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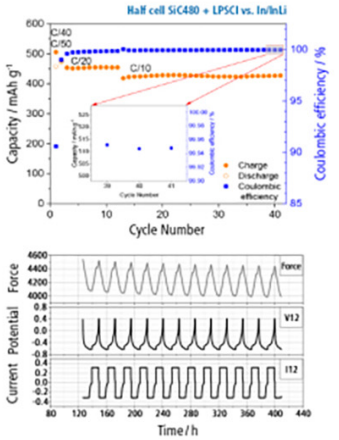
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Technologies and models for effective cleaning of rolling bearings from various types of operational contamination

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Abstract. Ensuring the necessary cleanliness of rolling bearings is a very complex and important scientific, industrial, and economic problem. Solving this problem allows for increasing the accuracy of machines and equipment that contain rolling bearings, significantly improving their operational properties and durability. As a result, this approach leads to a reduction in the use of metal, lubricants, and energy resources, as well as noise and vibration [1–3]. Ensuring technological cleanliness is relevant for both new bearings and those that have been in service and are being reused. The main types of contamination are metal particles (microchips formed during cutting or wear products), corrosion products, lubricant polymerization products, or accidental contamination from the external environment. Therefore, to solve the problem of ensuring the necessary cleanliness of ball bearings of various sizes, we have developed a model and technology for cleaning such bearings from various types of technological contamination, which is described in detail in this scientific work.

1. Introduction

Ensuring technological cleanness is important for both new bearings and those that have been in service and are being reused. For bearings that have been in service, typical contaminants are wear products from friction surfaces and lubricants that have changed structurally during operation. For new rolling bearings, the most common contamination is micro- and submicrometallic contamination that accumulates on all surfaces of bearing parts after machining. In both cases (for new rolling bearings and for rolling bearings that have been in operation), characteristic contaminants are micro-metallic contaminants (in the case of new bearings, these are cutting products, and in the case of used bearings, these are wear products) [4, 5]. According to statistical data, such contamination can be randomly distributed or form peculiar colonies. Metal contaminants, which primarily settle on working surfaces and are retained there by electromagnetic forces and adhesion, are one of the main sources of noise and vibration in operational, serviceable rolling bearings. Therefore, methods for assessing the performance of rolling bearings based on noise and vibration criteria are currently being actively developed [6, 7]. In any case, contamination is one of the main causes of wear on bearing tribo-surfaces and the destruction of rolling bearings as a whole.

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In industry, ultrasonic cleaning methods are most widely used, the effectiveness of which is well substantiated in specialized scientific literature [8, 9]. Ultrasound effectively destroys adhesive bonds between micro-metal and the base material of the bearing, contaminants in the form of oxides, lubricant residues, and other contaminants. However, ultrasonic methods are not effective enough to remove such contaminants beyond the working surfaces of bearings, which makes their use in this case not entirely appropriate. But the promising use of ultrasonic cleaning methods, especially in the bearing industry, is evidenced by a fairly large number of patents for inventions that have been obtained in many countries around the world [10, 11] recently.

The authors of this work have repeatedly researched and tested, including at enterprises in the bearing industry, a non-contact pulse-magnetic turbulent method for cleaning rolling bearings [5]. The method has shown high efficiency in cleaning bearings from micro-metal, but it does not allow for the qualitative destruction of non-metallic bonds, especially in miniature rolling bearings with an outer diameter of less than 30 mm.

Therefore, to ensure the necessary industrial cleanliness of bearings, it is necessary to design special equipment and develop appropriate methods, models, and technologies [12, 13].

2. Materials and Method

In this work, the authors propose technological solutions for the implementation of the rolling bearing cleaning process and a process model (Fig. 1) based on the use of ultrasonic methods and combined pulse-magnetic turbulent methods. Aviation gasoline or heated water should be used as the working cleaning fluid.

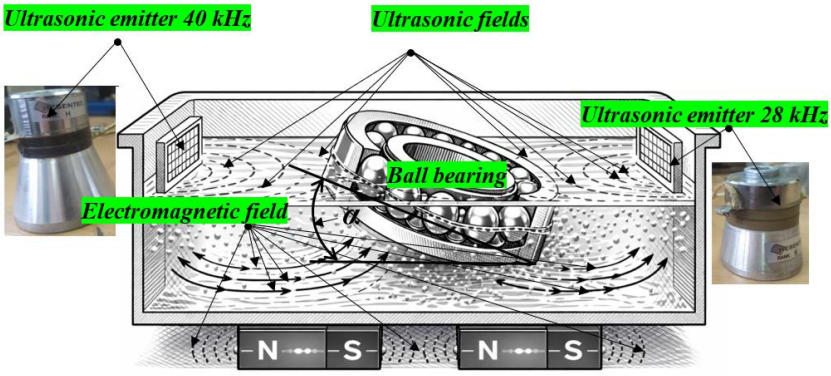


Figure 1. Model of ball bearing cleaning.

In Fig. 1, the ball bearing is placed in the cleaning device bath at an angle α equal to 30° – 45° (depending on the bearing size). The bath is filled with working fluid. To ensure the necessary cleaning efficiency of the rolling bearing, three components are used: ultrasonic fields; electromagnetic fields and cleaning and hydrodynamic properties of the working fluid.

The physical fields used are created by corresponding ultrasonic emitters and electromagnets of various powers. This provides a cleaning effect that consists in reducing the forces of adhesive and electromagnetic interaction between contaminants and working surfaces, softening and useful degradation of contaminants (delamination, chipping, and possible erosion). After that, such contaminants are removed from the working surfaces of the bearings into the filtration zone of the cleaning device, using turbulent flows.

The filtered liquid can be reused, which is an important aspect when introducing resource control and recovery technologies in enterprises [1, 14]. The cleaning time is selected individually depending on the degree of contamination and the type and size of the rolling bearing and ranges from a few seconds to 2 minutes. The cleaned bearings are preserved or reused.

3. Result and discussion

3.1 The effect of an ultrasonic field on a bearing

The ultrasonic field consists of a large number of waves propagating, in our case, in the working fluid without attenuation to an extent that allows the ultrasonic radiation source to propagate. According to previous studies [4], ultrasonic waves propagate without attenuation in such an environment, as they do in air. When ultrasonic waves encounter various types of solid obstacles, they bend around them and create cavitation in the working fluid, which manifests itself in the form of microbubbles (see Fig. 1). Cavitation further enhances the effect of ultrasound in breaking the bonds between contaminants and the working surfaces of bearings [15]. The use of different radiation sources (28 and 40 kHz) significantly improves the cleaning process, since the movement of the ultrasonic wave $\xi = A\cos(\omega t - k)$ will be pulsed. Frequencies of 20 – 30 kHz contribute to the rapid dissolution of surface contaminants and do not cause damage to the products. Frequencies in range from 35 to 45 kHz most often provide the fastest and most effective dissolution of contaminants, especially in grooves and cavities [8, 15].

In our case, in the bearing undergoing cleaning, there are shaded areas, i.e., areas between the bearing elements (separator, raceways, and rolling elements) where ultrasonic waves do not penetrate. This effect is explained by the fact that four ultrasonic radiation sources with different radiation frequencies are used, which are placed opposite each other along the axis, and the bearing is placed at a certain angle α to the flat surface of the bath in which the cleaning takes place.

Cleaning rolling bearings with ultrasonic fields destroys the adhesive, electromagnetic, and other bonds that attach various types of contamination to the working surfaces of the bearings. However, using only ultrasonic fields, it is not possible to effectively remove contaminants from the working surfaces of rolling bearings.

3.2 The effect of a pulsed electromagnetic field on a bearing

Acceleration to a specified rotational speed of a ball bearing of any size that can be cleaned is achieved using an alternating pulsed magnetic field created by multipole electromagnetic inductors of any configuration. When the alternating magnetic field is turned off, the ball bearing undergoing cleaning continues to rotate inertially for some time. This can be used as a method for diagnosing performance [16, 17]. The duration of the electromagnetic field is selected individually, depending on the design, size, and degree of contamination of the bearing. Unlike the ultrasonic field, according to research data, the electromagnetic field acts only on 30% of the ball bearing area (the rest of the bearing area is shaded). This is due to the peculiarity of the physical interaction of the electromagnetic field with the bearing material.

The action of the electromagnetic field effectively destroys the electromagnetic and partially adhesive bonds between the working surfaces of the bearing and the contaminants. In addition, the electromagnetic field not only sets the bearing being cleaned in motion without contact, but also creates turbulent flows in the working fluid.

3.3 Washing and hydrodynamic effects of working fluid on rolling bearings

The cleaning effect of the working fluid on the rolling bearing being cleaned is obvious, and the hydrodynamic effect is of particular interest.

Turbulent flows that arise in the working fluid under the action of an electromagnetic field contribute to the removal of contaminants from the rolling bearing being cleaned, first into the working fluid and then into the filtration system. In addition, given the peculiarities of the bearing's placement at an angle α, work is performed to move the fluid with the contaminants located in it, which is explained by Bernoulli's principle.

Thus, a comprehensive approach to cleaning rolling bearings of various sizes and degrees of contamination contributes to the effective and rapid cleaning of such bearings. The comprehensive approach involves the use of ultrasonic and electromagnetic fields, as well as the cleaning and hydrodynamic properties of the working fluid in special equipment used for cleaning bearings.

3.4 Determination of the effectiveness of bearing cleaning using the developed technology

The technology for cleaning ball bearings of various sizes involves cleaning them on a specially designed cleaning device, where the cleaning process is reflected in the developed model (Fig. 1). Cleaning takes place in a working fluid environment using ultrasonic and electromagnetic fields.

One of the main criteria for cleaning efficiency is the overall noise and vibration level before and after cleaning (Fig. 2).

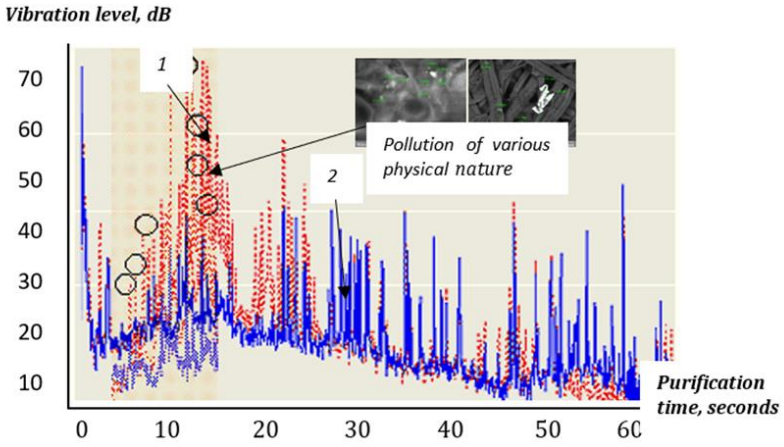


Figure 2. Oscillograms of the overall vibration level: 1 is before cleaning, when the bearing contains contaminants of various physical nature; 2 is after cleaning using the selected technology.

As can be observed in Fig. 2, the level of total vibrations of contaminated bearings may exceed 50 % compared to bearings cleaned using the developed technology. The removed contaminants have different physical properties.

Further analysis of the particles removed from the bearings showed that the number of R microparticles removed during the contactless combined cleaning process using the developed technology depends on their size L and is determined by the graphical dependence – Fig. 3. Depending on the size, the number of detected particles is distributed as follows: 50 – 330 μm – 8 %, 10 – 30 μm – 12 %, 5 – 10 μm – 20 %, less than 5 μm – 60 %.

The size and nature of microcontaminants removed from ball bearings subjected to cleaning were studied using SEM analysis (Fig. 4). The detected contaminant particles had the following

characteristic shapes: cubic and/or irregular particle shapes (Fig. 4 – a, b, c, e), in the form of metal shavings (Fig. 4 – b, c), scales (Fig. 4 – e, f), and in the form of amorphous conglomerates, presumably residues of old preservative grease (Fig. 4 – d, e).

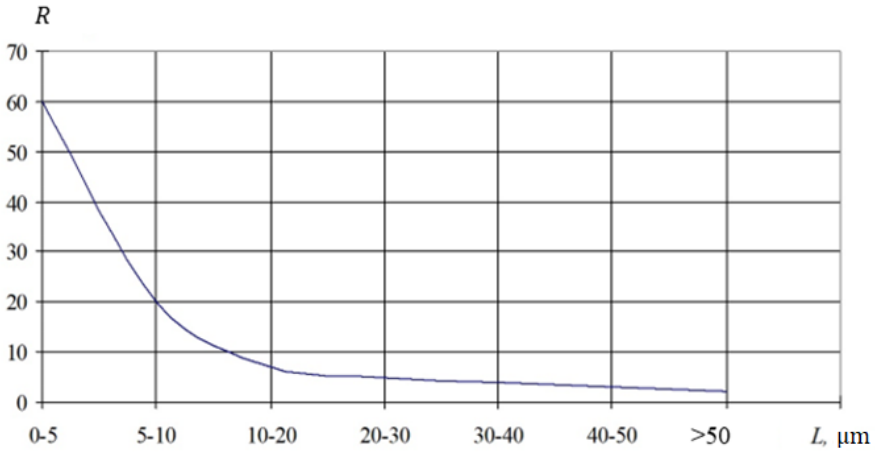


Figure 3. Graph showing the relationship between the number of contaminants *R* and their average linear size *L*.

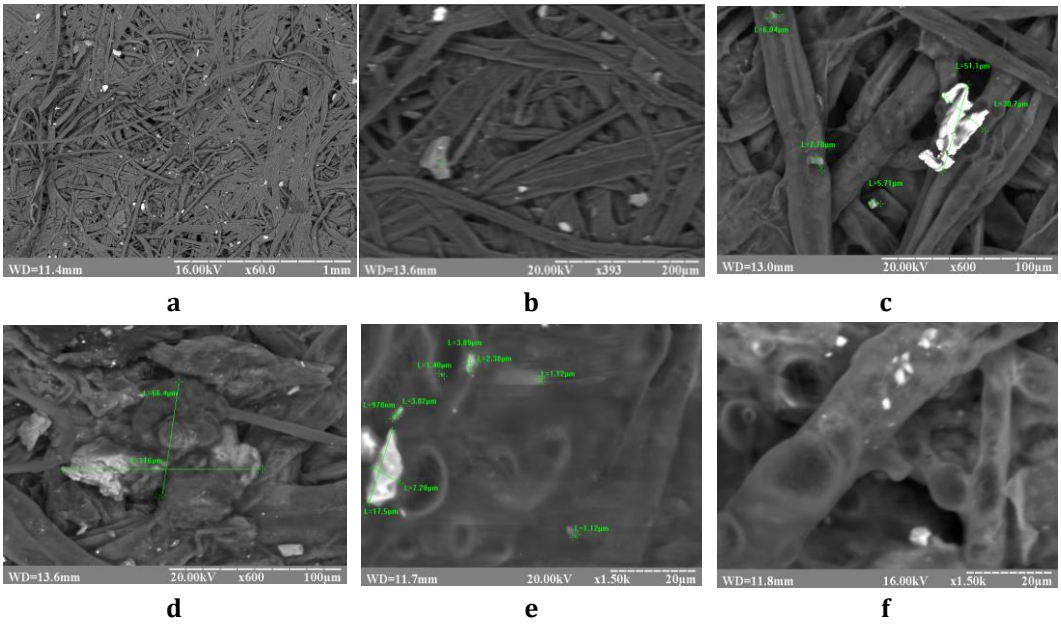


Figure 4. Fractograms of the studied contaminants: a, b, c, e are cubic and/or irregular shape; b, c are in the form of metal chips; e, f are in the form of scales; d, e are in the form of old oil residues.

SEM analysis of microparticles removed after cleaning showed that 80 % of the removed particles are ferromagnetic in nature and are retained at the boundaries of the domain structure of bearing part surfaces. It is noteworthy that about 5 % of the removed solid microparticles are metal-ceramic conglomerates, characteristic of the wear process of the abrasive tool used during

the final grinding of bearing surfaces, and microchips of various types. These particles are most dangerous not only for ball bearings during operation, but also for all friction pairs of oil systems.

4. Conclusions

During the research, a model and technology for cleaning rolling bearings from contaminants of various physical nature were developed, the effectiveness of which is based on the use of ultrasonic and electromagnetic fields, cleaning and hydrodynamic properties of the working fluid.

After cleaning, the overall vibration level of the bearings is reduced by up to 50 %. Depending on the size, the number of detected particles is distributed as follows: 50 – 330 μm – 8 %, 10 – 30 μm – 12 %, 5 – 10 μm – 20 %, less than 5 μm – 60 %.

Analysis of the physical nature of the contaminants showed that 80 % of the removed particles are ferromagnetic in nature, almost 5 % of the removed solid microparticles are metal-ceramic conglomerates formed by abrasive tools during final grinding, and the rest are other contaminants.

The results obtained are useful in the manufacture, repair, and maintenance of rolling bearings of various sizes and accuracy classes, especially miniature and precision bearings.

References

[1] Holmberg K and Erdemir A 2019 *Tribology International* **135** 389–396
[2] Yaroshevich N, Yaroshevych O, Lyshuk V. 2021 Drive Dynamics of Vibratory Machines with Inertia Excitation *Vibration Engineering and Technology of Machinery* **95**. 37–47
[3] Yaroshevich N, Gursky V, Puts V *et al* 2022 *Vibroengineering Procedia* **42** 1–6
[4] Kostyunik R, Mikosianchyk O, Stelmakh A *et al* 2025 *Journal of Engineering Sciences* **12** A10–A19
[5] Stelmakh A, Kostyunik R, Mikosianchyk O *et al* 2023 *Journal of Engineering Sciences* **10** A31–A40
[6] Rabah A and Abdelhafid K 2018 *Journal of Vibroengineering* **20** 240–257
[7] An G, Tong Q, Zhang Y *et al* 2021 *Mathematical Problems in Engineering* 6629474
[8] Weller R N, Brady J M and Bernier W E 2013 *Journal of Endodontic* **6** 740–743
[9] Mason T J 2016 *Ultrasonics Sonochemistry* **29** 519–523
[10] An ultrasonic cleaning method of bearing balls and device 2025 Patent WO1998031478A1
[11] Bearing flushing compositions and methods 2025 Patent US11021671B2
[12] Kostyunik R E, Mikosyanchyk O O, Shymchuk S P et al 2025 *Naukovi notatki* **84** 210–213
[13] Kostyunik R E, Mikosianchyk O O, Stelmakh A U *et al* 2025 Technologies and models for effective cleaning of rolling bearings from various types of operational contaminants *XX International Freik Conf. on Physics and Technology of Thin Films and Nanosystems* (Oct. 06–10, 2025, Ivano-Frankivsk, Ukraine) 216
[14] Techno-Economic Analysis of a Hybrid Renewable Energy System (HRES) with Biogas-Powered Combined Heat and Power (CHP) and Photovoltaic (PV) Systems Benedicta Croce et al 2025 *J. Phys.: Conf. Ser.* **3143** 012003
[15] Verhaagen B, Rivas D F 2016 *Ultrasonics Sonochemistry* **29** 619–628
[16] Xue L, Li N, Lei Y and Li N 2017 *Materials* **10** 675
[17] Zhang S, Zhang Y, Li L *et al* 2018 *Structural Health Monitoring* **17** 3–14