Formation of the quality indicators of the working surfaces of the rings of the roll bearings in finishing operations

Alexander Zverovshchikov*, Vladimir Zverovshchikov and Sergey Nesterov
FGBOU VO "Penza State University", Penza, Russian Federation

* azwer@mail.ru

Abstract. The results of the study of the quality indicators of the surface of rolling bearing rings after the operation of fine grinding with an abrasive wheel and polishing with a profile elastic tool of abrasive particles compacted with inertial forces are presented. The advantages of processing with an elastic tool and the effect of processing modes on the roughness of the working surface of the rings, the amount of waviness and cut are shown. Recommendations on the practical application of the new technology are given.

Rolling bearings are widely used in machine-building and machine-tool manufacturing, road and rail transport, and aviation. Improving the quality of the raceways of the bearing rings will increase the reliability of various machines and mechanisms.

The surface quality of parts, which determines many indicators of the effectiveness of various mechanisms, is formed mainly in the finishing operations of the technological process and is mainly produced by abrasive tools. Achieving quality indicators on the contacting surfaces of complex curvilinear shape due to the high complexity of finishing works. The manufacture of bearing rings according to different technologies and modes leads to significant fluctuations in the quality indicators of the surface layer, and the durability of such parts may differ by several dozen times. Therefore, the task of developing and introducing into production new productive technologies for processing curved surfaces that provide a steady improvement in the quality of the surface is relevant.

A progressive technology of finishing various parts with shaped working surfaces, in particular rings, is centrifugal-abrasive treatment [1], in which free abrasive particles of a hydroabrasive medium under the action of inertial forces are formed into an elastic cutting tool that is profiled along the contour of the surfaces of the parts being processed.

To assess the accuracy parameters and indicators of the quality of the working surfaces of rings processed by the new technology, experimental studies were conducted on the outer rings of rolling bearings No. 7205, the inner surface of which has a conical surface (Figure 1, a). The presence of a bulge on the treadmill rings creates significant technological difficulties when processing abrasive tools on the bundle. The dimensions of the treadmill profile are shown in Figure 1, b.
Processing was carried out on a pilot industrial machine TsPU-1M with grinding material from electrocorundum of normal grade 14A of different grain sizes. The surface roughness was estimated on the device "Surtronic", and the undulation and cut of the rings on the device "Thalirond – 51".

An important quality indicator of the performance of the bearing rings, along with the accuracy of the geometric shape and size, is the roughness of the working surfaces. The value of roughness set by the designer creates favorable conditions for parts operating under conditions of contact friction, as it reduces the running-in time, reduces wear and increases durability. Studies of the formation of surface roughness of the rings by the parameter $R_a$ were carried out according to the method of multivariate experiment planning. The following variables were taken as technological factors: the rotational speed of the carrier, in the slots of which the container supports are placed, $n_v$, min$^{-1}$; rotational speed of containers with machined rings around its own axis $n_k$, min; grit of grinding material $z$, micron and processing time $t$, min.

A full factorial experiment 24 was put in the center of the plan, and then a transition was made to the central composite plan of the second order according to a known technique.

After statistical processing of the experimental results, a polynomial model was obtained that adequately describes the mechanism for the formation of surface roughness, in the form:

\[
R_a = 0.0298856 + 277 \cdot 10^{-7} n_v - 620 \cdot 10^{-7} n_k - 363 \cdot 10^{-7} z - 611 \cdot 10^{-7} n_v \cdot z + 0.036378 + 0.0444343 \cdot 10^{-7} n_k^2 + 2.453 \cdot 10^{-7} z^2
\]

The rotational speed of the carrier $n_v$ determines the pressure $p$ of abrasive particles compacted in the cutting tool on the surface of the rings, and the speed of rotation of the containers with the rings installed in them is equivalent to the cutting speed $v_k$ / The calculated values of contact pressure $p$ and cutting speed $v_k$ are given in Tables 1 and 2.

### Table 1. Contact pressure $p$ of an elastic tool made of abrasive particles of grade 14A on the surface of the rings for different frequencies of rotation of the carrier $n_v$ ($n_k = 1800$ min$^{-1}$, $n_v = 500$ µm; the volume density of abrasive particles $\rho_a = 1.87$ g / cm$^3$; monolithic grinding material density $\rho_m = 3.9$ g / cm$^3$).

| $n_v$, min$^{-1}$ | 500 | 700 | 900 | 1100 |
|-------------------|-----|-----|-----|------|
| $p$, MPa          | 0.05| 0.075| 0.1 | 0.125|

### Table 2. Cutting speed $v_k$ for different speeds of rings $n_k$ with capacities ($n_v = 1000$ min$^{-1}$).

| $n_k$, мин$^{-1}$ | 235 | 523 | 816 | 1106 | 1397 |
|-------------------|-----|-----|-----|-----|-----|
| $v_k$, м/с        | 4,58| 5,25| 5,93| 6,61| 7,29|
According to the model obtained, graphical dependences of the influence of individual technological factors on the surface roughness were constructed (figure 2).

Character of graphic dependence on figure 2, and suggests that with increasing carrier rotational speed, the surface roughness of the rings decreases and reaches a minimum value at a contact pressure of $p = 100 \ldots 110$ kPa (dependence 1), and with further increase of pressure on the polished surface there are some serious risks, which leads to a slight increase in surface roughness. At the same time, during the processing cycle, the abrasive particles are rounded, and the roughness parameters of the surface will be determined by the size of the micro and submicrelief of the rolled up abrasive particles. Reducing the processing cycle to 6 and 3 minutes, ceteris paribus, leads to the formation of a coarser roughness (dependences 2 and 3), since the protrusions of the tops of the abrasive particles do not have time to round and go to the surface. Deep risks are associated with the introduction of individual peaks into the metal surface, which reduces polishing efficiency.

![Figure 2](image-url)

**Figure 2.** The change in surface roughness with varying technological factors: a) the effect on the surface roughness $R_a$ of the frequency of rotation of the carrier $n_v$ (the contact pressure of the compacted layer $p$) and the treatment time $t$ (1 is the polishing time 9 minutes; 2-6 minutes; 3-3 minutes); b) the effect on the surface roughness $R_a$ of the container rotation speed $n_k$ (cutting speed $v_k$ and grain size $z$ of the grinding material (1 - grain size F70; 2 - F36; 3 - F22).

It was established that the speed of rotation of the rings around its own axis has an optimum zone of $v_k = 5.25 \ldots 5.93$ m / s (figure 5b, dependence 1). At the same time the grit of the grinding material is important. The best results are obtained using the F36 grain size (particle size $z = 500$ μm). The use of smaller F70 or large F22 abrasive particles (dependencies 2 and 3) is undesirable, since small particles, copying the microprofile of the surface of the part, will produce metal removal, both from the protrusions and from the cavities of the irregularities, making it difficult to level the treated surface, and large grains, possessing a greater mass, exert a high pressure on the metal surface, which, along with removing the irregularities of the initial surface, is accompanied by the formation of new asperities and the larger the grain, the more characteristic this trend ntsiya to increase surface roughness.

The studies made it possible to determine the following effective modes of centrifugal abrasive machining of rings: the contact pressure of an elastic tool is $p = 0.1 \ldots 0.12$ MPa; the speed of rotation of the rings around its own axis is $v_k = 5 \ldots 6$ m / s; the particle size of the grinding material is $z = 500 \ldots 600$ microns.

In these modes, the rings were pre-certified for controlled parameters. Profile rings after fine grinding and centrifugal abrasive machining are shown in figure3.
Studies have found that the angle of inclination of the treadmill, forming a ring, to the axis of the ring remains almost unchanged after polishing compared to the initial value after the final grinding. The surface roughness $R_a = 0.1\text{–}0.12 \mu m$ is stably achieved. The surface waviness of $H_a$ decreased from $H_a = 0.44 \ldots 0.78 \mu m$ to $H_a = 0.16 \ldots 0.36 \mu m$, the ovality decreased by $1 \ldots 2 \mu m$, and the size of the faceting of the rings remained almost unchanged, which is due to the large pitch of the macro roughnesses on the surfaces of the rings; therefore, the inertial compacted instrument, due to the rheological properties around it, reproduces the original shape with uniform removal of the metal.

The absence 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.

A high-performance original design of ring trimming machines [2,3,4] has been developed. Research results show the promise of using new technology for machining precision parts with annular surfaces, mostly of complex shape.

References

[1] Zverovshchikov V.Z. Dynamics of centrifugal processing of parts by discrete grinding material: monograph - Penza: Publishing house Penz. state University, 2005. - 200 p.

[2] Auth. Cert. No. 986746 (USSR) Device for centrifugal abrasive machining of ring-type products / Martynov A.N., Koltunov I.B., Zverovshchikov E.Z., Zverovshchikov V.Z., Rakitin S.G. claimed 29.04.81, publ. 7.01.83, bul. № 1

[3] Auth. Cert. No. 1007941 (USSR) Device for abrasive machining of parts / Martynov A.N., Zverovshchikov E.Z., Zverovshchikov V.Z., Karpov V.A., Pshenichny O.F. claimed 1.12.81, publ. 30.03.83, bul. № 12

[4] RU 2304503 C1 Russian Federation, IPC B24B 31/104. Device for centrifugal processing of parts / Zverovshchikov, V.Z., Zverovshchikov, A.E., Zverovshchikov, A.V., Belashov, M.V. Applicant and patent holder: Penza State University, claimed 14.02.2006, publ. 20.05.2007, bul. No. 23