TECHNOLOGICAL PROCESSES FOR THE REPAIR OF PLAIN BEARINGS OF INTERNAL COMBUSTION ENGINES BASED ON A MODERN APPROACH

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Abstract. *This article presents an in-depth analysis of wear processes occurring in plain bearings (liners) of internal combustion engines (ICEs), their causes, and their impact on performance. The types of abrasive, adhesive, fatigue, and corrosive wear observed on bearing surfaces are studied from a mechanical and tribological perspective. Modern technologies used for reconditioning worn bearings are also analyzed, and an improved repair method is developed. The proposed method improves engine reliability, extends its service life, and reduces operating costs.*

Keywords: *internal combustion engine, plain bearing, wear, tribology, repair technology, reconditioning.*

Introduction

It is widely accepted that internal combustion engines are one of the primary power sources for modern transport and industrial equipment. Reliable and long-term engine operation largely depends on the condition of its bearing components, particularly the plain bearings. These bearings support the load on the crankshaft and connecting rod journals and ensure rotation with minimal friction. The energy generated in the combustion chambers of an internal combustion engine's cylinders is used as a friction bearing for the connecting rods that rotate the crankshaft. It is important to note that because the rotational speeds and loads in this system are extremely high, friction within the components must be drastically reduced. Otherwise, the engine will fail very quickly. To reduce friction, all critical contact surfaces within the engine are surrounded by a micron-thick layer of oil formed by a specialized lubrication system.

However, many aspects of friction and wear processes at contact surfaces remain poorly understood. When surfaces rub, mechanical, electrical, thermal, and chemical processes occur simultaneously. Friction can harden or soften metal, increase or decrease its carbon content, saturate or dehydrate it, convert gold and platinum into oxides, and polish or weld the surfaces of components. Friction is a complex, self-organizing process in which systems are formed that deliberately and in a specific sequence damage the surface or, conversely, reduce wear. Despite the high level of solutions for calculating the strength, rigidity, and priority of machine components, the current state of friction and wear theory does not allow designers to reliably predict the wear resistance of adjacent surfaces. In particular, despite the fact that more than a century has passed since its development, calculations based on hydrodynamic lubrication theory do not possess the same accuracy and reliability as calculations performed using material resistance methods, which assume a constant oil film between the rubbing surfaces.

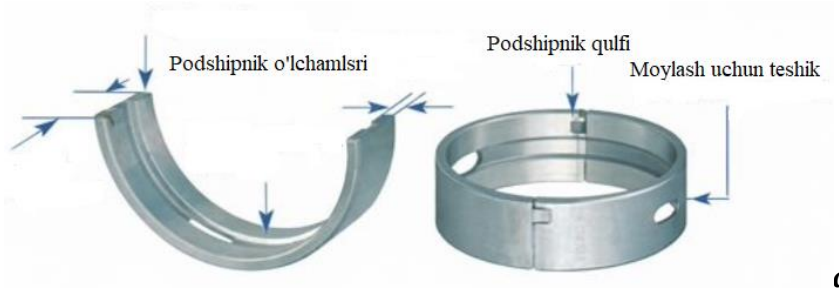
In the future, increasing the service life, productivity, and performance of machines and mechanisms depends largely on how positively and completely tribological issues are resolved. Therefore, in recent years, leading designers, technologists, and scientists from various fields

worldwide have been striving to solve tribological problems. As a result, machine service life is extended not only through rational design, technological, and operating conditions, but also through the development of a comprehensive theory of friction, wear, and lubrication based on advances in physics, chemistry, and materials science. In particular, the discovery of hydrogen wear laws opens up new possibilities for increasing the wear resistance and reliability of machine parts subject to friction.

Friction in bearings, gears, and piston systems leads to wear of the contact surfaces and energy loss. Therefore, friction in this context is considered a harmful factor. In brakes and clutches, as well as in friction and belt drives, it is beneficial to maintain an operating mode in which the friction force increases to a certain value without exceeding permissible wear limits. The correct selection of friction pair materials and oil type, as well as the adaptation of the design of the friction parts to operating conditions, determine the efficiency of the mechanisms and help improve the durability and reliability of the friction structure.

It is necessary to note that method is being developed to prevent complete wear of the original component material by creating new self-organizing structures on the surface of friction parts based on the laws of synergy. Tribological problems are currently being widely studied at factories and enterprises, universities, and research institutes. Scientific and practical conferences are held, and monographs and numerous articles are being published. A large body of theoretical and practical research has accumulated test results and observations on improving the wear resistance and reliability of friction machine parts.

This oil film surrounding metal parts forms only under sufficiently high oil pressure. It is between the crankshaft journal and the bearing that this oil "layer" forms, dramatically reducing friction. Thus, camshaft bearings act as a protective element that protects one of the most important engine components—the camshaft—and significantly extends its service life. During operation, plain bearings undergo various wear processes as a result of high loads, poor lubrication conditions, increased temperature, and external contamination. This can lead to loss of engine power, increased vibration, and serious malfunctions. Therefore, identifying wear processes, analyzing them, and developing effective restoration technologies are urgent scientific and technical challenges.



a)



b)



c)



d)

Figure 1. Plain bearings: a – dimensions, b, d – bearing wear rate, c – location.

Wear processes occurring in plain bearings include abrasive, adhesive, fatigue, and corrosive (Table 1). Wear occurs when solid particles (dust, metal debris) enter the engine oil. This process scratches the bearing surface, reducing the thickness of its working layer (Figure 1).

Adhesive wear occurs when surfaces are in direct contact with each other under conditions of insufficient oil film. This results in microwelding and material migration. It is essential to mention that under the influence of repeated alternating loads, microcracks form in the bearing material, which over time lead to migration of the protective layer. Chemical corrosion occurs on the bearing surface under the influence of fuel combustion products and aggressive substances. This situation is especially accelerated by the use of low-quality oils.

Table 1. Main types of wear in plain bearings

	Type of food	Reasons	Consequences
1	Abrasive	Solid particles in oil	Surface scratches, increased clearance
2	Adhesion	Insufficient oil film	Material transfer
3	Fatigue	Reload	Cracks and coating failure
4	Corrosion	Chemically aggressive environment	Surface erosion

The wear determination process for plain bearings is as follows:

Engine → Bearing → Visual Inspection → Measurement → Oil Analysis → Conclusion.

Plain bearing wear is determined by the following methods:

1) visual and microscopic inspection;
2) determining radial clearance using measuring instruments;
3) detecting metal particles during oil analysis;
4) vibration diagnostics and acoustic monitoring.

These methods allow for an accurate assessment of the degree of wear and the selection of a repair strategy. Currently, the following technologies are widely used for bearing refurbishment:

1) remelting of antifriction coatings (babbitting);
2) plasma and thermal spray coatings;
3) restoration with polymer-composite materials;
4) laser surface hardening technologies.

These methods are used to restore the bearing's working surface and extend its service life. This article proposes the following improved process sequence for plain bearing repair:

1. Complete disassembly and cleaning of the bearing;
2. Diagnosis of the type and degree of wear;
3. Mechanical and chemical preparation of the working surface;
4. Application of a modern antifriction coating;
5. Final treatment and control measurements;
6. Testing and commissioning.

The proposed technology improves engine reliability and reduces repair costs. There are several effective methods for restoring plain bearings based on modern bearing repair technologies (Table 2).

Table 2. Bearing Reconditioning Technologies

Technology	Scope	Advantage
Babbitt	Classic bearings	Cheap and reliable
Plasma coating	High load	Solid surface
Polymer coating	Light engines	Low friction

Technological card of the repair process (Table 3).

Table 3. Technological card of the repair of a sliding bearing

Stage	Action	Equipment	Result
1	Disassembly and cleaning	Washing machine	Clean detail
2	Diagnostics	Micrometer	Eating is determined
3	Provide coverage	Plasma device	Surface is restored.
4	Final processing	Machine tool	Ready-made bearing

Conclusion

It can be concluded that the proposed technological approach extends the service life of plain bearings, improves engine reliability, and reduces repair costs. Wear processes occurring in the plain bearings of internal combustion engines have a significant impact on overall engine efficiency. Their timely detection and restoration using modern technologies significantly increases engine life. The developed repair method is practically effective and can be widely implemented in service and repair facilities.

REFERENCES

1. Efimov, V., "Chromium Plating and Metallization in Automotive Repair," 1936.
2. Kadyrov, S.M., Musabekov, Z.E., "Methods for Restoring Worn Metallized Parts," Official Bulletin, 4(10), 1987.
3. Kadyrov, S.M., Musabekov, Z.E. Uzbek Journal "Problems of Mechanics" No. 3, 4, 1994. Pp. 34-37.
4. Kadyrov S. M., Musabekov Z. E., "Electric Arc Spraying": Restoration of the D-144 Diesel Crankshaft. Journal "Automobile Industry", No. 9, 2001, p. 25.
5. Kadyrov Sarvar Mukadirovich, Lebedev Oleg Vladimirovich, Khakimov Anvar Mutalibovich. Automotive Parts Restoration Technology. Tashkent "Ukichich", 1995.
6. Kazartsev V. I., Kazantsev A. S. Restoration of Automotive and Tractor Engine Crankshafts. Herald of Mechanical Engineering, No. 6, 1956.

7. Kazartsev V. I. Comparative Evaluation of Advanced Methods of Restoring Automotive and Tractor Parts, Coll. of scientific papers. Work of the Leningrad Institute of Agricultural Mechanization, vol. 1, p. VIII, 1954.
8. Kazartsev V. I. Operational tests used in the restoration of automotive and tractor parts. Collection of scientific papers of LIMSX, vol. 1, p. X, Selkhozgiz, 1953.
9. Shorsharov M. Kh., Karakozov E. S. "On the need for activation during welding of metals in the solid state" (Welding Production, 1971, no. 6, pp. 68-74).
10. Shorsharov M. Kh., Karakozov E. S., Myakishev Yu. V. "Features of the interaction between metals being joined under the influence of elevated temperature and pressure" (Physics and Chemistry of Materials Processing. 1971, no. 6, pp. 68-74).
11. Yakimavičius I. S. Electrometallization protective coatings and the possibilities of their application for food industry equipment. Abstract of dissertation, Kaunas, 1956.
12. Kadyrov S. M., Musabekov Z. E. Modern methods of restoring parts. Study guide. Tashkent, 1998.
13. Adams J. Beytrag für Kenntnis das Mefallspritzvorganges und der Eigenschalten gesprtzter Stahisrhichten. Dissertation, Hannover, 1953.
14. Matting A., Becker K. Experimental study of the mechanism of metal formation. Apraying–Sclnveiszen und Schneiden, 1954, Vol. 6, #4, 5 12"– 149. Journal of the Institute of Metals, 1954, Metallurgical Abstracts, p. 134.
15. Problems of Obtaining High-Quality Plasma-Sprayed Material. Iwamoto Nobuwa. Proceedings of the 7th International Conference on Vacuum Metallurgy, Tokyo, November 26–30, 1982. Special. Melting and Medium Coating. Voi. l'Tokyo, 1982, 283–294.
16. Surface Engineering Using Laser and Physical Vapor Deposition Techniques - Rigsby G.M. "G. Metally", 1984, 36 8, 31–34.
17. Musabekov Z., Khakimov J., Yangiboev A., Tayrova N., Usmonov J., Petruchenko A. Flow stabilization and pulsation in the external channels of fuel engines. (2023) IOP Conference Series: Earth and Environmental Science, 1142 (1), Article No. 012022. DOI: 10.1088/1755-1315/1142/1/012022
18. Tulaev B.R., Musabekov Z.E., Daminov O.O. "Application of supercharging to internal combustion engines and increasing efficiency while achieving high environmental standards". AIP Conference Proceedings 2432, 030012 (2022). DOI: 10.1063/5.0090304
19. Musabekov Z.E., Khakimov J.O., Ergashev B. Differential equations for calculating gas exchange in an internal combustion engine. E3S Web of Conferences 264, 01003 (2021). International Scientific Conference "Structural Mechanics, Hydraulics, and Hydraulic Engineering (CONMECHYDRO 2021)." April 1-3, 2021. Published online: June 2, 2021. DOI: 10.1051/e3sconf/202126401003