

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Annotation. This work is devoted to the study of modern methods of finishing complex profile surfaces, in particular, considered cycloidal screw surfaces, typical for single-screw machines of volume type. The operating conditions of parts with cycloidal screw surfaces are analyzed. In the article the technical requirements provided in the process of finishing are identified, and a method and device for implementing the method of finishing in the conditions of automated multi-product production are offered.

Introduction
Improving the design and performance of machines is often associated with an increase in the proportion of parts with complex surfaces [1]–[4]. A characteristic product that includes complex-profile parts is pumping and compressor equipment, in particular, single-screw pumps. Single-screw pumps are widely used in many industries (engineering, instrumentation, oil and gas industry, food production), where they are used to solve a wide range of tasks: lifting oil and reservoir fluids from wells, in-field pumping of liquids and oil and gas mixtures, transportation of various products in the food and wine industry, dosing of liquids and applying various mixtures on the surface, 3D printing, etc. [5].

Pumps of this type are volumetric rotary hydraulic machines that provide performance and durability when pumping liquids containing mechanical impurities and do not have lubricating capabilities. These characteristics are achieved by the principle of operation and design of the working bodies (screw pair). The principle of operation of single-screw pumps is to create a pressure of the injected liquid or other substance, carried out by moving the liquid by a screw metal rotor rotating inside the stator of the appropriate shape (figure 1). The screw pair consists of an elastic lining of the cage-the stator, and a screw with a wear-resistant surface-the rotor. The working bodies of these pumps have cycloidal screw surfaces with different types of profiles.

Figure 1. Principle of operation of a screw pair
The vast scope of application of such pumps makes it necessary to manufacture various versions of the screw pair geometry, the sizes of which have a wide range: from small sizes — in dispensers, to large — sized-in the oil industry. The development of methods and approaches to improve the quality of complex-profile surfaces of working bodies of single-screw pumps in conditions of multi-product production is an urgent problem [6]–[9], the solution of which is devoted to this work.

Screw pumps in operation can work in quite difficult conditions: with liquids and pastes containing abrasive particles; with chemicals; with food additives and other chemically aggressive environments. These operating conditions negatively affect the life of the pump's working parts. The most common causes of failure of the rotor of a screw pump are abrasive wear, acid exposure, fatigue wear, and pitting corrosion (figure 2) [5].

The influence of factors that lead to rotor failure during operation must be minimized. In order to reduce the chemical and corrosion wear of the rotor, it is necessary to use materials that have sufficient chemical resistance for the manufacture of the rotor. This material is stainless austenitic steel. Increasing wear resistance is realized by increasing the surface quality parameters of the cycloidal screw surface: increasing the hardness, reducing the surface roughness.

These requirements can be met by heat treatment of parts with subsequent application of finishing methods. The following methods are used as finishing methods: abrasive treatment (bound and free abrasive), surface plastic deformation (SPD), chemical and electrochemical methods [10]–[14]. The use of these methods depends on the volume of production.

**Methods**

Processing of rotors made of corrosion-resistant austenitic steels is possible only by PPD and magnetic abrasive polishing methods, which allow to increase the microhardness of the surface and at the same time reduce the surface roughness.

The most promising methods of SPD include combined hardening, software methods for applying additional oscillating and oscillating movements to the main process, and static-pulse processing of SPD [15], [16].

The essence of magnetic abrasive polishing is that the processed surface of the part or powder with magnetic and abrasive properties placed in a magnetic field, report a forced movement relative to each other. Metal removal is carried out as a result of the force action of the powder on the surface of the part and the specified relative movements (figure 3) [17].

The method of static-pulse processing of SPD consists in periodic pulse action on the loaded surface by a striker through a statically loaded waveguide, which allows more precisely controlling the distribution of microhardness and residual stresses at a significant depth of the hardened surface layer (figure 4) [15].
These methods are based on the use of special equipment and tools for processing complex-profile surfaces, which limits their use in conditions of multi-product production. In view of this, it was proposed as a method of finishing processing to apply rolling toroidal roller of complex profile surfaces directly on metal-cutting equipment with CNC without changing the scheme of basing and fixing the workpiece. This solution provides high flexibility due to software control of the rolling process, will avoid the appearance of basing errors due to the implementation of the "one-step" processing principle, as well as reduce the labor intensity of production of parts containing complex-profile screw surfaces, due to the implementation of processing in automated mode.

Based on the above, it can be concluded that it is advisable to use software methods of PPD on CNC machines. As a tool, it is proposed to use a roller with a toroidal deforming surface [18], which will provide the possibility of rolling the cycloidal helical surface of rotors with different geometric parameters on standard CNC equipment.

**Results and discussion**

To implement the method of rolling a complex profile surface on a multi-purpose CNC machine, it is necessary to develop a tool that allows running on metal-cutting equipment [19] [20].

As a tool for processing, it is proposed to use a device containing a roller with a toroidal working surface, a housing that acts as a guide and accommodates an elastic element, and a tool cone for installation in the machine spindle by an automatic tool change system (figure 5). Creating the necessary pressure in the contact zone of the roller and the workpiece is carried out by deforming the elastic element inside the device body by a certain amount. The constant value of the deformation
is provided by controlling the processing process by means of the CNC. Moreover, given that the stiffness of the technological system can differ significantly at different points, the value of the working deformation of the elastic element should be an order of magnitude greater than the value of the deformations of the technological system under the action of the rolling force [21].

![Figure 5. Sketch of the device for running-in](image)

The use of the proposed device will allow for forming and finishing-hardening processing in automatic mode on a single operation, which becomes possible due to the expansion of technological capabilities of CNC equipment. In addition, this approach will reduce the preparatory and final time by increasing the concentration of the transition on a single operation, and the implementation of the principle of processing "in one step" allows you to avoid the occurrence of errors based on the stage of finishing processing of a complex surface.

**Conclusions**

As a result of the analysis of modern methods of finishing and strengthening processing of complex profile surfaces, it was found that the most progressive for processing cycloidal screw surfaces of parts made of austenitic steels in the conditions of automated multi-product production is software rolling with a toroidal roller on multi-purpose machines. The developed device for rolling on a CNC milling machine allows you to expand the technological capabilities of this class of equipment and produce shaping and finishing-hardening processing in an automated mode, which is an indisputable advantage for multi-product production.

In the future, it is planned to simulate the process of rolling in conditions of variable stiffness of the technological system, due to this, to clarify the modes of rolling and then implement the processing process on complex-profile blanks, rolling in one step after forming on a CNC milling machine.

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