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Main trends in intensification of rotor-screw processing of parts

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Abstract. The ways of productivity increase in details finishing-strengthening processing executed in rotor-screw technological systems are presented. It is shown that the use of rotor-screw machines makes it possible to combine the parts machining using a vibrating field with a large amplitude of oscillations and their transportation in a streamlined form of production organization. Two main directions of rotor-helical processing stimulation are identified: on the basis of structural changes in the screw rotor, as the main working element of the rotor-screw machine and by equipping the screw rotor with activation elements of the process. The classification of screw rotors is presented, which allows purposeful search for the most effective designs of screw rotors and the mechanism is revealed of their influence on the process of parts finishing-hardening processing. Dependence is established for determining the longitudinal movement speed of the parts being processed in the screw rotor. The constructive-technological scheme of the rotor-screw machine is proposed, which allows increase of the productivity of the process and simplification of the design of machines for their implementation, by dismembering the complex screw propulsion of the load mass, which takes place in the screw rotors, into relatively simple in kinematic sense motions. The technological possibilities of rotor-screw processing application for finishing-strengthening operations are presented.

1 Introduction

The increase in productivity and in finishing and strengthening operations energy costs reduction during the machine parts manufacture can be provided by introducing rotor-screw machines into technological practice. These machines combine two, in general, independent but essentially interconnected technological tasks - processing of parts, using a vibrating field with a large oscillations amplitude and their transportation in the streamlined form of production organization.

The intensity of the rotor-screw treatment (RST) depends on the dynamic parameters determined by the regimes, the process duration, the granulated processing bodies characteristics and dimensions, the machined parts material mechanical properties, and the like.

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Further improvement of the process and the development of the RST, identifies two fundamental areas of intensification:

– The first is the RST intensification on the basis of the structural changes in the screw rotor – as the main working element of the rotor-screw machine. Constructive ways of RST intensification mainly solve the problems associated with changing the processing medium particles motion dynamics. The change in the medium dynamic state leads to an increase in the force factors of the particles contact with the surface being processed.

– Second, the RST intensification by equipping the screw rotor with activation elements of the process. The introduction of additional elements into the screw rotor working area ensures the uniformity of the particles dynamic effect on the processed part.

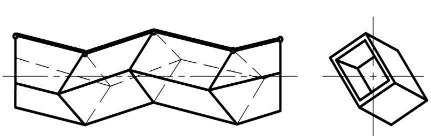
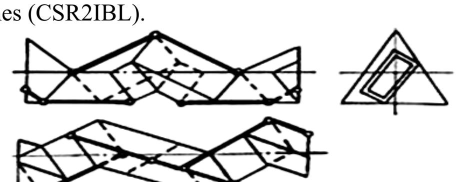
2 Classification of screw rotors and their influence on the intensification of processing

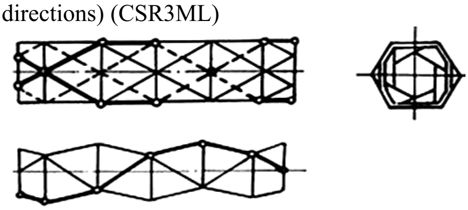
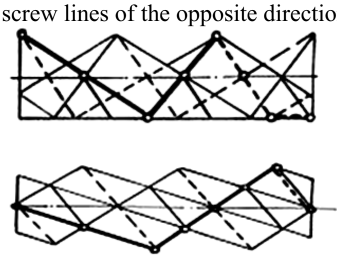
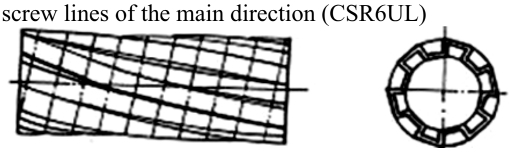
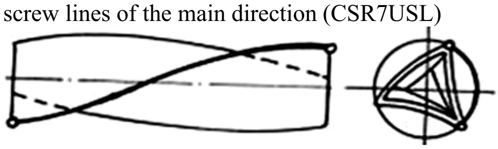
As noted earlier, the screw rotors are characterized by the technological process execution, during the processing objects transportation in an undirected state through the working space of the working bodies at an arbitrary speed. This possibility of combining transport and technological functions in one machine is realized by using working bodies with discretely disposed along the perimeter, flat elements of various shapes and sizes, different combinations of which makes it possible not only create and implement oscillations of processing objects with an oscillations amplitude up to 10 - 1000 mm or more inside the screw rotors, but also to control the vibrational process of these objects of processing, while reducing transport or technological effect [1,2].

The presented classification of screw rotors (Table 1) allows purposeful search for the most effective designs of screw rotors. The heart of the proposed classification are parameters that characterize transport or technological movements in one or another degree: the type and pitch of the screw lines, their direction, dimensions, shapes and plane elements arrangement. Each of these types of screw rotors, depending on the shape, number and flat elements size, includes 7 classes, differing in their design features and types of screw (zigzag) lines.

This classification of screw rotors through combining the structural elements provides the necessary speed of the rotor-screw technology system.

Table 1. Classification of screw rotors (SR)

The SR class and its image	Main advantage and disadvantages
1st class – screw rotors of zigzag shape with zigzag lines of the main direction along their perimeter (CSR1ZL). 	Advantages: – simple design; – the average mass motion intensity. Disadvantages: – the uniform mass motion is; – not high transportability, only at an angle to the SR axis.
2 class – screw rotors with intermittent broken lines (CSR2IBL). 	Advantage: – action on the particles of vibration in three mutually perpendicular directions; – stationary motion of particles in a screw rotor; – the intensity of mass motion is high. Disadvantages: – low transportability, only at an angle to the SR axis.

3 class – screw rotors with multidirectional broken screw lines of the same pitch (main and opposite directions) (CSR3ML) 	<u>Advantage:</u> – increased productivity; – high mass motion intensity. <u>Disadvantages:</u> – low transportability – complex in the design.
4 class – screw rotors with multidirectional broken screw lines, in which the pitch of the screw lines of the main direction is twice as large as the pitch of the screw lines of the opposite direction (CSR4 ML) 	<u>Advantage:</u> – the low transportation speed of; – complex mass movement; – high performance; – the high mass intensity motion; <u>Disadvantages:</u> – transportability is low; – difficult to design.
5 class – screw rotors with multidirectional broken screw lines, in which the pitch of the screw lines of the main direction is four times larger than the pitch of the screw lines of the opposite direction (CSR5ML). 	<u>Advantage:</u> – intensive mixing; – high; – transportability. <u>Disadvantage:</u> – complex in design.
6 class – screw rotors with unidirectional broken screw lines of the main direction (CSR6UL) 	<u>Advantage:</u> – simple design; – intensive mixing.
7 class – screw rotors with unidirectional smooth screw lines of the main direction (CSR7USL) 	<u>Advantage:</u> – simple construction; – high transportability. <u>Disadvantage:</u> – very low mass movement intensity.

A typical scheme of the technological system for finishing and hardening of parts using screw rotors is illustrated in Figure 1.

In the rotating screw rotor 4, through the loading 8, the working medium and the parts to be processed are continuously loaded. When the screw rotor 4 rotates, the media particles of the working medium move along the screw grooves and are discharged into the hopper to receive processed parts and working medium particles. Thus, when the screw rotor 4 rotates, the working medium particles and the processed parts are gripped by the inner screw surface, and are lifted up in the direction of rotation. Under the action of gravitational forces and the angle of natural slope, the particles of working media and the machined parts move towards each other at certain angles and to the walls of the rotating screw rotor 4 and move towards the unloading. Since the surface of the screw rotor 4 is continuous, the process of moving the subsequent portions of the machined parts and the particles of working media that rise and fall down, and move at different angles, is continuous as well. Since the flat elements of the inner surface of the screw rotor 4 are arranged at an angle to each other, each portion of the particles of the working media and the processed parts interact with each other and with the walls of the screw rotor. Depending on the design of the screw rotor, it is possible to significantly widen the range of changes in the resultant vectors of the relative displacements of the particles of the working medium and the machined parts, as well as increase the probability of their collisions both with each other and at the initial moment of detachment from the walls of the screw rotor 4, where they have a reserve of kinetic energy and move with great kinetic energy, providing parts processing intensification.

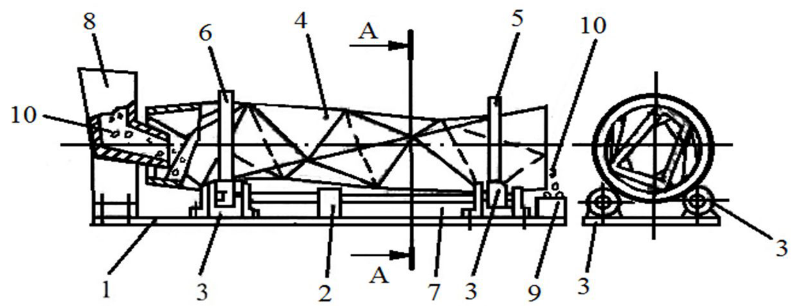


Fig.1. Rotor-screw machine for finishing hardening of parts (1 – frame, 2 – drive, 3 – roller bearings, 4 – screw rotor, 5 and 6 – two rims, 7 – drive shaft, 8 – loader, 9 – bunker for receiving processed parts and particles of working media; - machined parts and particles of working media).

On the basis of analytical and experimental studies, a dependence is proposed for determining the longitudinal velocity of the machined parts in a screw rotor in the form:

$$V_п = A_o \cdot (\omega^3 + B_1 \cdot \omega^2 + B_2 \cdot \omega + B_3), \quad (1)$$

where: A_o – coefficient depending on the working conditions of the screw rotor ($A_o = f(K_{V,} m_{1,} m_2)$; $B_{1,} B_{2,} B_3$ – coefficients that characterize the design features of screw rotors; m_1 – the mass of the machined parts; m_2 – mass of particles of the working medium; K_V – coefficient of filling the internal cavity of the screw rotor ($K_V = V_m / V_{p.c.}$); V_m – volume of masses of parts and particles of working media loaded into the internal cavity of the screw rotor; $V_{p.c.}$ – volume of the internal cavity of the screw rotor; ω – angular rotational speed of the screw rotor.

Since the rotation of the screw rotor 4 from the drive 2 is transferred by means of four roller bearings 3, the replacement of the screw rotor of another design and shape is accomplished by removing 3 the screw rotor 4 with two rims 5 and 6 from the roller bearings and by mounting the other type of screw rotor the same size and relative position of the rims in its place.

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3 Application of activation elements for intensification of processing

Screw rotors provide high productivity and continuity of processing due to a complex constructive form, the implementation of which in practice causes certain difficulties.

The use of the second RST intensification direction of the allows solution of this problem by dismembering the complex-screw motion of the loading mass, which takes place in the screw rotors, to relatively simple in kinematic sense motions. At the same time, it is necessary to increase the productivity of the process and simplify the design of machines for their implementation.

As an example, Figure 2 shows the rotor screw machine for finishing hardening of parts, equipped with a working member in the form of a cylindrical rotor with built-in screw springs. Such working bodies are easy to manufacture and like screw rotors they provide the possibility of spatial parts machining [3].

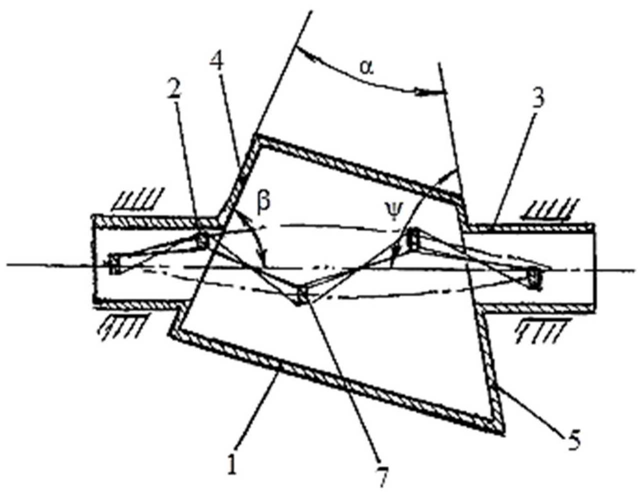

Fig. 2. Scheme of a rotor-screw machine for processing parts (1 – rotor, 2 – spring of convex shape, 3 – pin, 4 and 5 – rotor rotor walls).

The cylindrical rotor 1 with end walls 4 and 5, placed at different angles not only to the horizontal axis of rotation but also to each other, is installed obliquely with respect to the horizontal axis.

Through the entire length of the rotor a spring 2 is mounted of a convex shape with a flat cross section of turns, which is equipped with a device for changing the pitch of the turns by stretching or compressing it.

When the rotor 1 rotates, the processed parts and particles of the working medium move along different elliptical trajectories, the dimensions of which vary along the length of the rotor 1 in each cross section, while the machined parts perform a complex spatial motion in a vertical plane – along elliptical trajectories, since the rotor 1 is made in the form of an inclined cylinder, and in the horizontal plane – reciprocating one. As a result, the flow of moving processed parts and particles of the working medium is not stationary, the dimensions and location of the active action of the parts and particles of the working medium change markedly during one revolution of the rotor 1. Therefore, as a result of disruption in the ordering of the motion of the load mass, their motion becomes more active, zone of low mobility is liquidated, the energy intensity of their collisions with each other and with the walls of the rotor 1 increases. The process of the machined parts and particles of working media movement unsteadiness is aggravated by the location of the end walls 4 and 5, which create zones of different pressure, which significantly changes the load mass motion direction along the axis of rotation of the rotor 1. Therefore, the load mass under the influence of the geometric slope of the rotor 1 and the difference in pressure of the end walls of the elliptical shape 4 and 5 to each other and to their rotation axis, can not only move along complex trajectories, but also move from loading to unloading. This is facilitated by the internal tension spring 2.

4 Conclusion

The accumulated experience in the research of the application of rotor-screw machining on finishing-strengthening operations made it possible to establish its technological capabilities and conditions for effective implementation:

– the greatest impact on the performance of rotor-screw processing is provided by the rotation speed of the rotor, with the increase of which it grows linearly up to a certain limit (70rev/min), further increase leads to a decrease in treatment intensity due to equality or excess of centrifugal inertia forces with the weight of the processed parts;

– optimum filling factor of the internal cavity of the screw rotor $K_V = 0{,}5$;

– the removal of metal from the machined parts in the screw rotors occurs continuously, at practically constant speed;

– with an increase in the area of the cross section of the screw rotor, the velocity of the longitudinal motion of the load masses increases approximately in a linear relationship.

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