



Performance analysis of turbocharger rotor friction pairs of an automobile engine

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Abstract

Turbochargers are used in modern engines to increase their performance by increasing the amount of air supplied. To increase wear resistance, researchers and engineers are improving integrated technologies for strengthening turbocharger assemblies. The purpose of this study is to evaluate and analyze the influence of integrated strengthening technologies on the wear resistance of the turbocharger assembly. Integrated strengthening technologies include the use of new materials, coatings, design changes and manufacturing processes that improve the strength, thermal stability and wear resistance of the turbocharger assembly. A comprehensive analysis was carried out, including experimental tests, mathematical modeling and numerical simulations. Analyzed tests of wear resistance on specially designed stands simulating the real operating conditions of turbocharger units. The results can be used to analyze the effect of integrated strengthening technologies on wear resistance, considering various parameters such as temperature, torque and operating time.

Key words: turbocharging, rotor, wear bearings, testing, modeling

Introduction

Turbochargers are used in modern engines to increase their performance by increasing the amount of air supplied. However, when operating at high temperatures and rotational speeds, turbocharger assemblies are subject to significant wear and tear, which can affect their long-term operation and reliability. To overcome this challenge and achieve greater wear resistance, researchers and engineers are improving integrated technologies for strengthening turbocharger assemblies.

The purpose of this study is to evaluate and analyze the influence of integrated strengthening technologies on the wear resistance of the turbocharger assembly. Integrated strengthening technologies include the use of new materials, coatings, design changes and manufacturing processes that improve the strength, thermal stability and wear resistance of the turbocharger assembly.

In this study, a comprehensive analysis including experimental tests, mathematical modeling and numerical simulations has been carried out. Analyzed tests of wear resistance on specially designed stands simulating the real operating conditions of turbocharger units. The results can be used to analyze the effect of integrated strengthening technologies on wear resistance, considering various parameters such as temperature, torque and operating time. The results of the above research analysis will help to improve the design and manufacture of turbocharger units, contributing to increase their wear resistance and duration of operation. This can have a significant practical impact on the automotive and aerospace industries where turbocharged engines are used, providing greater reliability and lower maintenance and repair costs.

Analysis of the designs of the turbocharger friction assemblies of modern engines is important for understanding their efficiency and interaction with other engine components. The main components of turbocharger friction include bearings, sealing rings and adjustment mechanisms. Bearings: Bearings play an important role in ensuring smooth rotation of the turbocharger. Two types of bearings are commonly used - rolling and sliding. Rolling bearings, such as ball or roller bearings, provide less friction and wear, but require additional lubrication or cooling. Plain bearings, such as film or hydrodynamic bearings, can handle high loads but have more



friction. O-rings provide a seal between the moving parts of the turbocharger, such as the shaft and housing. They prevent air or oil leaks and reduce joint wear. O-rings are usually made of high-strength materials that are resistant to friction and high temperatures. Some modern turbochargers have adjustment mechanisms that ensure optimal performance in different engine operating modes. For example, variable geometries of turbines or compressors allow changing the air flow depending on engine speed. These adjustment mechanisms require precise frictional contacts and are of great importance to the efficiency of the turbocharger.

The analysis of the designs of the friction units of turbochargers of modern engines allows to improve their strength, durability and efficiency. The results of such an analysis can contribute to the further development of turbocharger technologies and the improvement of engine performance.

Basic material

In studies of turbine blades for turbocompressors [1] distinguish two types: guide vanes, which are mounted in the turbine stator, and working vanes, which are fixed on the rotor. Working blades are the most complex in design and have the greatest variety. The design of the working blades can be represented as a complex system consisting of three main parts: the tail, the working part and the head. Each of these parts has a large number of design variations. The working parts of the guides and working blades differ in several features: the shape of the cross-sections and their relative location along the axis of the blade, the presence of overhanging elements over the profiles of the working part, and the way the surfaces are constructed. According to the shape of the sections and their mutual location along the axis, the working parts are divided into parts with a constant profile and a variable profile. Overhangs such as a tail or shelf, or both, may be present over the ends of the working part of the vane, or there may be no overhang. According to this feature, the working parts of the blades are divided into open, semi-open and closed. If the structural element hangs from one end of the blade, for example, from the tail side, and there are no overhanging elements from the side of the head or in the working profile part of the blade, then such designs of blades are classified as blades with a semi-open profile of the working part. Blades with a closed profile have overhanging elements on both ends of the working part. Such blades have a tail hanging over the working part on one side, and a thickening on the other.

According to the described features, there is a wide variety of designs of turbine blades studied in the literature. In order to increase the reliability of small-sized turbochargers used in supercharging systems of auto-tractor diesel engines, a study was conducted [1], the results of which include the following stages.

An original scheme for cooling the bearing of a small turbocharger is proposed and developed. One of the advantages of the scheme is the use of compressed air to cool the bearing. This compressed air is supplied selectively only at critical system operating modes. Local and automatic control of bearing cooling avoids deterioration of overall engine efficiency.

A motorless experiment was conducted to evaluate and confirm the effectiveness of the developed bearing cooling system. The study investigated the effect of excess air pressure in the range of 0.1-0.3 MPa on cooling efficiency. The results of the experiment showed that when using a cooling system with an excess pressure of 0.1 MPa, a reduction in the temperature of the bearing from the critical value of 190 °C to acceptable values of 100-120 °C is achieved after 250 seconds from the moment of coolant supply.

In order to further improve the design of the bearing unit, a mathematical model of the thermal state of the bearing, in particular of the bronze bushing with local cooling, was developed. The results of the motorless experiment were used to refine this mathematical model. As part of the modeling, the boundary conditions of the thermal conductivity problem for surfaces cooled by compressed air were determined.

The conducted study revealed the effectiveness of the proposed cooling scheme of the bearing of a small-sized turbocharger for supercharger systems of auto-tractor diesel engines. The results of the experiments and the developed mathematical models provide grounds for further improvement of the design and implementation of the developed system of automatic regulation of the thermal state of the bearing.

Gas-thermal strengthening methods [2] and restoration of friction parts and assemblies, in particular, plasma spraying, have great potential for the production and repair of aircraft gas turbine engines. Plasma spraying is a universal and technological method that can be used to apply protective coatings to various parts and assemblies. In order to widely use this method in the field of engine construction and repair production, it is necessary to actively work on increasing the range of modern materials resistant to failure that are suitable for plasma spraying. To improve the reliability and operational characteristics of these coatings, it is also necessary to improve the technologies of their application and subsequent processing to ensure the necessary service properties.

The choice of material for plasma spraying and the correspondence of its properties to the technological possibilities of a specific spraying method is a key factor for the successful implementation of gas-thermal methods [3]. Today, a number of enterprises produce various powders for plasma spraying, but information about their composition, properties and purpose is limited, incomplete and outdated. Choosing the most effective and economically feasible coating for a specific part depends on its operating conditions and is a difficult task. The recommendations contained in the literature regarding the selection of coatings "resistant to failure" are not always a sufficient basis for their use in specific conditions, as they are accompanied by clear limitations of the mechanical load parameters.

To assess the performance of gas-thermal coatings in real operating conditions, it is necessary to conduct special tribotechnical tests on installations that simulate the friction modes of real tribocouples. Only after such studies, it is possible to determine the optimal parameters and operating ranges of gas-thermal coatings for specific conditions of friction and load.

In general, the development of new materials for plasma spraying and the study of their properties is an urgent task. In addition, it is important to deepen research on the influence of operating conditions on the performance of gas-thermal coatings, as well as the development of test methods that would ensure the reliable use of such coatings in real conditions.

Turbojet engines (GTDs) have their own characteristics regarding the requirements for lubricants [3]. In comparison with piston engines, in GTE, the lubricant is isolated from the combustion chamber, where the fuel burns. In addition, in the most responsible friction nodes, such as bearings, mainly rolling friction is realized, rather than sliding, which is characteristic of piston engines. The coefficient of rolling friction in GTE is much lower than the coefficient of sliding friction.

In turbojet engines, the turbocharger shaft is well balanced and operates without sudden variable loads at high speeds and significant axial and radial loads. This places special requirements on lubricants, which must ensure stable and effective lubrication of the friction surfaces of the turbocompressor shaft.

Lubricants for turbojet engines must have the following properties:

- high thermal stability, the lubricant must be able to withstand the high temperatures that occur in gas turbines and avoid degradation or oxidation under extreme operating conditions.
- high resistance to oxidation, the lubricant should minimize the formation of deposits and sludge that may occur as a result of oxidation at high temperatures.
- the ability to provide effective lubrication of the turbocharger shaft and other friction components, which reduces heat generation and wear.
- the lubricant should provide stability and minimal wear under high axial and radial loads occurring in the friction nodes.

In Article[4]the question of increasing the durability of the turbocharger by using composite materials is considered. It is noted that some methods of restoring and strengthening parts cannot provide the necessary resource, especially for parts working in abrasive and corrosive environments. Therefore, the use of composite materials becomes a relevant direction for improving the wear resistance and other properties of parts.

The article describes a new method of restoration and strengthening of turbocompressor parts using chemical vapor deposition of metals (CVD - method). This method is based on the decomposition of organometallic compounds. As a result of research, it was established that the developed composite material, obtained using the CVD method, provides an increase in the wear resistance of parts by two to two and a half times compared to new parts. The article also provides a detailed description of the turbocharger, its design and problems associated with its operation. It is noted that the turbocompressor operates in conditions of high rotation frequencies and elevated temperatures of exhaust gases containing chemically aggressive compounds. These factors lead to wear of the turbocharger parts, especially the bearing assembly and the middle housing. The article emphasizes that almost all parts of the turbocharger are subject to wear, and the most damaged part is the middle housing part. The main defects of this part are described, such as wear of the bores under the sleeve, due to crumpling, mechanical abrasion and abrasive wear.

All these facts emphasize the need to develop and implement new ways of restoring and strengthening turbocharger parts in order to increase their durability and wear resistance. The use of composite materials obtained using the CVD method can be one of the effective solutions in this direction. Deposition of coatings by the CVD method is carried out by thermal decomposition of organometallic compounds (MOC). The text states that it is advisable to use chrome coatings obtained by thermal dissociation of chromium hexacarbonyl ($Cr(CO)_6$) in the gas phase to strengthen the parts of the turbocompressor. It is noted that such coatings have a specified microhardness in the range from 12.0 to 20.0 GPa. The conclusions drawn in the text are that the use of the CVD method for the deposition of chrome coatings can significantly increase the wear resistance and durability of turbocharger parts. It is noted that this method makes it possible to obtain a coating with high microhardness, which allows the working surfaces of the bushings to resist abrasive wear.

The paper [5] discusses the importance of turbochargers in modern machines and problems related to the reliability of these units. It is indicated that most modern tractor engines are equipped with turbochargers, but as their prevalence increases, so does reliability, and turbochargers play a significant role in engine failures.

The author notes that a study of the reliability of turbochargers of KamAZ engines showed that these units are among the least reliable units, and the average duration of operation before failure is only 40,000 km. The costs of repairing such units are also significant and amount to about 12% of the cost of engine repair.

It is noted in the work that scientists conducted a lot of research on ensuring and increasing the reliability of machines and units, including turbochargers. However, there are not enough studies on the reliability of turbochargers, so the purpose of this work is to investigate ways to increase the reliability of turbochargers of tractor engines. It is noted that in the city of Dnipro and the region there are several powerful enterprises engaged in the repair of turbochargers, but the main reason for failure of turbochargers is wear and jamming of the bearing assembly. At the same time, the manufacturing quality of domestic turbochargers lags behind American and European manufacturers, and their service life is only up to 700,000 km.

The article also considers the design of turbocharger bearing units and notes that most failures are caused by hydroabrasive wear of bearing unit parts. There is a limit mode of friction, the temperature increases, and the bearing can seize or break. The author emphasizes the possibility of restoration and repair of turbochargers, which allows to significantly reduce repair costs. It is noted that up to 80% of parts can be restored, which helps to reduce the cost of repairs.

This text discusses various methods of restoring turbochargers after repair, including the use of various processing and coating technologies. It is pointed out that many of these methods have disadvantages such as the complexity of the equipment, the high cost and the need for highly skilled workers.

One of the promising directions is the technology of finishing anti-friction non-abrasive processing (FABO), which involves the frictional interaction of the tool with the surface of the part in order to improve run-in and increase wear resistance. Another promising method is epilamination, which involves applying an epilam - a multicomponent system with organofluorine surface-active substances - to the surface of the part.

In work [6] it is indicated that the electrospark treatment method is promising and can be used to increase the post-repair durability of turbocompressors. Studies have shown that the use of electrospark processing with the application of coatings on the surface of the shaft and bushing with involved metals (for example, steel 65G, nickel-bronze-copper) led to a decrease in the coefficient of friction by 15% and an increase in wear resistance by 22%. Studies indicate the expediency of using methods of electrospark treatment, FABO and epilamination to increase the reliability of refurbished turbocompressors. However, these methods need further research and optimization in different conditions and regimes.

Electrospark coating is a versatile method that can be used to refinish not only the rotor shaft, but also slide bearings and turbocharger housing parts. It allows you to increase the microhardness of the surfaces of the friction pair and increase their inter-repair service life.

Turbocharging with an additional electrically driven compressor is a promising topology for improving engine performance [7]. At low engine speeds, an electrically driven compressor can achieve a very high compression ratio, as it is designed to increase boost pressure at low engine speeds. This allows you to have a sufficient reserve for flushing resistance at low engine speeds. The electric motor drives only the compressor, which allows you to increase the boost pressure faster. This improves the response of the system to changes in engine load and allows you to quickly gain the required boost pressure. The use of high-tech materials for the manufacture of the compressor rotor allows to reduce its inertia. Since the electrically driven compressor is not connected to the turbine, it does not need high heat resistance, which allows the use of lighter materials. Turbocharging with an additional electrically driven compressor has great potential to improve transient response at low engine speeds. This system allows for better sustained power at low engine speeds. However, an electrically driven compressor cannot be used at high engine speeds due to the limited range of mass flow. The disadvantage of this system is the need to generate all the electrical energy to power the electrically driven compressor through a generator or alternator that runs from the engine shaft. An electrically driven compressor is usually smaller in size compared to a turbocharger because its main function is to increase boost pressure at low engine speeds with a sufficient margin of washout resistance.

The turbocharger bearing system [8] must hold the rotor in a given position and thus must withstand the rotor forces that occur during turbocharger operation. Therefore, its components must be designed taking into account the expected loads on the bearings. The design of the bearing system used also has a significant effect on the overall efficiency of the turbocharger and the performance of the internal combustion engine. It should perfectly match the trade-off between bearing friction and load capacity. For example, the attainable low end torque of an engine is reduced if the bearing system creates more frictional losses than is inherently necessary for safe and durable operation, as most of the available turbine power must be used to compensate for bearing losses instead of providing boost pressure. In addition, the transient speed of the turbocharger rotor can also be compromised, and therefore the response of the turbocharged internal combustion engine to the load step becomes less efficient than it could be. Apart from the radial bearings, the thrust bearing is a component that needs some attention. This can already account for approximately 30% of the total bearing friction, even when no load is applied, and this fraction increases even more under thrust loads. It must withstand the net thrust load of the rotor under all operating conditions, which is the result of the superimposed aerodynamic forces created by the compressor and the turbine wheel. The problem for determining the thrust forces arising on the engine is the non-stationary load under pulsation conditions. Conducted experimental studies of the axial movement of the rotor, as well as changes in thrust force under engine operating conditions, using a specially prepared compressor lock nut in combination with an eddy current sensor. The second derivative of this signal can be used to estimate changes in traction force. In addition, a modified thrust bearing equipped with strain gauges was used to cross-validate the results of the position measurement and the traction force simulation. All experimental results are compared with an analytical model of the thrust force, which is based on simultaneously measured pressure signals determined by the crankshaft angle, before and after the compressor and turbine stages. The results provide insight into axial turbocharger rotor oscillations occurring during the engine cycle for several engine operating moments. In addition, they allow us to judge the accuracy of thrust modeling approaches that are based on measured pressures.

The stability of the turbocharger rotor is governed by a combination of rotor dynamics and fluid dynamics [9], as the high-speed rotor system is supported by a pair of hydrodynamic floating ring bearings consisting of inner and outer fluid films connected in series. To investigate the stability, this paper develops a finite element

model of the rotor system taking into account the exciting forces such as rotor unbalance, fluid hydrodynamic forces, lubricant supply pressure, and self-weight. Dimensionless analytical expression of nonlinear oil film forces in floating ring bearings was obtained based on the theory of short bearings. On the basis of numerical modeling, the impact of rotor imbalance, oil viscosity, oil supply pressure, and bearing clearances on the stability of the rotor system of the turbocompressor was studied in [9]. Disciplines of stability of two films and dynamic characteristics of the rotor system are given.

The thermal state of the sliding bearings has a great influence when calculating the dynamics of the flexible rotor of the turbocharger. Experimental studies have shown that the temperature difference between the turbine and compressor bearings can reach twenty degrees. In addition, the temperature is unevenly distributed over the lubricant layer. It intensifies in the zone of increased pressure. The task of assessing the thermal condition of rotor sliding bearings is relevant. In [10], the effect of eccentricity on the pressure distribution in a thin lubricating layer of a non-Newtonian fluid is considered. The distribution of temperatures and pressures in the lubricant layer is constructed taking into account the rheological properties of the lubricant. The boundary conditions that were used to solve the problem were taken from the experiment. The results will be used to solve the problem of turbocharger rotor dynamics.

The objectives of the study [11] were to develop a dynamic model for rotary ball bearing systems of a turbocharger, to correlate the simulated shaft motion with experimental results, and to analyze the corresponding bearing dynamics. The high-speed turbocharger test stand was designed and developed to measure the dynamic response of the rotor under various operating conditions. Displacement sensors were used to register the movement of the shaft in the range of operating speeds. To achieve the objectives of the analytical study, a discrete element radial thrust ball bearing model was coupled with an explicit finite element shaft to simulate the dynamics of a turbocharger test bench. A bearing cartridge consists of a common outer ring, a pair of split inner rings, and a row of balls at each end of the cartridge. The rotor is modeled using the finite element method. The cartridge and rotor models are coupled in such a way that the motion of the flexible rotor is transmitted to the inner rings of the cartridge with corresponding reaction forces and moments from the bearings applied to the rotor. The rotor model was used to investigate the shaft motion and bearing dynamics as the system crosses critical speeds. A comparison of the analytical and experimental shaft motion results resulted in minimal correlation, but showed similarity across critical speeds.

The publication [12] presents the possibility of extending the service life of the sealing ring of the rotor shaft in an automotive turbocharger using an Al-Fe intermetallic alloy. The complex results of tribological, metallographic and profilometric tests of this alloy on the T-05 stand made it possible to present a real friction node. Based on empirical tests, it will be possible to determine which alloy (Al-Fe alloy or the one currently used for automotive turbocharger rotor shaft sealing rings) has better tribological properties. For this purpose, the study was based on an experiment that involves three main factors determining the wear of the studied association. The result of the experimental plan was obtaining three-dimensional diagrams showing the influence of wear factors on the friction force and surface topography.

In Article[13]the results of studies of turbocharger shaft bearings under different lubrication regimes (dry friction and lubrication with different types of oils) are given. In particular, the wear of the surface of the turbocharger shaft was evaluated. One of the most frequent breakdowns is the jamming of the turbocharger shaft in the sliding bearing, which causes it to rotate, which leads to the destruction of the unit and expensive repairs. Based on the tests, it was established that the average value of the representative fracture surface on the turbocompressor shaft is reduced with the help of less viscous soil. A similar situation was observed when new oil was used instead of processed oil - this affected the value of the diameter of the cracks.

The journal and thrust bearing design process remains a key aspect in the development of the center section of an automotive turbocharger. The rotor assembly must be supported both radially and axially, ensuring safe operation with extended service life. Both types of bearings must be designed with many limitations in mind. Housing bearings are designed with an emphasis on shifting unwanted critical frequencies beyond the operating range while supporting various types of non-linear oscillations. Thrust bearings are configured to provide a balanced ratio of load capacity and frictional losses. In general, during design, both types of bearings are treated as two different entities, even if they work with the same central section. At work[14]the cross influence of trunnions and thrust bearings during the design process of thrust bearing pads is investigated. It is carried out by taking into account the interaction of thrust and support bearings during transient nonlinear acceleration simulation. The main attention is paid to the designs of pads with different geometric dimensions, which, based on stationary calculations, have almost the same load properties and friction losses. It is shown that thrust bearings consisting of such pads do not necessarily have the same effect on the nonlinear vibrations of the rotor unit during start-ups. The interaction of the abutment and the support of the support leads to transient hydrodynamic properties of the pad that no longer correspond to steady-state predictions. It is shown that thrust bearings equipped with geometrically identical linings, but differently located around the circle, interact with the rotor assembly differently depending on the nature of the radial bearing. A floating plain bearing in combination with a thrust bearing with symmetrical or asymmetrical pad distribution can have a positive or negative effect on shaft movement and load capacity.

The turbocharger is characterized by low weight and a high-speed rotor that reaches a rotation speed of up to 350 rpm. To withstand these extremely high rotational speeds, the shaft is usually supported by floating ring

bearings, resulting in complex rotor dynamics. The work [15] summarizes the dynamics of the rotor of automotive turbochargers, presents its expected general behavior along with a review of the literature on the most important topics related to the dynamic analysis of the turbocharger. The non-linear effect of a floating ring bearing on shaft lateral vibration is discussed, as well as the effect of various bearing systems on turbocharger response, including the effect of a thrust bearing on axial and transverse rotor dynamics. Current studies on turbocharger modeling and research are also presented. Most of the work relies on the development of high-accuracy, low-computational models, including several different effects, such as temperature fluctuations and mass-conserving cavitation algorithms in lubricated bearings, research into new floating ring and thrust bearing geometries, and optimal solutions to reduce friction loss. er- or understated.

Modern turbochargers are high-speed rotating devices, usually supported by fully floating or semi-floating bearings. Depending on the size and operating speed of the turbocharger, the dynamics of the rotor changes significantly. Industrial turbochargers operate at frequencies below 20,000 rpm and their rotor weight is significant, resulting in quasi-linear rotor dynamics. In contrast, automotive turbochargers rotate at up to 300,000 rpm with non-linear dynamic rotor characteristics. Because of this nonlinearity, the rotor movement is intense, and the load on the bearing changes dynamically all the time. The consequence of this is a reduction in the service life of the turbocharger. At work[16]the effects of changing bearing clearances are described, as well as the differences between semi-floating and fully floating bearing designs based on journal articles and scientific publications on the subject. In addition, the phenomenon of damping and vorticity within the bearing system will be investigated and presented in a comprehensive literature review of automotive turbocharger rotor dynamics.

A promising solution for increasing the specific power of motor-tractor equipment is turbocharging, which allows to increase the power by up to 50%. At the same time, a significant increase in speed, load and temperature regimes leads to a significant increase in the number of failures and a decrease in reliability by 2-3 times. In Article[17] Voltheoretical and experimental studies have established that the temperature of the bearing and oil at the turbocharger drain changes under the influence of the oil temperature at the entrance to the rotor bearing, the frequency of rotation of the rotor shaft and changes in the oil pressure at the entrance to the . bearing. This allows you to set the performance limits of the bearing in extreme operating conditions. Installation of an autonomous lubrication and braking device maintains the required level of reliability and increases reliability. The hydraulic accumulator, installed in the lubrication system of the regular part of the engine turbocharger, lubricates and cools the rotor bearings when the engine crankshaft speed drops. The built-in braking device reduces the idle time of the rotor and thereby prevents oil starvation and dry friction of the rotor bearing. The joint use of a hydraulic accumulator and a braking device minimizes the risk of dry friction and accidental failure of the turbocharger. It has been proven that the rotor braking device, built into the engine intake system, with the calculated design parameters, reduces the time of rotor exposure by 30-35%. This reduces the dimensions and operating time of the hydraulic accumulator and at the same time eliminates jumps in the compressor section and any damage to its parts. In these conditions, the development of independent bearing lubrication systems and their replenishment with the help of built-in hydraulic accumulators during start-up, significant loads at minimum crankshaft rotation frequencies and engine shutdown is relevant.

In Article[18]an analysis of tribological research is provided regarding the most promising method of restoring the primary resource of engines using gas-dynamic spraying. It was established that to reduce the coefficient of friction and increase the wear resistance of the coating, the use of copper-zinc powders of the C-01-11 brand, applied by the method of gas-dynamic spraying, is theoretically justified. It was established that the physical and mechanical properties of the coatings (roughness, microhardness, friction coefficient) on the restored turbocharger meet the manufacturer's requirements. The coefficient of friction in the connection of the rotor shaft (reduced copper and zinc powder) with the sliding bearing (from tin-lead bronze Bros - 10 - 10) is 20% less than in the connection where the rotor shaft is made of steel 40. The total wear of a bearing unit with a restored gas-dynamic sprayed rotor shaft is 20% less than in a unit where the rotor shaft is restored according to the basic technology. The technology of restoring the surface of the turbocharger rotor shaft under the sliding bearing (gas dynamic spraying) has been developed, which increases its resource by 23% compared to the basic technology of repairing the rotor shaft. . This makes it possible to increase its operating time with the established regulatory and technical documentation for overhaul of the engine. A stand for testing diesel turbochargers with recuperation technology has been developed, which allows determining the parameters and characteristics of diesel turbochargers in different periods of operation, break-in and adjustment. Bench tests have shown that turbochargers with reconditioned rotor shafts using the proposed technology increase overall performance by 13% more after 2,000 hours of operation than turbochargers repaired using the basic technology. Operational tests have shown that turbochargers repaired using the proposed technology have a working life of 989 moto-hours more than turbochargers repaired according to the existing technology.

Conclusion

A comprehensive analysis was carried out, including experimental tests, mathematical modeling and numerical simulations. Analyzed tests of wear resistance on specially designed stands simulating the real operating conditions of turbocharger units. The results can be used to analyze the effect of integrated strengthening technologies on wear resistance, considering various parameters such as temperature, torque and operating time.

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Фасоля В., Гетьман М., Старий А. Аналіз працездатності пар тертя ротора турбокомпресора автомобільного двигуна.

Турбокомпресори використовуються в сучасних двигунах для підвищення їх продуктивності шляхом збільшення кількості поданого повітря. Для підвищення зносостійкості дослідники і інженери вдосконалюють інтегровані технології зміцнення вузлів турбокомпресора. Метою даного дослідження є оцінка та аналіз впливу інтегрованих технологій зміцнення на зносостійкість вузла турбокомпресора. Інтегровані технології зміцнення включають в себе застосування нових матеріалів, покриттів, конструкційних змін та процесів виготовлення, які покращують міцність, термічну стійкість та зносостійкість вузла турбокомпресора. Проведений комплексний аналіз, включаючи експериментальні випробування, математичне моделювання та числові симуляції. Проаналізовані випробування зносостійкості на спеціально розроблених стендах, що моделюють реальні умови роботи вузлів турбокомпресора. Результати можуть бути використані для аналізу впливу інтегрованих технологій зміцнення на зносостійкість, враховуючи різні параметри, такі як температура, обертовий момент і час роботи.

Ключові слова: турбонаддув, ротор, підшипники зношування, випробування, моделювання