Increase of efficiency of finishing-cleaning and hardening processing of details based on rotor-screw technological systems

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Abstract. The article proposes technical solutions for increasing the efficiency of finishing-cleaning and hardening processing of parts on the basis of rotor-screw technological systems. The essence, design features and technological capabilities of the rotor-screw technological system with a rotating container are disclosed, which allows one to expand the range of the resulting displacement vectors, granules of the abrasive medium and processed parts. Ways of intensification of the processing on their basis by means of vibration activation of the process providing a combined effect on the mass of loading of large and small amplitude low-frequency oscillations are proposed. The results of the experimental studies of the movement of bulk materials in a screw container are presented, which showed that $K_v = 0.5-0.6$ can be considered the optimal value of the container filling factor. The estimation of screw containers application efficiency proceeding from their design features is given.

1. Introduction
At present, devices with a vibro activator [1] are widely used for finishing-cleaning and hardening of parts at machine-building enterprises. The experience of practical application of vibrating machines shows that they work efficiently when their working chamber oscillates with an amplitude of 0.5 - 8 mm. Exceeding the specified amplitude-frequency characteristics leads to a significant decrease in the period of their operation. In addition, when using vibrating machines for finishing-cleaning and hardening of parts, a serious problem requiring resolution is the issues related to loading, unloading of parts from the working area and their subsequent transportation. In order to avoid this contradiction, as well as to expand the range of technological equipment amplitude-frequency, it is proposed to use technological systems with actuating devices in the form of screw containers to perform finishing-cleaning and hardening processing of parts [2-4].

2. Rotary-screw technological system with rotating container
The proposed design of the rotor-screw technological system for finishing-cleaning or strengthening machining of parts (Figure 1) consists of: frame 1, made in the form of a welded frame, the main motion drive consisting of electric motor 2, reducer 3 and four roller bearings with flanges 4 are fixed on the frame. Screw container 5, provided with two rims 6,
is supported by roller bearings. The bed is equipped with means for loading 7 and unloading 8, as well as rubbish-disposal hopper 9. Above the hopper in the container there are 10 holes for waste disposal (flashes, metal burrs, scales, etc.)

The rotary screw machine with rotating container works as follows. The working medium and the parts to be processed are continuously loaded into machine rotating container 5, through the means for loading 7. As the container rotates, the working medium and the work pieces move along the helical grooves and are discharged from it into means 8. The processing waste (flashes, burr material, scale, etc.) is discharged to waste bin 9 through holes 10.

Thus, when container 5 is rotated, the granules of the abrasive media and the work pieces are gripped by the inner screw surface, and in the direction of rotation they rise and move towards the discharge side. Upon reaching a certain height under the action of gravitational forces and the formed natural slope angle, the abrasive granules and the machined parts move towards each other at certain angles and to the walls of rotating container 5 and move towards the unloading side. Since the surface of the container is continuous, the process of moving of subsequent portions of the machined parts and abrasive granules that rise and fall downward moves at different angles is also continuous. Since the container inner surface flat elements are at an angle to each other, each portion of the abrasive granules and the work pieces moves along its direction vector toward the discharge side, which greatly intensifies the interaction of the abrasive granules and the work pieces with each other and with the walls of screw container 5.

As a result of this construction of container 5, the range of changes in the resultant displacement vectors, granules of the abrasive medium and the work pieces is greatly expanded, and therefore each abrasive granule and workpiece move in different direction vectors, which provides a high probability of collisions at the initial moment of detachment from the container walls, where they have a certain supply of kinetic energy and move with a large kinetic energy, so the processing of details is intensified.

It is known [3] that the value of the speed of longitudinal displacement of the machined parts and granules of the abrasive medium in container 5 is significantly affected by the change in filling factor \( K_v \). To determine the optimum value of \( K_v \) for the rotor-screw machine, experiments were performed, with changes in the inclination angles \( \Theta \) of the screw container \( (\Theta = 4^\circ - 7^\circ) \). These studies have shown that \( K_v = 0.5 - 0.6 \) can be considered the optimal duty cycle value.

The actuating device of the rotary screw machine container 5 shown in Fig. 2 is made of sections 11 mounted from two subsections 12 and 13 made of three or more alternately joined sides of isosceles trapezios 14 and isosceles triangles 15.

In subsection 12, base 16 of trapezium 14 and base 17 of triangle 15 are disposed in different directions of the subsection, the sections are connected to each other by the large bases of trapezoids 18, 19 as in Figure 2, and the subsections are connected to the section so that the bases of isosceles
triangles, one subsection 12 of base 17 are connected to the upper base, 20 isosceles trapeziums of second subsection 13, and the bases of the isosceles triangles of the second subsection, subsection 13, base 21 are connected to upper base 22 of isosceles trapeziums 14, of first subsection 12. As a result of such successive assembly of container walls 5, five right and five left hand helical polygonal lines with the same pitch are formed around the perimeter. One of the five left broken spiral lines with the steps of 23-24-25-26-27, and one of the five right-hand broken lines with the steps of 28-29-25-30-31 are shown by a thickened line.

![Figure 2. General view of rotor screw machine container](image)

3. Intensification of rotor-screw processing of parts by means of the process vibration activation

To ensure the effect of vibroliquefaction and as a consequence the loading mass activation (processed parts and particles of working media) in rotor-screw technological systems, it is proposed to perform a combined effect of large and small amplitude low-frequency oscillations on it.

Since in the rotor the magnitude of the motion amplitude of the load masses is determined and limited by the through screw rotor diameters, then to solve this problem it is necessary to use a screw rotor with a large spread of diameters of the cross-sectional diameters along the screw rotor length, for example made in the form of a spiral tunnel with a triangular cross section [3].

Figure 3 shows a machine for finishing-cleaning and hardening of parts, in which the proposed scheme of the total (simultaneous) effect on the mass of loading oscillations of large and small amplitudes is realized. In the presented design of the machine there is no vibroactivator, since small amplitude oscillations in the technological system are created due to the imbalance of the screw rotor itself and the load mass placed in it.

The machine consists of screw rotor 1, loading 2 and unloading 3 devices and a drive (not shown). Helical rotor 1 is provided with sleeves 4 and 5 rotatable in bearing supports 6 and 7. Toe 8 of loading device 2 enters the bore of bushing 4 of screw rotor 1. Loading device 2, bearing supports 6 and 7, with screw rotor 1 mounted therein, are fixed to frame 9. Frame 9 is placed on two pairs of pneumatic tanks 10, 11 which are fixed to frame 12. Screw rotor 1 is made in the form of a broken, spiral-shaped tunnel with a triangular passage section, mounted from sections 13. Each section is mounted from one rectangle 14 and two lateral trapeziums 15 and 16, the lower bases of which are equal to the lateral side of the rectangle, and the upper bases of trapezoids 15 and 16 are equal to each other, the remaining free two sides of rectangle 14 are equal to the lateral sides of the trapezoids with the formation of end openings in the form of equilateral triangles, inclined in different directions and to the axis of the sections.

When assembling screw rotor 1, each subsequent section is rotated relative to the previous section by an angle corresponding to a rotation on one side of the triangle in such way that the axis of the sections are inclined to each other from the condition of their intersection. As a result of joining the sections, screw rotor 1 is formed in the form of a broken spiral shape tunnel, with a triangular cross-section and with broken lines along the perimeter of 17-18-19, 20-21-22, 23-24-25. When screw rotor 1 is mounted and sections 13 are rotated clockwise, a screw rotor is formed with the right direction of
the spiral shape of the tunnel, with the right direction of the discontinuous screw broken lines. When screw rotor 1 is mounted and sections 13 are rotated counterclockwise, a screw rotor with a left direction of the spiral shape of the tunnel is formed, with the left direction of the discontinuous screw broken lines.

![Figure 3](image-url)

**Figure 3.** Machine for finishing-cleaning and hardening of parts, in which the load mass is subjected to the combined (simultaneous) effect of low-frequency oscillations of large and small amplitudes

The machine for finishing-cleaning and hardening (Figure 3) works as follows. Screw rotor 1 is filled with a continuous flow of workpieces and working media through charging device 2. When screw rotor 1 rotates, the machined parts and media particles communicate a complex spatial motion with superimposition of oscillations in three mutually perpendicular directions excited by the geometry of screw rotor 1 with asymmetric motion of the load masses and imbalance as a result of a disturbance in the stationarity of the flow of the workpiece and particles of working medium by a geometric shape of the screw rotor sections, their mutual arrangement relative to each other and to the axis of rotation. In this case, the centers of symmetry of the inner surface of screw rotor 1 in each of its cross-section elements along its length are displaced relative to the axis of rotation, which disrupts the stationary motion of the machined parts and working medium particles. Due to the simultaneous impact of complex spatial motion with high amplitude and high-frequency oscillations of small amplitude, the miscibility of the machined parts and particles of the working media, their intensity of interaction with each other and with screw rotor walls 1 is increased. The mass flows of the processed parts and working medium particles move inside the screw rotor from loading to unloading. With further movement, the processed parts and working medium particles are discharged into discharging device 3.

4. **Conclusions**
Technical-and-economic advantages of using rotor-screw technological systems arise due to the expansion of the range of changes, resulting displacement vectors, particles of working media and
processed parts, increasing the intensity of their mixing and reorientation, and increasing the speed of their movement from loading to unloading. This makes it possible to increase the productivity of finishing-cleaning and hardening parts.

By giving the processed parts and working media particles a complex spatial motion with a large amplitude and simultaneously affecting them in three mutually perpendicular directions with a small amplitude, the processing intensity, the energy intensity of the interaction of the machined parts and working medium particles with each other, with the walls of screw rotor 1 increase and an effective finishing-cleaning and hardening processing of parts in rotor-screw technological systems is provided.

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