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OPERATING CONDITIONS OF ROLLING BEARINGS IN AGRICULTURAL MACHINERY, THEIR CAUSES OF FAILURE AND CONSEQUENCES

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Abstract

This article presents an analytical overview of the operating conditions of rolling bearings used in agricultural machinery, along with the causes and consequences of their failure. One of the main reasons for the failure of rolling bearings is fatigue-induced flaking and wear of the friction surfaces. Key contributing factors include external load effects on rolling surfaces; deformation of the rolling surface that increases localized contact stresses; internal defects of bearing components; reduction in surface hardness due to elevated temperatures from external heat sources; and corrosion of the rolling surfaces.

Keywords: *Rolling bearing, wear resistance, strength, hardness, lubricability, heat resistance, vibration resistance, corrosion resistance, friction unit*

In the design of modern machinery and agricultural equipment, between 150 to 350 types and sizes of bearings are used for various purposes. In this regard, the development of modern mechanical engineering has imposed high demands on friction units, particularly on bearing assemblies. One of the key measures to ensure these requirements are met is to enhance the wear resistance of bearing units.

For many types of bearing assemblies, the main criteria for improving wear resistance include strength, hardness, lubricability, heat resistance, vibration resistance, corrosion resistance, precision, and others (Ivanov M. N., 2008; Timofeev S. I., 2007; Lelikov O. P., 2006; Reshetov D. N., 1989; Shoobidov Sh. A., 2020; Mirzaev K. K., Shoobidov S. A., 2022).

In modern machine designs, various types and sizes of bearings are used depending on their type and installation location. These bearings must not only ensure wear resistance but also meet a range of other requirements such as low noise operation, reduced metal consumption, and a high degree of standardization, among others.

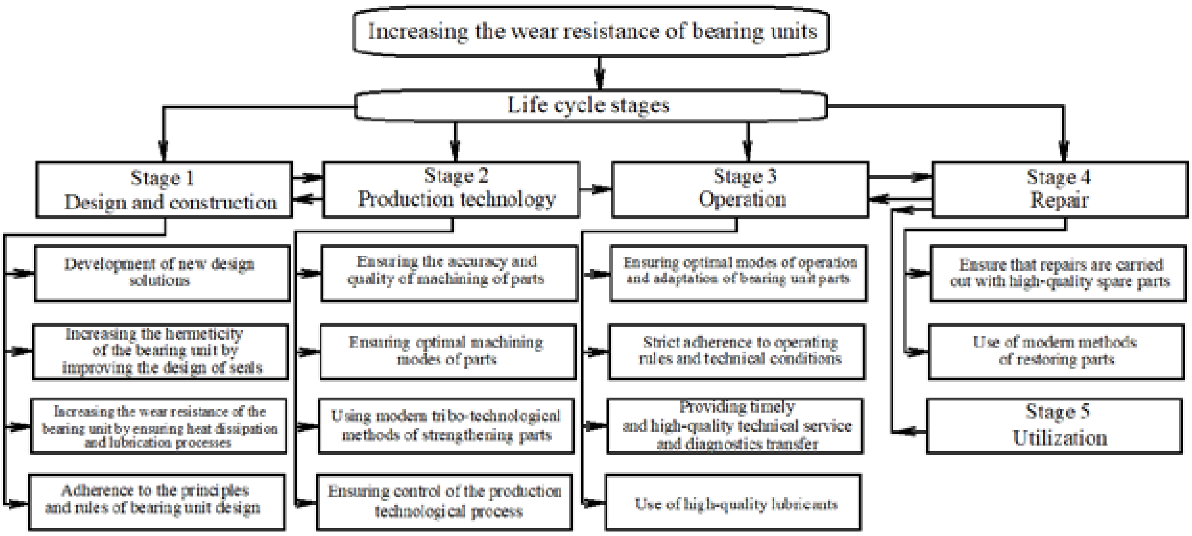
Despite continuous improvements in the design and operating conditions of bearing friction units, the issue of wear resistance in their components remains largely unresolved and continues to attract serious attention from designers, technologists, and users.

Analytical studies on failures due to insufficient wear resistance show that the service life of bearing components is significantly lower than the total service life of the machine – ranging between 30% to 60%. This results in increased labor and material costs for maintenance and repair during operation.

Therefore, enhancing the wear resistance of bearing friction units is a key engineering challenge that retains its relevance over time and requires various scientific approaches and directions.

To develop a scientific basis for a systematic approach to improving wear resistance throughout the entire lifecycle of mechanical products, future stages of mechanical engineering development should consider the integration of machine design, manufacturing, operation, and maintenance technologies (Suslov A. G. 2007; Fedonin O. N., 2001; Mirzaev K. K., Shoobidov S. A., 2022; Shaabidov Sh.A., Irgashev A., Mirzaev K. K. 2012). For instance, the operational cycle stages of bearing units are illustrated in the following diagram (fig. 1).

Figure 1. *Life cycle stages of bearing assemblies*



The issue of improving the wear resistance of bearing friction units remains consistently relevant, as trends in the development of science, technology, and engineering lead to increasing complexity in the design of friction units and their components. Additionally, operating conditions have become more demanding in terms of load, speed, temperature, vibration, and other parameters. Simultaneously, there is a trend toward reducing the external dimensions and specific mass of friction units, decreasing material and energy consumption, and increasing the degree of standardization (Chichinadze A. V., Brown E. D., Boucher N. A. and others. 2001; Shets S. P., 2011; Mirzaev K. K., Shoobidov S. A., 2022; Shaabidov Sh.A., Irgashev A., Mirzaev K. K., 2012).

Currently, in the construction of many machines and agricultural equipment, bearing assemblies are used that involve not only rolling but also relative sliding motions (rotational, reciprocating, or combined). The wide variety of bearing types, both individually and in combination with other structural elements, form bearing friction units with specific service life characteristics.

According to some sources, if new bearings are assembled correctly and operated according to standard parameters (lubrication, alignment, etc.), they can perform reliably and demonstrate high wear resistance throughout their calculated service life (Kogaev V. P., Drozdov Yu.N., 1991; Kuzmin V. A., 1990; Fadin Yu.A. 2004;

Mirzaev K. K., Shoobidov S. A., 2022). However, as bearings reach the limits of their operational lifespan, they tend to fail due to surface wear and fatigue-induced spalling.

Throughout the entire operational lifespan, bearing assemblies are subject to failures of varying intensity, necessitating additional costs for their elimination.

Analytical data shows that under real operating conditions, before a machine reaches its end-of-life stage, approximately 30% to 50% of its bearings are typically replaced.

Moreover, 40% to 70% of the downtime during maintenance of machinery is spent addressing bearing unit failures. More than 60% of bearing failures in agricultural machinery occur during actual usage.

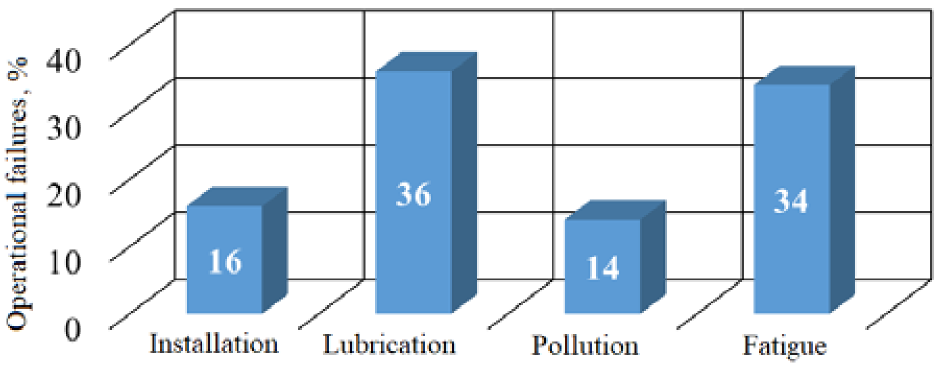
The percentage distribution of operational failures in machine and mechanism bearings is illustrated in figure 2.

The loss of wear resistance in bearings leads to operational failures that directly affect both operational safety and environmental conditions. During operation, the sudden failure of a machine or its components is diagnosed through technical condition monitoring, indicating whether a bearing needs to be replaced or not.

Operational costs related to the repair and maintenance of bearing assemblies can be 2 to 3 times higher than the cost of manufacturing them.

In practice, bearing assemblies are subject to gradual, sudden, and emergency failures during the use of machines. In such cases, the bearing may partially or completely lose its performance, failing to meet one or more of the functional requirements it was designed for. Therefore, timely identification of defects in rolling bearings is essential. Continued use of defective bearings can lead to the failure of not only other components of the unit but also the housing of the assembly itself. For this reason, it is important to develop methods to determine the type of downtime, identify the causes, and diagnose such conditions (Shets S. P. 2011; Shoobidov S. A., Mirzaev K. K., 2018; Shaabidov Sh.A., Nigmatullaev S. I., 2006; Zangiev A. A., Skorokhodov A. N., 2006; Mirzaev K. K., Shoobidov S. A. 2022; Shaabidov Sh.A., Irgashev A., Mirzaev K. K., 2012).

Figure 2. *Histogram showing the percentage ratio of bearing failures during machine and mechanism operation*



The defects of rolling bearings include the following: fatigue wear of friction surfaces; spalling of friction surfaces; abrasive wear; atmospheric corrosion; fretting corrosion; brinelling; false brinelling; surface scratches; assembly-related damage; overheating damage; load-induced damage; fracture and fragmentation of bearing elements; misalignment of bearing rings; damage to the separator; damage caused by improper lubrication; and thermal cracks on the outer surface of the outer race (Reshetov D. N., 1989; Shets S. P., 2011; Kuzmin V. A., 1990; Chermenskiy O. N., Fedotov N. N., 2003; Gorokhovsky G. A., 1999; Seregin A. A., 2010; Mirzaev K. K., Shoobidov S. A., 2022; Shaabidov Sh.A., Irgashev A., Mirzaev K. K., 2012).

One of the main reasons for the failure of rolling bearings is the spalling caused by fatigue wear on friction surfaces. The contributing factors to such wear include: the impact of external loads on the rolling surfaces; deformation of the rolling surfaces that increases localized contact stress; internal defects of bearing elements; reduced hardness of friction surfaces due to increased temperature from external heat sources; corrosion of the rolling surfaces.

The fatigue-induced spalling of rolling bearings can be reduced, and their wear resistance can be improved by enhancing the tribotechnical properties of lubricants. In particular, the addition of anti-wear additives to the lubricant composition yields positive results.

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