Technological support of the form-profile of the profile of the rings of the rolling bearings

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Abstract. The methods of forming the working surfaces of the rings of rolling bearings are considered. The influence of the shape of the profile of the rings on the performance characteristics of bearings is shown. The schemes of finishing the rings by superfinishing with profile bars and polishing with an inertial compacted abrasive particles are given. A new technology for improving the quality of the working surfaces of the rings is proposed and the results of experimental studies of the efficiency of ring processing are presented.

A promising direction in the formation of specified performance characteristics of rolling bearings is to improve the quality indicators of working surfaces.

Research by the Institute of Mechanical Engineering of the Academy of Sciences of the Russian Federation has established that rational profiling of the tracks and rolling elements can increase the durability of bearings six times or more.

Therefore, improving the finishing of parts with a complex surface geometry, despite the variety of processing methods, is relevant, as the manufacture of such parts with stringent requirements for surface roughness and dimensional accuracy leads to significant costs.

One of the possible ways to solve this complex technical problem is the application of the technology of inertial compaction of the grinding material to transform free abrasive particles into an elastic cutting tool that copies the profile shape of the details.. The compaction of the grinding material particles occurs under the action of centrifugal forces, and the cutting process occurs as a result of the contact interaction of the surfaces of the processed rings with the abrasive layer compacted into the profile tool as a result of their relative movement [1].

Under the action of the inertial force field, the abrasive tool is formed from the mass of particles of the grinding material in the form of a ring or a segment that acts on the surfaces of the parts to be machined and provides accurate profiling on hard-to-reach areas, contact with which is difficult for abrasive tools on the bond. The higher the degree of compaction of the grinding material, the greater the contact pressure exerted by abrasive particles on the surface of the part, increasing the removal rate of the metal.

Under production conditions, the final formation of the internal geometry of the bearing rings is carried out by profile bars on super-finishing machines. However, precision shaping and control of cutting properties of bars is not well understood and is laborious, optimizing the conditions of contact interaction of the cutting contour of the bar to increase the number of active cutting grains, increasing the rigidity of the contact surfaces of the tool and part are a complex technological task. The low level of versatility and technological flexibility of the superfinishing process for processing various types of
bearing rings does not guarantee the stability of the operating characteristics of the working surfaces of the rings in automated production conditions.

Thus, standard roller bearings with a straight line forming the working surfaces of the raceways of the rings have high rigidity and accuracy of rotation, but do not allow distortions during installation and operation, and this is unattainable in real conditions. At the same time, even the minimum misalignment of the bearing rings leads to a dramatic decrease in the durability and load capacity of roller bearings, since the distortion changes the distribution of loads along the length of contact between rolling elements and rings, and increases vibration and noise levels, as well as sticking and fatigue damage on contact surfaces.

More rational contact conditions are achieved by changing the shape of the raceway profile of the rings, when the raceways are formed by large circular arcs (bombins). Shaping rings with bombed raceways allows up to three times the durability of roller bearings.

Ball bearings are more resistant to the negative effect of installation and operational distortions, since the working surfaces of the rings of standard bearings have an arc profile.

However, for these bearings, more rational conditions for contacting the balls with the groove of the raceway of the ring can be achieved by changing the shape of the raceway profile, which will increase the durability of the bearing by 2 ... 2.5 times compared to the standard design.

Diagrams of the distribution of contact pressures in bearings with a bombed raceway for roller and elliptical shape of the groove profile for ball bearings are shown in figure 1.

![Diagram](image1.png)

**Figure 1.** Diagrams of the distribution of contact pressures: a) in a roller bearing with a bombed raceway; b) in a ball bearing with an elliptical profile of the gutter P - contact pressure; $\Theta$ - the maximum skew angle of the axes of the bearing rings; $R_e$ is the radius of the groove raceway; $d_{w}$ - diameter of the bearing ball.

Processing was carried out on a pilot industrial machine TsPU-1M with grinding material from electrocorund. Machining of bombed raceways and elliptical grooves of the rings of rolling bearings is more labor intensive especially in finishing and finishing operations.

Superfinishing is widely used as a final treatment of the working surfaces of the rings. The formation of rings of roller and ball bearings is produced on superfinishing machines. (figure 2)
Forming the rings of roller (a) and ball (b) rolling bearings: 1 - blank (ring); 2 - abrasive bar; 3 - the surface of the ring roller bearing; 4 - the trajectory of the movement of the bar; Q - the force of the clamp bar; n0 - the frequency of oscillating movements of the bar; B - the width of the bar; \( V_k \) - the speed of rotation of the ring.

Superfinishing is carried out with fine-grained abrasive bars with the removal of thin (0.1 ... 5 micron) microstructures. At the end of the machining cycle, the cutting process goes into nursing mode (boundary friction), in which the abrasive stones smooth and polish the surface of the ring without removing chips. Superfinishing of curvilinear surfaces is usually carried out in two transitions: on the first, the main metal removal is carried out, and on the second, the required surface roughness is formed. However, this structure of the technological operation significantly reduces productivity and increases the cost of ring processing.

Analysis of the results of superfinishing under production conditions showed that up to 40% of the rings with the initial roughness \( R_a = 1.25 ... 0.8 \) \( \mu \)m (after the grinding operation) have traces of sanding marks and require re-processing, and the profile can be distorted. Therefore, for a stable reduction of surface roughness, it is necessary to carry out the superfinishing process in several transitions.

The low level of versatility of superfinishing machines does not allow processing of rings of different shape on the same machine, since the tool paths and the kinematics of the machine will be different.

Therefore, it is important to resolve the issue of the versatility of the process equipment and increasing the technological flexibility of the process of finishing the rings of rolling bearings.

For a sustainable reduction of the roughness of the working surfaces of the rings of rolling bearings without distorting the geometric shape of the profile, various methods of processing parts with a free abrasive are used. These are technologies of jet waterjet processing, spindle vibration finishing in vibrating containers, centrifugal spindle processing with compacted working medium and magnetic abrasive polishing with special ferroabrasive powders (cermets). But all of them have certain technological disadvantages, which significantly limit the scope of their effective use. Therefore, they are not widely used in production.

More promising for finishing the rings of rolling bearings is the processing tool formed from free abrasive particles in the abrasive suspension, under the action of inertial forces. The principal structural schemes for processing the inner [2,3,4] and outer surfaces of the rings [5,6] are shown in figure 3.
Figure 3. Principal design schemes for processing the inner (a) and outer (b) surfaces of rolling bearing rings with inertia-compacted grinding material.

Hydroabrasive suspension is served in a container with rings installed in it (figure 3, a) or a drum (figure 3, b). Under the action of inertial forces caused by the rotation of containers with an angular velocity \( \omega_1 \), particles of the solid fraction of the suspension are transformed into a cutting tool in the form of a segment (figure 3, a, section A-A) or a ring concentric to the inner wall of the cylindrical drum (figure 3, b, section B-B). The rotation of the rings installed in cylindrical containers or on mandrels, with an angular velocity \( \omega_2 \), creates conditions for moving the surfaces to be treated with respect to the elastic abrasive tool, which ensures polishing of the outer (see figure 3, a) or inner (see figure 3, b) rings of rolling bearings.

To assess the performance of the process and the accuracy indicators of the new ring processing technology, experimental studies were conducted on the outer rings of rolling bearings No. 7205, the inner surface of which has a conical surface. The presence of a bomb (bulge) on the treadmill rings creates significant technological difficulties when processing abrasive tools on the bundle.

Processing was carried out on an experimental industrial machine TsP-1M with grinding material from electrocorundum normal grade 14A with different grain sizes. The surface roughness was
estimated on a “Surtronic” instrument, and the wave-shaped and cut-off rings on a “Talirund 51” instrument.

Research has shown that the removal of metal per ring diameter is up to 30 ... 40 microns with a unit ring processing time of 7 ... 8 seconds. The angle of inclination of the generatrix of the treadmill to the axis of the ring does not change from the initial one. The surface roughness $Ra = 0.1 ... 0.12 \mu m$ is stably reached. The waviness of the Hb surface decreased from Hb = 0.44 ... 0.78 $\mu m$ to Hv = 0.16 ... 0.36 $\mu m$, the ovality decreased by 1 ... 2 $\mu m$, and the size of the faceting of the rings remained almost unchanged, which is explained by the large step of the macro roughness and inertia - compacted instrument due to the rheological properties rounds it and reproduces the original form with a uniform metal removal.

The following effective modes of processing rings are determined: the contact pressure of an elastic tool $P = 0.1 ... 0.12 \text{ MPa}$; the speed of rotation of the rings around its own axis $\vartheta = 5 ... 6 \text{ m/s}$; particle size of the grinding material $Z = 500 ... 1000 \text{ microns}$.

The lack of burns, the stability of the surface roughness of the profile of the rings, the use of cheap grinding material, the versatility of the process equipment are important advantages of the new technology. Developed high-performance original design of machines for finishing rings [7,8,9].

The cutting properties of abrasive grinding tools are largely determined by the structure of the pores. Compare the pore volume in grinding wheels (rods) and in the compacted abrasive layer. The pore volume in grinding wheels is mainly determined by the hardness of the wheel. For circles of white electrocorundum 24A, the pore volume in percent is: for the circle of structure number 6, grain size F40, hardness K, L - 34.8%, hardness M, N - 31.1%, hardness O, P - 20.9%, and for the structure of circle No. 10, the grain size is F40, hardness K, L - 39%, hardness M, N - 37.1%, hardness O, P - 24.3%. At the same time, for the compacted layer of abrasive material 24A F40, the pore volume was 54%, and for 24A F90 it was 56%, that is, with decreasing grain size, the porosity increases.

The feature of new technology consists in an indissoluble combination of process of cutting to lubricant and cooling with liquid of suspension which under the influence of centrifugal forces gets directly into a zone of contact of the cutting particles with the surface of metal. It provides the low-temperature nature of abrasive cutting and leads to formation in blankets of metal of the squeezing residual tension up to 300 ... 350 MPa at a depth up to 0.015 ... 0.02 mm that favorably affects operational properties of rings. The size of renting of metal reaches 30 ... 40 microns on diameter of a ring at piece time of processing of one ring 7 ... 8 seconds that demonstrates high efficiency of abrasive cutting by the elastic inertial condensed tool.

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