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The patterns of changes in the degree of lubrication of the crankshaft bearings of car engines depending on the parameters of the load-speed modes of operation

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Abstract

The practice of operating machines and mechanisms indicates that bearing wear is one of the main reasons for limiting their durability. This especially applies to the sliding bearings of crankshafts of car engines, where the intensity of wear of their working surfaces significantly depends on the properties of the lubricant. An experimental study of the wear resistance of the sliding bearings of the crankshafts of car engines was carried out on the KI-5543 model break-in and braking stand. In experimental studies, BELZONA Super E-Metal insulating material was used to provide electrical isolation of the main and connecting rod bearings of the crankshaft from the cylinder block of the car engine. The experimental dependencies of the values of the criteria characterizing the degree of lubrication of the friction surfaces on the parameters of the load-speed modes (the moment of the applied force and the frequency of rotation of the crankshaft) were obtained. The ranges of values of the investigated parameters, in which the effective operation of the sliding bearings of the crankshaft of car engines is implemented, have been revealed.
Keywords: crankshaft sliding bearings, criteria for the degree of lubrication, bench tests, mode of friction, wear, lubricant.

Formulation of the problem

The most important reason for the failure of the sliding bearings of the crankshafts of cars is the wear of the friction surfaces of the liners and necks. The intensity of wear of the working surfaces of sliding bearings depends on the properties of the lubricant and the modes of the lubrication process under the conditions of vehicle operation. Wear of the friction surfaces leads to an increase in the diametric gap, ovality and conicity, destruction of the anti-friction layer of the bearing. This helps to reduce the load-bearing capacity of the lubricating layer and reduce its minimum thickness, increase the probability of destruction and, accordingly, increase the duration of the contact interaction of the friction surfaces [1,2]. It is known that violation of the liquid lubrication regime intensifies the process of wear of the main and connecting rod bearings of the crankshaft, and therefore the rate of consumption of the resource of the engine and the car as a whole.

The practice of operating cars shows that the durability of main and connecting rod bearings of crankshafts of car engines is limited by the type and intensity of wear. For automobile engines, structural and technological methods of increasing the wear resistance of crankshaft sliding bearings are used. Operational methods of increasing their wear resistance are also acceptable. The stage of operation of machines and mechanisms is the most expensive and has a significant reserve for increasing their durability.

Analysis of recent research and publications

During the operation of the car engine, the operating conditions of the crankshaft sliding bearings must be ensured in the liquid lubrication mode in the acceptable ranges of the load and speed modes of the car's operation.

The research of the wear resistance of bearings, including crankshaft sliding bearings of car engines, under different lubrication regimes, is devoted to the works of domestic scientists V.M. Pavliskyi [3], A.G. Kuzmenka

[4], O.V. Dykha. [4-6], V.V. Aulina [1,2,7], V.A. Voitova,[8] and other scientists, as well as a number of foreign scientists [9-17]

The issue of the influence of various factors on the lubrication process in crankshaft sliding bearings is considered in works [1,3,4,8,13,16,17]. At the same time, insufficient attention is paid to the criteria that characterize the degree of lubrication of the friction working surfaces during the operation of the car.

Further research is needed to identify patterns of changes in the degree of lubrication of crankshaft sliding bearings of car engines depending on the parameters of the load-speed modes of its operation.

The purpose of the work

The purpose of this work is to establish the patterns of changes in the criteria that characterize the degree and regimes of the lubrication process in the main and connecting rod bearings of the crankshaft depending on the parameters of the loading and speed regimes of their operation.

Research results

An experimental study of lubrication processes in crankshaft sliding bearings was carried out on the break-in and braking stand of the KI-5543 model of a specially prepared automobile engine with main bearings electrically isolated from the engine cylinder block. BELZONA Super E-Metal from BELZONA® (USA) was used as an insulating material. This material has high strength and dielectric properties (Table 1, Table 2), and therefore the main bearings of the car engine are electrically isolated from the cylinder block.

Table 1

General characteristics and chemical resistance of insulating material BELZONA Super E-Metal

General characteristics	Field of application	Processing time at 293 K, min	Hardening time at 293 K, min	Chemical resistance
A two-component, paste-like material that hardens quickly	For emergency repairs, sealing of leaks, obtaining long-lasting adhesives connections	5	20	Good resistance to relatively highly diluted inorganic acids, alkaline solutions and salts; special resistance to lubricants

Table 2

Physical and mechanical properties of the insulating material BELZONA Super E-Metal

Specific volume, cm3/kg	Strength limit under tensile and shear deformations, MPa, when connected to:	Strength limit at compression, MPa	Hardness by Brinell, NV	Heat resistance, T, K
450	- structural steel - 17, - stainless steel - 17, - aluminum - 12	76	15.9	Under conditions of immersion in lubricant up to 423°K

A shielded wire (Fig. 1) was soldered to the liners of the crankshaft of the tested engine, which, during assembly, was led out through a drilled groove in the place of the connector of the engine cylinder block cover and the gasket of the oil sump seal to the outside of the block.

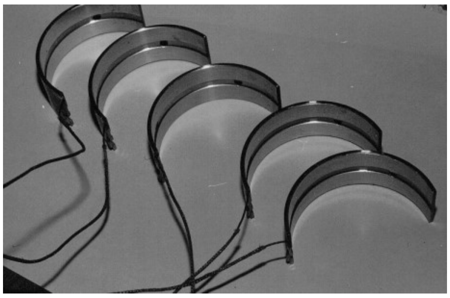

Fig. 1. Fixing the crankshaft main bearings with soldered wires

The wires were led to a five-channel connector, and a current collector was attached to the neck of the crankshaft (Fig. 2).

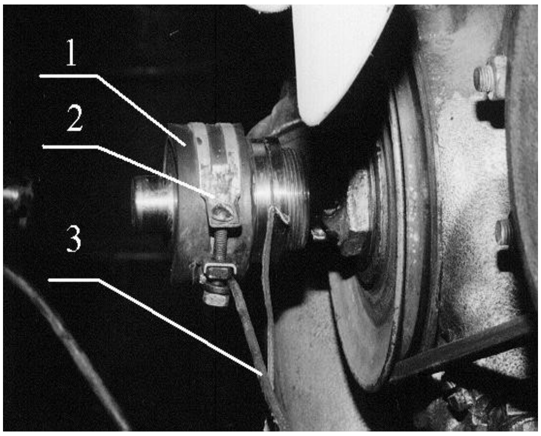

Fig. 2. Fastening the current collector on the crankshaft: 1 – rubber gasket, 2 – clamp, 3 – bracket

Through the test mode analyzer, one end of the power wire was attached to the wires of the liners, and the other - to the current collector. The value of the criterion $P_g^{m.b}$, which characterizes the relative duration of the existence of the liquid lubrication regime or the duration of the existence of the lubricating layer between the friction surfaces. When attaching the power wire to the cylinder block, the value of the criterion E_g, which characterizes the duration of the existence of the lubricating layer in the sliding bearings of the crankshaft of the car engine. In this case, the liners were electrically connected to the block of cylinder liners.

The studied engine, after applying a layer of BELZONA Super E-Metal insulating material on the original friction surfaces, corresponded to the pre-worked state. The research was conducted in two stages. The first stage is bench running of the engine according to the modes recommended by the manufacturer. The second stage is engine run-in, which consists in periodically repeating engine load modes with certain combinations of parameters of the load-speed modes of its operation: the values of the loading moment M and the frequency of rotation of the crankshaft n according to a two-factor plan built using the provisions of mathematical planning of the experiment [1,8]. The scheme for measuring the parameters of the lubrication process in the sliding bearings of the engine crankshaft is shown in Figure 3.

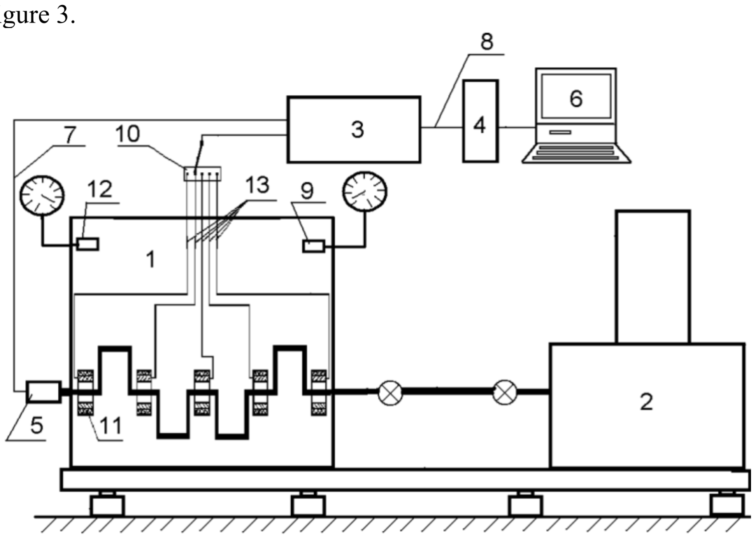

Fig. 3 - Scheme of measurement of the parameters of the lubrication process in the sliding bearings of the crankshaft of a car engine during bench tests:1 - engine; 2 – break-in and braking stand; 3 – analyzer of friction modes; 4 - connection device; 5 - current collector; 6 – computer; 7, 13 – power wires; 8 – tire; 9 – lubricant pressure sensor; 10 - connector; 11 – dielectric layer; 12 – coolant temperature sensor

Research modes: load on the crankshaft M - 0...60 N·m, speed of rotation of the crankshaft n - 1000...2600 min $^{-1}$ .To simplify the analysis of the results of the bench tests, it was assumed that the lubrication regime of the crankshaft sliding bearings is characterized by two states: contact of the friction surfaces (dry friction or boundary lubrication), complete separation of the friction surfaces (liquid lubrication). The grouping of lubrication modes can be justified by several reasons: the difference in the intensity of wear of the friction surfaces by several orders of magnitude [1,3,8], as well as the difference in the dielectric permeability of the lubricating layers [1]. An experiment plan was drawn up for the study of the lubrication process in the main bearings of the crankshaft according to two criteria:

$$P_g^{m.b}\, i = f(M, n) \text{ and } E_g = f(M, n) \quad (1)$$

This made it possible to build appropriate regression mathematical models after the running-in process is completed, when the values of these parameters are at a stable level and characterize the balanced technical condition of the car engine.

According to the results of the analysis of the database of bench tests, graphical dependences of the change in the criterion $P_g^{m.b.}i$ (where *i* the serial number of the main bearing under study), from the load parameter M (Fig. 4) and the frequency of rotation of the crankshaft of the car engine n (Fig. 5).

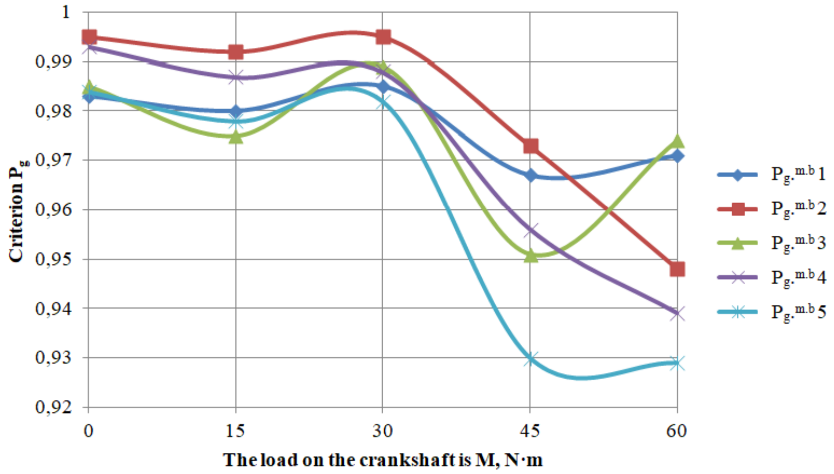

Fig. 4. Patterns of changes in the value of the $P_g^{m.b}$ at a stable level from the load parameter

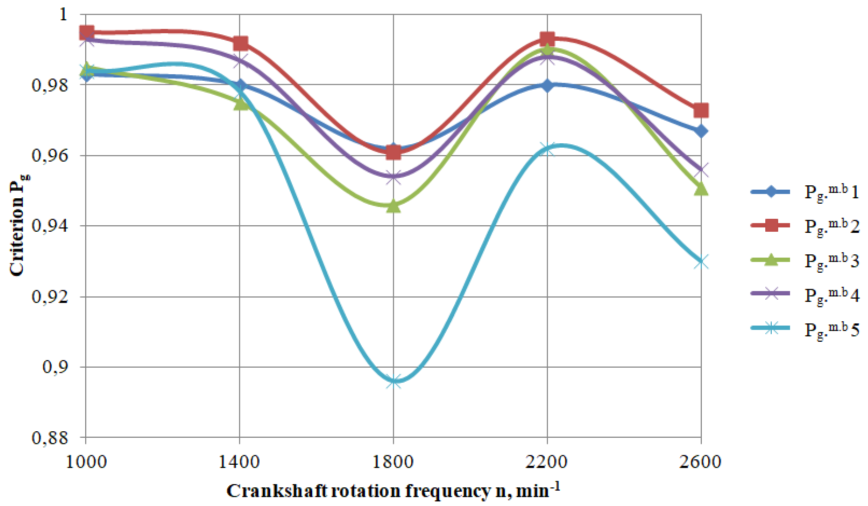

Fig. 5. Patterns of changes in the parameter $P_g^{m.b}$ at a stable level depending on the frequency of rotation of the crankshaft of the car engine

It was found that the patterns of changes in the value of the criterion $P_g^{m.b.}$ from the loading and speed parameters have a non-linear character in the presence of areas of effective operation of the car engine.

Two-factor bench tests of the engine were carried out. According to the results of the research, a regression model was built in the form of the dependence of the E_g on the parameters of the loading and speed modes of its operation:

$$E_g = 0.7951 + 2.2615\ 10^{-3} M + 1.1303\ 10^{-4} n - 5.0944\ 10^{-5} M - -4.0701\ 10^{-8} n^2 - 3.6473\ 10^{-7} M\, n \quad (2)$$

The regression model of the E_g with the specified parameters was obtained using application program packages on a PC with verification of its adequacy

Figure 6 shows a graphical interpretation of the regression model of the E_g.

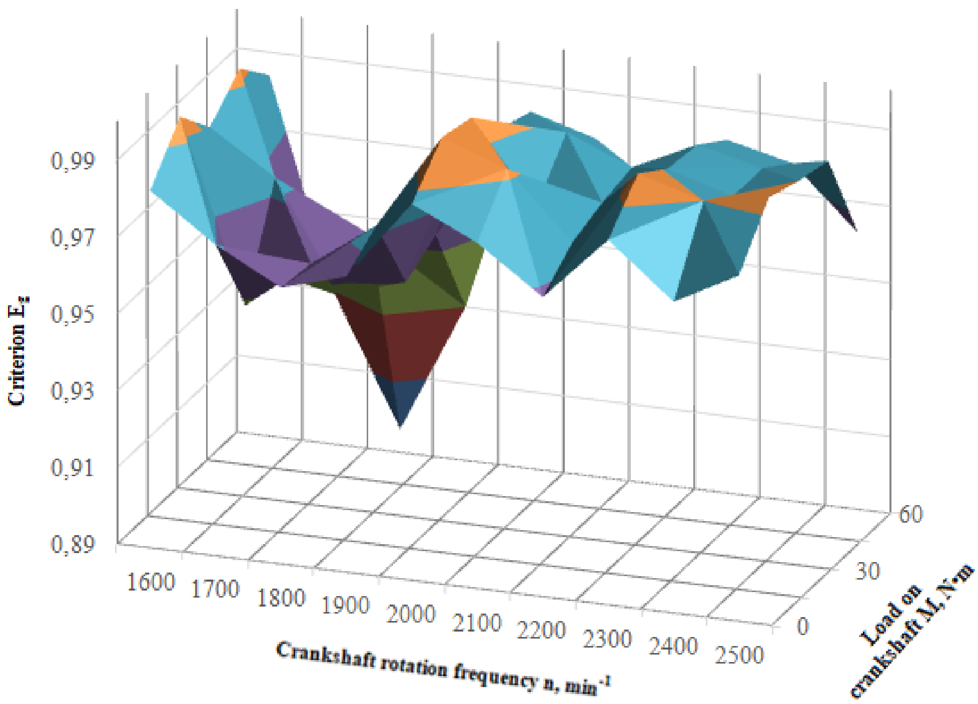

Fig. 6. The nature of the change of the E_g from the parameters of the load-speed mode of operation of the car engine

The test of homogeneity of variances of criterion E_g was carried out according to Cochran's criterion with a confidence probability of 0.95 under conditions of load M = 30 N m, n = 2000 min^{-1}. The homogeneity of variances in the equilibrium points of the factor space indicates the independence of the variance of the optimization criterion E_g from its absolute value. Fulfillment of this condition, along with others, allows you to use regression analysis when processing the obtained test results.

Conclusions

1. It was determined that to study the change in the degree of lubrication of crankshaft sliding bearings of car engines depending on the parameters of load-speed modes of operation, it is possible to use the criterion $P_g^{m.b.}$, which characterizes the relative duration of existence of the liquid lubrication regime, and the criterion E_g, which characterizes the relative duration of existence of the lubricating layer in the crankshaft sliding bearings.
2. Modes of bench tests of engines and a scheme for measuring the criteria of $P_g^{m.b.}$ and E_g, in the process of lubricating the sliding bearings of the crankshaft of the car engine.
3. Experimentally revealed patterns of changes in the criteria for the degree of lubrication of crankshaft sliding bearings depending on the load and rotation frequency during a stable mode of its operation. Areas of effective flow of lubrication processes and stable formation and duration of the existence of a film of lubricant on the working surfaces of the sliding bearings of the crankshaft of the car engine have been determined.

References

1. Methodological and theoretical foundations of ensuring and increasing the reliability of the functioning of automobile transport systems: a monograph / V. V. Aulin, D. V. Golub, A. V. Hrynkiv, S. V. Lysenko; under. general ed. Prof. V.V. Aulina. – Kropyvnytskyi: KOD, 2017. – 370 p.
2. Aulin V., Lyashuk O., Gupka A., Tson O., Mironov D., Sokol M., Leshchuk R., Yarema I. Tribodiagnosis of the surface damage of tribo-coupling parts materials during machine operation // Procedia Structural Integrity . - 2024. - Volume 59. - P. 428-435.
3. Increasing the wear resistance of tractor engines [Text]: diss... Dr. Tech. Sciences: 05.02.04 / Vasyl Mykhailovych Pavliskyi; National Agrarian University - K., 1999. - 350 p.
4. Contact, friction and wear of lubricated surfaces: monograph / A. G. Kuzmenko, A. V. Dykha. – Khmelnytskyi: KhNU, 2007. – 344 p.
5. Dykha O.V, Sorokatyi RV, Babak OP (2011). Rozrakhunky she trials on nadiinist mashyn i konstruktsii: navch. possible [Khmelnytskyi : KhNU] 151 p.

6. Dykha, O., Padgurskas, J., & Babak, O. (2021). Prediction of the life time of cylindrical tribosystems of a vehicle. In IOP Conference Series: Materials Science and Engineering (Vol. 1021, No. 1, p. 012036). IOP Publishing.

7. Aulin, V., Gypka, A., Liashuk, O., Stukhlyak, P., & Hrynkiv, A. (2024). A comprehensive method of researching the tribological efficiency of couplings of parts of nodes, systems and aggregates of cars. Problems of Tribology, 29 (1/111), 75-83. https://doi.org/10.31891/2079-1372-2024-111-1-75-83

8. Vojtov, V., Biekirov, A., & Voitov, A. (2018). The quality of the tribosystem as a factor of wear resistance. International Journal of Engineering & Technology, 7 (4.3), 25-29.

9. Bernát, R., Žarnovský, J., Kováč, I., Mikuš, R., Fries, J., & Csintalan, R. (2021). Microanalysis of Worn Surfaces

10. Al-Quraan, T.M, Mikosyanchik, O.O, Mnatsakanov, R.G, & Zaporozhets, O.I (2016). Structural-Energy characteristics of tribotechnical contact in unsteady operational modes. Modern Mechanical Engineering, 6 (3), 91-97.

11. Kučera, M., Kučera, M., & Pršan, J. (2012). Possibilities for classification of tribological processes with regard to energy.

12. Adetunla, A., Afolalu, S., Jen, TC, & Ogundana, A. (2023). The Advances of Tribology in Materials and Energy Conservation and Engineering Innovation. In E3S Web of Conferences (Vol. 391, p. 01014). EDP Sciences.

13. Ismailov , G.M, Tyurin , A.E, Gavrilin , A.N, Nevinitsyna , V.S, & Lomovskaya , SA (2020, September). Study of the identification model of tribological interaction of friction couples. In IOP Conference Series: Materials Science and Engineering (Vol. 919, No. 2, p. 022056). IOP Publishing.

14. Aleutdinova , M.I, Fadin , V.V, Kolubaev , A.V, & Aleutdinova , V.A Contact characteristics of metallic materials in conditions of heavy loading by friction or by electric current. Friction and Wear Research (FWR). 2014. No. 2. 22-28.

15. Dunaev A.V, Pustovoy I.F Experience of using electric effects on engine oils and friction in . Journal of machinery manufacture and Reliability. 2020. Vol. 49, no. 11. P. 980-989. URL: https://doi.org/10.3103/s1052618820110035.

16. A study of the effect of electrostatic processing on performance characteristics of axle oil / P. Konovalov et al. Eastern-European journal of enterprise technology. 2018. Vol. 1, no. 1 (91). P. 4–12. URL: https://doi.org/10.15587/1729-4061.2018.120977.

17. Study of electrohydrodynamic properties in insulating liquids and research of an alternative mixture to mineral oil for energy transformers / J. Rouabeh et al. Journal of electrostatics. 2022. Vol. 115. P. 103684. URL: https://doi.org/10.1016/j.elstat.2022.103684.

Гупка А., Аулін В., Ляшук О., Гриньків А., Гудь В. Закономірності зміни ступеню змащення підшипників колінчастого валу двигунів автомобілів від параметрів навантажувально -швидкісних режимів експлуатації

Практика експлуатації машин та механізмів вказує на те, що зношування підшипників є однією з головних причин обмеження їх довговічності. Особливо це стосується підшипників ковзання колінчастих валів двигунів автомобілів, де інтенсивність зношування їх робочих поверхонь істотно залежить від властивостей мастильного матеріалу.

Експериментальне дослідження зносостійкості підшипників ковзання колінчастих валів двигунів автомобілів було проведено на обкатно-гальмівному стенді моделі КІ-5543. В експериментальних дослідженнях використано ізоляційний матеріал BELZONA Super E-Metal для забезпечення електричної ізоляції корінних та шатунних підшипників колінчастого валу від блоку циліндрів двигуна автомобіля. Отримано експериментальні залежності значення критеріїв, які характеризують ступінь змащування поверхонь тертя від параметрів навантажувально-швидкісних режимів (моменту прикладеної сили та частоти обертання колінчастого валу). Виявлено діапазони значень досліджуваних параметрів, в яких реалізується ефективна експлуатація підшипників ковзання колінчастого валу двигунів автомобілів.

Ключові слова: підшипники ковзання колінчастого валу, критерії ступеню змащування, стендові випробування, режим тертя, зношування, мастильний матеріал.