10.31653/smf47.2023.240-248

Lebedev B.[1], Uminsky S.[2], Korolkova M. [2], Melnik A.[1]

[1]National University "Odessa Maritime Academy"
[2]Odesa military academy

TECHNOLOGY FOR THE RESTORATION OF DIESEL CRANKSHAFTS WITH THE STRENGTHENING OF NECKS

Formulation of the problem. The resource of a marine diesel engine before overhaul depends mainly on the state of the crank mechanism, and the crankshaft is the main link in this mechanism. Crankshafts are among the most critical parts of engines and are operated under conditions of variable loads. Shaft journals are subject to sliding friction at high speeds and high specific pressures. The crankshaft is one of the most important expensive engine parts (its cost is more than 10% of the cost of the entire engine) - to a large extent determines its resource [1-3]. During the operation of such complex and expensive units as internal combustion engines, sudden failures occur, which are caused by parts with defects that require replacement or restoration, and in most cases the necessary technologies for this are not available. As a result of wear, the initial dimensions of the mating surfaces of the parts change, and their geometric shape is distorted if the wear proceeds unevenly. The bonded surfaces of the parts show scratch marks, scuff marks, local metal spalling or spalling, or surface cracks. The latter arise mainly due to metal fatigue. The operation of parts under loads exceeding the calculated ones, and violation of the rigidity and relative position of parts in the assembly, in addition to wear, can lead to more noticeable residual deformations in the form of curvature, torsion, dents, etc. Parts operating at high temperatures are also subjected to action gas corrosion and warping. and additional parts, pressure, welding, surfacing, metallization, electrolytic reduction [1-3]. The presence of parts with repair dimensions, in addition to violating interchangeability, increases the cost and complicates the defect detection, restoration and control of parts, as well as the technological process and assembly organization.

Analysis of current research. The study of literary sources, domestic and foreign experience in the repair and restoration of parts has shown

that the known technologies and methods for the restoration of parts: electric arc surfacing, electrocontact methods of welding materials, electric arc metallization, plasma surfacing, etc., in some cases are difficult in technological execution, time-consuming, unproductive, limited in the possibility of application to eliminate certain defects. Crankshafts are the most complex and expensive parts of the "shaft" class. Their cost is 10-25% of the cost of the engine, and upon reaching the limit state, about 20% of the shafts are rejected. Technologies for the restoration of crankshafts by coating are mainly focused on ensuring the wear resistance of the journals, but at the same time, the fatigue strength is reduced by 25-30%, and the resource is inferior to the norm. Spraying is used, and the main sprayed material is chromium-nickel powders, which provide the necessary performance characteristics, but at the same time are characterized by high cost. and development of a technology for the restoration of cast-iron crankshafts by spraying with a mixture of powders that provide the necessary standard resource [4-7]. In terms of obtaining high performance characteristics of remanufactured shafts, an important role is played by the microstructure of the coating and its properties on the surface and in the zone of connection with the base material. Optimal in this case is a heterogeneous structure consisting of a matrix and carbides, the content of which is controlled by the presence and ratio of alloying elements. The formation of the type of carbides is strongly influenced by the ratio of chromium and carbon, and the formation of the properties of the matrix is strongly affected by the content of nickel and manganese, but highly alloyed materials of the austenitic class are expensive, therefore, one of the objectives of the study was to select an inexpensive surfacing material that provides the necessary performance characteristics during surfacing. The wear resistance and fatigue strength of deposited coatings can be significantly increased by applying surface plastic deformation after surfacing using tooling that forms a favorable coating texture [4–7]. In most cases, the increase in wear resistance due to hardfacing of high-carbon alloy material leads to a decrease in the fatigue limit of renewable parts. The analysis of crankshaft restoration processes showed that some of them contain energy-intensive operations, the other part increases wear resistance, but at the same time, fatigue strength decreases. To solve this problem, expensive equipment or materials are often used, which are not always justified in repair production. Bearings that are heavily loaded and operate at high speeds require a constant supply of pressurized lubricant to ensure hydrodynamic lubrication. If this is violated (instability of supply, a decrease in lubrication pressure), conditions of semi-liquid lubricants are formed, leading to a decrease in the thickness of the oil film and an increase in the likelihood of contact between microroughnesses of the shaft neck and the liner [8], heat generation in the bearing increases, as a result of which semi-ridine friction is associated with the danger of overheating and bearing failure. The process of shaft movement in plain bearings is due to changing operating conditions (friction) and shaft displacements in the bearing [9]. In the initial period of rotation and conditions of limiting lubrication, the shaft moves in the direction opposite to rotation, by an angle φ, under such conditions, the microroughnesses of the friction pair touch and wear. With an increase in the rotational speed, the shaft pushes the lubricant under it and "floats up", forming an oil wedge under it (hydrodynamic lubrication).

Fig. 1. Seizure of the crankshaft journal

The service life of the crankshaft is characterized by the possible recovery number. Another factor that characterizes the durability of the crankshaft is the resistance to tiring loads. Despite the different nature of the external manifestation of failures due to wear and fatigue, they are based on the same physical processes described by the laws of fracture mechanics, according to which most types of wear are of a fatigue nature. Non-compliance of the gaps with the technical conditions in the "neck-insert" interface, changes in the macrogeometry and roughness of the necks lead to a deterioration in the working conditions of the interface, which causes an intensive increase in the scoring of the interface during the running-in process. Analysis of the results of studies of defects in crankshafts that appear during operation shows that failure of crankshafts in most cases occurs:

- due to scuffing of the necks;
- with the dominant effect of bending in the plane of the crank;
- due to its destruction due to the constant growth of deformations and cracks and the gradual accumulation of local defects.

Changes in the clearances and ovality of the shaft journals as they wear affect the operation of the bearing. As the ovality of the journals increases, the runout of the crankshaft increases, which, in turn, affects their wear. It has been established [10] that there is a correlation between the wear of the crankshaft journals and the runout. Runout not only increases journal wear, which in turn further increases runout, but also increases crankshaft imbalance and engine vibration, and this leads to a decrease in shaft fatigue strength. To increase the durability and improve the operating conditions of diesel crankshaft bearings, it is necessary:

- to increase the wear resistance of the necks of the shafts;
- provide higher wear resistance of the necks compared to wear resistance.

stability of the antifriction layer of plain bearing shells.

The purpose of the work is to increase the efficiency of technical operation by applying the technological process of restoring crankshafts with the strengthening of the necks, which makes it possible to obtain an optimal set of parameters of the wear-resistant coating material and ensure their necessary durability.

Material and research methods. To restore the crankshafts of diesel engines, three technological schemes are used:

- polishing of necks on the repair size;
- polishing of necks on the repair size with the subsequent strengthening;
- coating to restore the nominal size of the necks with subsequent or simultaneous strengthening.

When overhauling a diesel engine, in order to restore the geometry of the journals and gaps in the bearings, the shaft journals can be ground to the repair size with the installation of liners of the repair size, respectively, or the shaft necks can be restored to the nominal size by spraying or welding. Modification with geomaterials should be considered the most optimal finishing operation for processing shaft journals, which makes it possible to obtain a roughness of not more than Ra = 0.1 μm. There is a need to develop new approaches when choosing a triboconnection and the required service life. Therefore, the development of a methodology for selecting the composition of geomaterials depending on the operating conditions and the specified service life of the triboconnection remains relevant.

The analysis of applied recovery technologies showed that:

- without further strengthening of the necks of the shafts, the fatigue and tribotechnical durability of the shafts is not ensured;
- the issue of developing such a technological process for restoring the crankshaft remains relevant, which would provide the necessary operational properties of the interface and manufacturability of products (low labor intensity, processing accuracy, specified coating roughness parameters). Presentation of the main material.

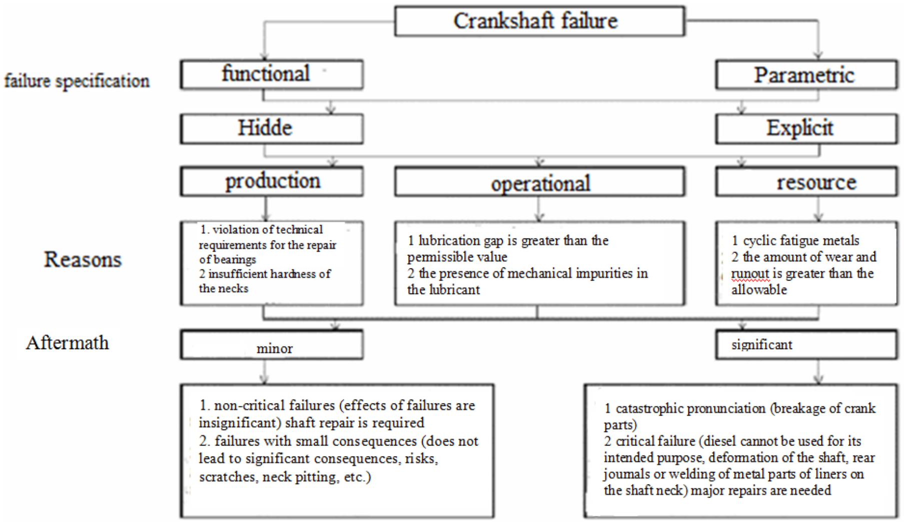

Fig. 2. Classification of failures, crankshafts

The result of functional stops of diesel engines caused by breakdowns of its individual parts and crank assemblies of the engine or other reasons, and precision failures - the values of the dimensional parameters of the necks go beyond the permissible limits. The consequences of such failures are increased wear and scuffing of the shaft journals. Bullying of the necks and melting of the anti-friction ball of the liners, as a rule, lead to deformation of the crankshafts, less often to the breakage of the shaft, i.e., to critical or catastrophic consequences.

As a result of neck wear, shape deviations from roundness (ovality) and cylindricity (taper, barrel or saddle shape) are formed. To reduce the likelihood of scuffing, dashes and scratches on the journals and reduce the wear rate, it is necessary to increase the hardness and wear resistance of the surface layer of the shaft journals. Wear of crankshafts significantly affects the wear rate of other parts of a diesel engine. From the above data, it follows that the dominant degradation processes that cause the predominant part of the functional ones are the phenomena caused by friction processes with limiting or mixed (semi-fluid) lubrication, much less tedious processes. The most promising compositions for strengthening friction surfaces are mineral and organomineral materials [11]. Then the method is selected. At present, the modification of friction surfaces is carried out by the friction method or ultrasonic treatment [11, 12]. To strengthen the necks of crankshafts, the most promising is the friction method. To reduce the likelihood of seizing and tearing during the running-in period and increasing the durability of the "shaft journal – bearing shell" triboconnection by reducing the wear rate, especially during the running-in period, the most promising way to strengthen the crankshaft journals is to create a ceramic-metal thin-film coating on the surfaces. To obtain high wear resistance of the coating, it is necessary to obtain a heterogeneous structure, which has a plastic and durable matrix and solid fillers. Metal-ceramic and organo-ceramic films have such a structure. At present, compositions of geomaterials (natural silicates with a layered structure) based on serpentinite and vermiculite [12] and polymer-silicate nanocomposites based on polytetrafluoroethylene and serpentinite [11], which are capable of forming protective metal-ceramic and polymer-ceramic films, are widely used to modify friction surfaces. on friction surfaces. The rate of layer formation (growth) is proportional to local temperature and pressure flashes at actual contact spots. The landing of the layer primarily occurs on the worn areas of the mating surfaces, as a result, the dimensions and shape of the parts are restored. Natural and artificial [12] silicates have a layered structure with a weak bond between the layers, which facilitates the shear between them. For example, magnesium [MG(OH)2] layers with silicon (Si2O3) layers alternate in the serpentine structure. Wear-resistant ceramic-metal films formed on friction surfaces in the presence of a lubricant composition with the addition of powdered magnesium hydrosilicate can have a hardness of 65–72 HRC, a roughness of Ra from 0.042 to 0.30 μm at a friction coefficient of 0.003, and a fracture temperature of 1700–2000 °C. the main mineral used to obtain ceramic-metal coatings is serpentine (antigorite, chrysotile and Lizard). Translated into oxides, serpentine contains 43 masses. % MgO, 44 wt. % SiO2 and 12.1-12.9 wt. %H2O. The composition of ingredients in serpentinites can vary widely [11]. The simplest and most technologically advanced way to modify the crankshaft journals is friction-mechanical, so that it allows machining and modification on one machine without reinstalling it. To modify the journals of the crankshafts by the friction-mechanical method, a steel or cast-iron indenter is used, which is pressed against the hardened surface with the necessary force. A mixture of mineral or organo-mineral materials with lubricant is fed into the tribocontact zone. The crankshaft is rotated on a lathe or a specialized machine for grinding crankshafts. The mechanism of formation of a wear-resistant ceramic-metal coating on the friction surface during the friction-mechanical processing method by supplying a lubricant composition containing minerals, organo-mineral or polymer-mineral compositions can be conditionally divided into 2 stages, which are performed in two technological operations:

- The application of a composite modifying material on the friction surface and the formation of individual sections, depending on the energy parameters (sliding speed and pressing force of the indenter to the surface to be strengthened), ranges from one to several minutes (maximum 6 minutes);
- Formation of a wear-resistant ceramic-metal coating.

The execution time of this technological operation does not exceed 1 hour (45-50 minutes). The wear resistance of the coating depends on the parameters of the formation mode (running). The formation of a wear-resistant metal-ceramic coating occurs due to the following processes. During the first technological operation, the friction surface is caricatured by harder particles compared to the hardness of the hardened material, which are part of the mineral or composition, and the particles are densely hardened into the recess of the microrelief. These processes are a necessary condition for launching two processes: abrasive wear (running in) and an unstable process of formation of a protective ceramic film. The microrelief is cleaned of all contaminants (products of wear and decomposition of lubricants, etc.) present on the friction surface.

Modification of the friction surface for the formation of thin-film ceramic-metal, organic-metal-ceramic and polymer-metal-ceramic coatings makes it possible to increase the wear resistance of the tribojoint "crankshaft journal - bearing shell". It is necessary that the composition ensures the creation of a coating having maximum hardness with minimum moduli of elasticity and coefficient of friction. The technological process of restoration of diesel crankshafts with the formation of composite coatings is carried out in the following sequence:

1. washing and cleaning of the shaft;
2. fault detection;
3. grinding necks to repair size;
4. neck modification;
5. quality control of the crankshaft.

Conclusions

Currently, composite materials are practically not used, which make it possible to provide the specified indicators of durability of restored parts, due to insufficient knowledge, lack of recommendations for their use depending on operating conditions and sufficient experience in solving technological problems.

To increase the durability of crankshafts up to 40 thousand hours and avoid scuffing, it is necessary to reduce the wear rate of friction surfaces by 1.5 times. To ensure the probability of failure-free operation for P(t) = 0.9, the wear rate of the friction surfaces should be reduced by a factor of 2.3. The recommended materials for modifying crankshaft journals (aluminosilicate modified with metallosiloxane and aluminosilicate modified with polysaccharide and magnesium carbonate) make it possible to increase the wear resistance not only of the shaft, but of the “crankshaft journal - bearing shell” interface, to reduce scuffing due to the formation of a metal-polymer-ceramic coating on the surface. At the same time, the cost of restoring the crankshaft increases only by 12-15%.

References

1. Сімдянкін А.А. Контактно-силова взаємодія деталей циліндро-поршневої групи: Монографія: К. - 2003. - 144 с.

2. Чорновіл М.І. Підвищення якості відновлення деталей машин /М.І. Чорновіл, С.Є. Поєдинок, Н.Є. Степанов - Київ, Техніка, 2009. - 168 с.

3. Гащук П.М., Миськів Т.Г.Нікіпчук С. В. Двигуни. Тепловий тадинамічний розрахунок. Навчальний посібник.-Львів: Українські технології, 2016.-144с.

4. Гур'янов, Г. В. Електроосадження зносостійких композицій / Г.В.Гур'янов. - Кишинів: Штііца, 2015. - 237 с.

5. Данилов, І.К. Моделювання та оптимізація структури експлуатаційно-ремонтного циклу ДВЗ / І.К. Данилов. – К.2014. - 110 с.

6. Черноіванов, В.І. Організація і технологія відновлення деталей машин. - Київ, Агропроміздат, 2009. - 336 с.

7. Radzevich,S/P/ Dudleys Handbook of Practical Gear Design and Manufacture/ 2 nd Edition, CRC Press, Boca Raton, Flonda, 2011, 1111 pages.

8. Bianco/G. And Radzevich,S/P/ Precision Gear Shaving/-Nev York/ Nova Sci ence Publishers/ 2010/- 321 pages.

9. Телух, Д. М. Введення в проблему використання природних шаруватих гідросилікатів у трибосполученнях [Електронний ресурс] / Д. М. Телух, В. В. Кузьмін, В. Н. Усачов // Інтернет-журнал «Тертя, знос, мастило». - 2009. - №3. – С. 1–10. - Режим доступу

10. Oliver, W. C., Pharr, G. M. Measurement of hardness and elastic modulus by instrumented indentation: Advances in understanding and refinements to methodology // J. Mater. Res. 2004. V. 19 № 1. P. 3-20.