ANALYSIS OF MATERIALS USED IN BEARINGS

Jasurbek Xolmirzayev
Assistant at the Andijan State Technical Institute
Republic of Uzbekistan
ORCID ID: 0009-0008-4627-4783
https://doi.org/10.5281/zenodo.21125532

Abstract: Currently, mechanical systems used in technological machinery dissipate a significant portion of energy through friction and heat loss. This not only reduces the operational efficiency of the machine's working components but also shortens its service life.

Аннотация: В настоящее время механические системы, используемые в технологических машинах, теряют значительную часть энергии на трение и тепловые потери. Это не только снижает эксплуатационную эффективность рабочих компонентов машины, но и сокращает её срок службы.

Key words: tribological systems, physico-mechanical properties, surface layer, energy losses, composite coatings, nano-additive lubrication, surface friction.

Ключевые слова: трибологические системы, физико-механические свойства, поверхностный слой, потери энергии, композитные покрытия, смазка с нано-добавками, поверхностное трение.

The reliability and long-term operational efficiency of technological machinery used in the mechanical engineering industry directly depend on the quality and precision of their key components, such as shafts and bearings, as well as the tribological properties of the materials employed. These elements are constantly subjected to mechanical loads, friction, thermal effects, and variations in lubrication conditions. Therefore, the proper selection of materials for shafts and bearings is crucial for extending their service life and enhancing energy efficiency. Machines designed according to modern requirements operate at high speeds, with large torques and variable loads. This necessitates the use of materials with superior mechanical, physical, and tribological properties compared to conventional carbon steels [19]. In particular, high strength, wear resistance, surface smoothness, and corrosion resistance are considered the primary criteria in contemporary tribology. Consequently, a detailed analysis of the composition of metals and alloys intended for shafts and bearings, as well as their processing technologies, is essential.

When selecting materials for shaft components, the primary criteria include strength, fatigue resistance, surface hardness, and machinability. The most commonly used shaft materials are steels such as 45, 40X, 40CrNiMo, 42CrMo4, and 38X2MYuA [20]. These are medium- to high-carbon alloy steels, with a key advantage being their high potential for modifying mechanical properties through heat treatment.

In a 2022 study published in *Engineering Failure Analysis*, N. Hou and colleagues [21] conducted a comprehensive investigation titled *"Failure Modes, Mechanisms and Causes of Shafts in Mechanical Systems"*, analyzing the causes, mechanisms, and prevention measures of shaft failures in various industrial machines. The authors also examined the influence of material selection, heat treatment, and surface strengthening technologies on the risk of failure.

According to their findings, among carbon and alloy steels, those subjected to heat treatment (e.g., 42CrMo4) exhibited the highest fatigue resistance.

In a study conducted by Steven Odi-Owei, Barisua E.N., and Kenny E.A. [22], the issue of extending the fatigue life of shafts used in machinery was thoroughly analyzed. The main objective of the research was to enhance the fatigue resistance and service life of shafts by improving their mechanical properties. To achieve this, the authors analyzed the operating conditions of the shafts, types of loading, material properties, and geometry. Steel was studied as the primary material, operating under dynamic loads caused by bending and torsion. The authors also demonstrated that the durability of shafts could be increased by incorporating alloying elements into the material composition and applying surface strengthening technologies.

Furthermore, when selecting materials for shaft components, not only the mechanical and tribological properties but also manufacturing technology, economic efficiency, and compatibility with operating conditions are important criteria. Factors such as operating environment, type of loading, rotational speed, and the frictional pair environment directly influence material selection. For this reason, medium-carbon alloy steels suitable for heat treatment are widely considered the optimal choice in practice. Looking ahead, the use of nanostructured coatings and steels manufactured via additive technologies for shaft components holds great potential. These materials offer superior performance under high loads without deformation, as well as advantages in resource efficiency and tribological stability.

Bearings are elements that support and allow the rotation of shafts, and their reliability largely depends on surface hardness, microstructural stability, and adaptability to the lubrication system. The most commonly used bearing steel is AISI 52100, a high-carbon, chromium-containing steel. The high hardness of this bearing steel enables it to resist wear under high loads and high-speed conditions. Due to the presence of chromium, a protective chromium oxide layer forms on the surface of the bearing steel. This protective layer provides excellent wear resistance, effectively preventing both wear and corrosion.

These steels typically have a hardness of 60–65 HRC and a microstructure composed of martensite enriched with fine carbides. Liu J. and colleagues noted that under boundary lubrication conditions, the coefficient of friction for this steel ranges from 0.09 to 0.11, which ensures smooth operation of the bearings. In recent years, composite materials and ceramic-based alloys, such as Al_2O_3–ZrO_2 and Si_3N_4, have been widely investigated for bearing elements.

For bearings operating under rotational loads, bronze and aluminum-based composite materials are also widely used. Research by Zhang W. and colleagues [23] demonstrated that in Al–SiC composite bearings, friction was reduced by up to 30%, and wear rate decreased by approximately two times. For high-temperature applications, ceramic-based bearings have also been developed, exhibiting high resistance to corrosion and thermal degradation.

Foreign scientific literature presents various approaches to the analysis of materials used in shafts and bearings. In their study, Babu and colleagues [24] thoroughly analyzed the main requirements for bearing materials and recommended metallic alloys—particularly Babbitt, bronze, and aluminum-based composites—as the most effective options. According to the authors, bearing materials must simultaneously be adaptable, thermally conductive, and fatigue-resistant.

IBAST | Volume 6, Issue 06, June

However, this study addresses the tribological issue directly from the perspective of the operating conditions of shafts and bearings in technological machinery, analyzing the potential to enhance their wear and friction resistance using laser technology. Therefore, the research covers a topic that is scarcely addressed in existing scientific literature. The primary focus of the study is to investigate the interrelation of friction, wear, and lubrication processes occurring on the surfaces of the shaft–bearing pair, as well as to improve their operational efficiency through resource-efficient technologies. In this way, the research does not compete with existing tribological studies but rather enriches them practically by applying laser-based surface treatment technologies. The results have significant scientific and practical value for improving the operational reliability of technological machines, extending their service life, and enhancing energy efficiency.

Previous studies have primarily focused on the general structural characteristics of bearings and their operational technologies, while issues related to improving tribological performance and enhancing surface properties using laser technology have not been sufficiently investigated. In particular, scientific research on the physical and mechanical changes occurring on the surface during laser-based surface modification, as well as their effects on surface hardness and frictional resistance, remains limited. Therefore, the development of laser surface treatment technologies aimed at improving the tribological properties and operational efficiency of bearings, along with determining their optimal parameters, is of significant importance for enhancing the performance of machinery and technological processes.

In recent years, research conducted by N. Hou and colleagues has introduced a new stage in this field. They analyzed failure cases related to shafts over the past 20 years, examining the conditions under which shaft failures occurred, including the influence of materials, loads, and environmental factors [25]. The results emphasize that modern material selection should consider not only mechanical properties but also diagnostic capabilities.

Suadad Noori Ghani and co-authors published a comprehensive review on enhancing the tribological properties of bearings using composite materials [26]. They analyzed polymer-matrix composites, reinforcement methods, and the use of nano-additives. The review highlights experiments aimed at improving wear resistance and frictional performance. Additionally, the advantages of metal-matrix composites in terms of high mechanical strength and resistance to wear and friction are discussed. The studies also analyze the incorporation of fibers, nanoparticles, and other nanomaterials, which significantly reduce the coefficient of friction.

The analysis of these studies indicates that, in order to enhance the performance of shafts and bearings, material selection should not be limited to conventional metallic alloys but should also rely on modern composite and coating technologies. Furthermore, a comprehensive assessment of surface properties, together with consideration of operating conditions, loading, and lubrication systems, is essential to achieve optimal operational efficiency.

References:

1.Ushakov, V. (2010). "Lazernaya obrabotka metallov", Mashinostroenie, Moskva.
2.ResearchGate maqolalari – lazer turlari ta’sirida hosil bo‘ladigan fazaviy o‘zgarishlar bo‘yicha.
3.Gheorghe, G. et al. (2020). "Laser Surface Engineering of Materials", Springer.

4.Kaplan, A. F. H. (2011). "Fundamentals of Laser-Material Interaction", Wiley.
5.Bäuerle, D. (2013). "Laser Processing and Chemistry", Springer.