REPUBLIC OF AZERBAIJAN

On the rights of the manuscript

ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

RESEARCH ON THE QUALITY AND RELIABILITY OF ROLLING BEARINGS IN MACHINES

Specialty: **3313.02- Machinery, equipment and processes**

Field of science: **Technical sciences**

Applicant: **Sadir Saday Guliyev**

Ganja-2025

The dissertation was completed at the department of Mechanical Engineering and logistics of the Azerbaijan University of Technology.

Scientific supervisor: honored scientist, doctor of technical science, professor **Tofig Bayram Gochayev**
honored scientist, doctor of technical science, professor **Bayram Muhammad Baghirov**

Official opponents: - doctor of technical science, professor **Mazahir Hamza Farzaliyev**
- doctor of technical science, professor **Fariz Gachay Amirov**
- doctor of philosophy in technical sciences,associate professor **Vusala Shakir Huseynova**

ED2.02 Dissertation Council operating at the Azerbaijan State University of Oil and Industry of the Higher Attestation Commission under the President of the Republic of Azerbaijan

Chairman of the dissertation council: doctor of technical science, professor **İbrahim Abulfaz Habibov**

Scientific secretary of the dissertation council: doctor of technical science, professor **Tahir Gaffar Jabbarov**

Chairman of the scientific seminar: doctor of technical science, professor **Zakir Ali Agha Rustamov**

GENERAL DESCRIPTION OF THE RESEARCH

Relevance and degree of completion of the topic. The machine-building complex is the sphere of production of various types of equipment, which determines the level of development of technological progress in each country. Bearings are one of the components that is strictly controlled by state standards when designing in this industry, as well as when designing products based on them. Bearings have a wide classification, and rolling bearings dominate among them. Rolling bearings are used to ensure uniformity of movement in rotating joints, as well as to reduce the level of friction between the contact surfaces, depending on their purpose. Bearings are widely used in the designs of various types of equipment and devices, including machines and mechanisms used in automotive, aviation, agricultural, metallurgical and other industries. Bearings must ensure reliability and safe operating conditions in the working process by supporting shafts and parts and assemblies located on them. Therefore, they have the necessary requirements, including high strength and hardness, resistance to wear, heat, vibration, as well as quality indicators such as maintainability. Along with them, the function of reducing dynamic loads and mechanical external influences in the operation of bearings is also of great importance [113][1]. The above-mentioned problems eventually lead to advanced complex indicators for improving the operational efficiency of rotating and friction: updating solutions to structural and technical technological problems. In this regard, it is important to explore the possibilities of using high-quality new building materials, including effective lubricants that facilitate operating conditions.

An analysis of available literature sources and production experience, as well as online research, shows that to ensure the quality and reliability of rolling bearings, along with theoretical calculations and methods to increase bearing capacity, a more

[1] Chichinadze, A.V. Friction, wear and lubrication (tribology and tribotechnics) / A.V. Chichinadze. - M.: Mashinostroenie, 2003. - 576 p

appropriate direction is considered to be a comprehensive solution to lubrication problems with new effective oils, taking into account the causes of failure of bearing parts [25][2]. A number of important studies and scientific studies have been conducted to improve bearings, improve their performance and select new oils. There is fundamental research in this field by scientists and specialists from both Azerbaijan and neighbouring and far-abroad countries. Among them are T.B. Gojaev, A.H. Janakhmadov, A.H. Abdullaev, B.M. Bagirov, A.G. Hasanov, I.V. Kragelsky, S.G. Dokshanin, D.N. Reshetov, A.V. Chichivadze, M.A. Lyutyi, V.P. Zhevtunova, as well as A. Kumara, A. Shadi, G. Xiangun and others. In addition to the fact that it should be noted the significant importance of the conducted research and the obtained scientific and experimental results, the issue of improving the quality, reliability and durability of rolling bearings, as well as their performance has not lost its relevance. In recent years, research on the use of ultrafine diamond graphite fillers as additives in oils to improve the performance of rolling bearings and their results has attracted increasing attention. This is due to the fact that nano additives not only reduce the viscosity of the oil, but also fill micro voids on the surface and form a non-corrosive layer with high hardness. Ultrafine diamond graphite additive is used as an additive to existing plastic oils. However, various sources provide contradictory information about the amount of ultrafine diamond graphite additive. This limits the use of this promising material in production.

This is due to the fact that a comprehensive research methodology and a feasibility study have not yet been developed to substantiate the amount of this promising additive, taking into account production conditions [53][3]. Therefore, in addition to improving the design and technological calculations to solve this

[2] Pashaev, A.M. Applied mechanics. Textbook. / A.M. Pashaev, A.Kh. Janakhmedov, R.A. Kabirli – Baku: Apostrophe, 2014. 512 p.

[3] Dokshanin S.G., Dokshanina I.I., Reduction of the adhesive component of the friction force when using a lubricant with the addition of ultrafine almozographite. Bulletin of the Federal State University. No.5(126), 2015.pp. 125-127.

problem, the rationale for determining the rational amount of an ultrafine diamond graphite additive as an additive to lubricants for bearings of machines and mechanisms is a matter of scientific, technical and practical importance. The research work is devoted to solving this urgent problem..

The direction, object, and subject of the study.

The main focus of the research is to increase the resource and reliability of bearing assemblies used in machine and equipment designs. The object of the study is the performance of rolling bearings in accordance with the requirements of GOST 3395-89. The subject of the research is the development of a method for determining the amount of ultrafine lubricant for lubricating bearings. For this purpose, a new composite material has been proposed with the addition of an ultrafine diamond graphite additive to the composition of the Litol-24 series lubricating oil.

Purpose and objectives of the study.

Based on a comprehensive assessment of the operability of rolling bearings, a rational amount of adding an ultrafine diamond graphite additive as a filler to a lubricating oil has been determined, providing an increase in quality and reliability, as well as an assessment of bearing performance.

To achieve this goal, the following scientific and experimental tasks were set:

1. Study of the nature and patterns of load distribution between rolling elements, taking into account the operating conditions and technical characteristics of bearings.

2. Theoretical substantiation of effective and promising lubricants and lubrication modes to increase the level of operability, reliability and durability, taking into account operating conditions and statistics of bearing failures.

3. Preparation of a test bench, which makes it possible to realize the specified goal and the tasks required for solving, and conducting appropriate experiments.

4. Analysis of the obtained results and establishment of the corresponding mathematical dependencies.

5. Application of the obtained results in industry and assessment of technical and economic efficiency.

Research methods. Theoretical research was conducted on the basis of the basic principles of mechanics, theoretical and applied mechanics. Experimental studies were conducted on a specially designed test bench in accordance with the requirements of relevant state standards, as well as using certified stands, auxiliary tools and measuring equipment. Photo and video materials were also used in the research process. The reliability of the theoretical results has been confirmed by experiments and resource tests conducted in laboratory and industrial conditions. The experimental data were processed using mathematical statistics methods..

Main provisions to be submitted for defense:

- the influence of kinematic and load parameters of bearings on their operability, reliability and durability based on the refinement of an analytical and experimental method for evaluating the operability of rolling bearings;
- evaluation of the possibilities of using a new ultrafine diamond graphite filler oil to improve the performance and reliability of bearings;
- a method for determining the rational amount of ultrafine diamond graphite filler material in mass-produced plastic oils to increase the reliability and durability of bearings;
- a method for determining the forces of static and propulsive resistance;
- justification for reducing the level of wear intensity.

Scientific novelty of the research.

Taking into account various modes of variable loads and real-world operating conditions, probabilistic and statistical models of bearing failure-free operation have been developed, as well as a methodology for evaluating uptime.

To improve the operability, reliability, and durability of bearings, a rational amount of ultrafine diamond graphite additive has been justified in the existing Litol-24 grease, as well as the lubrication regime.

It has been determined that 1% of the ultrafine diamond graphite additive by weight in the existing Litol-24 grease is an effective amount. Lubricant with this additive can reduce static resistance by 1.5-2 times or more, resistance to movement by 1.33, and wear rate of bearings by 2.26 compared to the existing grease. Effective lubrication leads to a 33% reduction in energy consumption, resulting in increased operability, reliability, and durability.

Theoretical and practical significance of the study.

The principle of selecting ultrafine diamond graphite additives to existing lubricants to improve the efficiency, reliability and durability of bearings can be used by researchers and design engineers as a methodological basis for solving other similar tasks. The scientifically based and practical research results recommended for introduction into production have been tested in real-world operating conditions at Azeraluminium LLC and, taking into account their posi-tive results, are recommended for use in production workshops. Sound technical and technological developments can be used in appropriate production conditions, as well as in equipment and technical means with rolling bearings in industrial enterprises. The theoretical and methodological research results can be used in the educational process at ATU, as well as in technical universities and colleges..

Approbation and application of works. The results of the research work were reported, approved and published at the following scientific, technical and scientific-practical conferences and seminars:

- Azerbaijan Technological University, International Scientific and Practical Conference "The main problems of university ranking", dedicated to the 98th anniversary of the birth of national leader H aydar Aliyev (Ganja-2021);
- Scientific Research Center "Mashinostroenie" of the Ministry of Education and Science of the Russian Federation. Conference "Machines, Aggregates and processes, design, Creation and modernization" (Saint Petersburg-2022);

- Russian Federation, Penza State University, XVI International Scientific and Practical Conference "Modern Problems of Science and Education" (Penza-2022); -

- Azerbaijan University of Technology, International Scientific and Practical Conference on "Design, Technologies and Inno-vations in the textile and Light industry" dedicated to the 99th anniversary of the birth of national leader Haydar Aliyev (Ganja-2022);

- Azerbaijan University of Technology, an international scientific and practical conference on the topic "The Fourth Industrial Revolution and Innovative Technologies" dedicated to the 100th anniversary of the birth of national leader Haydar Aliyev (Ganja-2023).

The practical results of the dissertation work were applied to rolling bearings operated on the production line in the workshop of pressure treatment and painting of Azeraluminium LLC. The expected annual technical and economic efficiency per 10 pairs of bearings is 711 manats.

The name of the organization where the dissertation work is performed.

The dissertation was completed at the Department of Mechanical Engineering and Logistics of the Azerbaijan University of Technology..

The total volume of the dissertation with an indication of the volume of the structural sections of the dissertation separately. The dissertation consists of an introduction, 4 chapters, main results, a list of references and appendices. The total volume of the dissertation is 183 pages of computer text, including 34 figures, 11 graphs, 24 tables, 4 appendices, and a list of 130 references. The dissertation introduction is 7 pages (11294 characters), the first chapter is 37 pages (53118 characters), the second chapter is 40 pages (48778 characters), the third chapter is 22 pages (29858 characters), the fourth chapter is 46 pages (60545 characters), the results are 2 pages (3500 characters), recom-mendations The production volume is 1 page (747 characters) and the list of references is 14 pages (21515 characters). The dissertation con-sists of 183 pages of computer text

with a total volume of 237663 cha-racters (excluding the list of references and appendices, 211075 characters).

CONTENT OF THE WORK

In the introduction, the relevance of the topic, the purpose of the research, the tasks set and the general characteristics of the dissertation are given.

First chapter. It is called "Modern problems of rolling bearings operation and ways to eliminate them." This chapter presents rolling bearings and their functional, technological, technical and operational characteristics. The characteristic features of malfunctions that occur in them during operation are analyzed. The possibilities and resources of existing methods and means of improving the operability, reliability and durability of rolling bearings as the main quality indicators are investigated. It is determined that the most promising of the developed methods and tools is the use of lubricants with an effective composition. At the same time, great results are achieved by reducing contact stresses in the bearings and increasing the polish and strength of the working surface during the lubrication process.

To this end, the prospect of improving the performance, reliability and durability of rolling bearings is substantiated by adding an ultrafine diamond graphite additive to the mass-produced plastic oil Litol-24 used in bearings. In addition, it has been shown that the addition of an ultrafine additive to oils in different quantities gives a different effect [20][4]. Therefore, the main goal of the work was to determine the effective amount of an ultrafine additive to plastic oils in real-world operating conditions and to define tasks to achieve this goal.

Second chapter It is called "A theoretical analysis of improving the performance and reliability of rolling bearings." This

[4] Guliyev, S.S. The main provisions of the theory of calculation of roller bearings and ways to meet the working conditions // - Ganja. Journal of Scientific Works of the Azerbaijan State Agrarian University, 2018, No. 1, pp. 111-115.

chapter analyzes the theoretical foundations of existing research on this problem. The factors affecting the reliability, performance and durability of the bearing, scientific research, ideas and developments aimed at solving this problem using the method of mechanical influences are investigated. It is determined that these developments, design and technological techniques and tools are important theoretical foundations for improving the quality of bearings by mechanical methods during operation. In addition, it is proved that currently one of the important areas for improving the productivity and quality of bearings, as well as the most affordable, is the use of ultrafine diamond graphite type additives in the lubrication of bearings. The advantages and theoretical foundations of using such additives for lubrication are analyzed. Then, the theoretical and methodological foundations of the method for determining the effective amount of nanodispersed diamond graphite additives in existing oils were developed [88][5]. It has been determined that, according to existing fundamental research, such an additive not only improves the performance of bearings, but also fills micro-depressions on the contact surfaces, creating a strong and durable layer on the surfaces, thereby increasing the service life of bearings. It was determined that since comprehensive studies of various compared oils were not carried out directly on the working body in real conditions, there are sharp differences between the results in terms of the effective amount of the specified additive.

Therefore, in order to obtain accurate and scientifically sound results, the quality indicators of a lubricant should be carried out directly on the bearing and on the working body under study. Based on this position, the determination of the effective amount of the studied ultrafine diamond graphite additive in the serial oil Litol-24 and its comparison with the existing oil Litol-24, taken separately, was investigated using a rolling bearing.

[5] Obraztsov L.N. Nanodiamonds in lubricating compositions //Fundamental Sciences: Physics, Moscow-2020, No. 9, pp.83-91

A simple experimental device has been developed and its basic structure has been substantiated, which makes it possible to conduct comparative studies and evaluations on a rolling bearing directly on the working body to determine the effective amount and advantages of various oil materials..

For this purpose, it was assumed that a load suspended from a cushion, the inner ring of which is stationary at a height of h, and the outer ring rotates, has a potential energy of $W = mgh$. When this load rotates the cushion and falls to the ground, it overcomes the force of resistance to movement caused by friction in the cushion and falls to the ground at a certain speed. According to classical mechanics, the mathematical dependence of this process can be written as:

$$h=V_0t + \frac{gt^2}{2}, \qquad (1)$$

where V_0 - starting speed, m /sec;

t - time, sec;

g- free fall emergency, m/sec^2.

The initial speed of the charge falling from a height h is zero, that is, $V=0$. In this case, the dependence of the time spent on reaching the ground of the load falling from the height h is as follows:

$$h= \frac{gt^2}{2} \qquad (2)$$

From here it can be determined that:

$$t=\sqrt{\frac{2h}{g}} \qquad (3)$$

From this it can be seen that the fall of the same load from the same height to the ground from the same distance occurs at the same time t_0. But if the suspended load moves the pad by rotating it, then it

is counteracted by a force of resistance to movement due to inter-part friction, and the load reaches the ground within a time t_1 different from that time. We do not take into account the resistance of the air, since it is very small, but also for all cases its resistance is the same. Any load with a mass of 1 kg from the experimental installation:

1 - when releases it, it's time for him to cover the distance *h* and reach the ground – t_0;

2 - when leaving the lean pad in the hanging position - t_1;

3 - when leaving the pad lubricated with Litol-24 oil - t_2;

4 - when leaving the pad lubricated with Litol-24 and an efficient amount of ultradispers diamond-graphite additive, the load drop time will be-t_3.

In each variant and each time we see the load falling from the same *h* load to the ground in a separate period. In theory, the differences between these times should always be as follows:

$$t_0 < t_1 > t_2 > t_3 \quad , \qquad (4)$$

where t_0 - load free fall time, sec;

t_1 - time for the load to fall by rotating the non-lubricated pad, sec;

t_2 - time for the load to fall by rotating the pad lubricated with Litol-24 oil, sec;

t_3 - it is time for the load to fall to the ground by rotating the pad lubricated with ultradisperse diamond-graphite doped oil on Litol-24 oil, sec.

Therefore, the listed parameters should be determined by experimental studies. For this, it is necessary to select the option of the existing Litol-24+ultradispers diamond-graphite admixture as efficient as Litol-24, that is, the lowest resistance to quiet friction, and in this option, to set the time of the load falling from different heights in case of dynamic movement.

So, in the ratio of these times:

t_1/t_2 - Efficacy indicator of Litol-24 oil;

t_2/t_3 - With the efficient variant Litol-24+, ultradispers diamond-graphite doped oil will have an efficiency indicator.

Based on the analytical reasoning commented above, theoretically, in the standing position of the inner ring of the pad, it is possible to experimentally determine the calm resistance force arising in the lubrication mode of the pad with various oils through the load given to the bowl suspended on the thread winding on the outer ring, as well as the parameters characterizing the effect then, by conducting compara-tive analyzes, it is possible to determine the advantage of the new lubricating material over the existing lubricating material and the most efficient optimal variant of the new additive material in oil. This will also make it possible to determine the rational amount of the additive, which is added to the existing oil in different quantities.

An experimental test device was developed, which made it possible to conduct an experiment on the specified principle, and numerous experimental studies were carried out on it.

Third chapter It is called "Software and methodology of experi-mental research". In this chapter, the comparative physico-mechanical properties of the serial (base version) Litol-24 and the modified (new version) Litol-24+ with ultradispersed diamond-graphite additives in rolling pads were studied.

The design, structure, and working principle of the experimental testing facility were explained, and the procedures for conducting comparative studies in the facility were described. Methods for determining calm resistance strength and resistance to movement were justified by introducing an optimal amount of ultradispersed diamond-graphite additive into existing Litol-24 oil in an experimental pad.

The method for determining the tolerance of pads greased with a certain amount of additives was described. The equipment and devices used in the experimental studies, as well as the processing of data obtained through mathematical statistics, were also discussed. ICT tools and photo and video recording were also used during the research.

Fourth chapter, titled "Results of experimental studies and their analysis," discusses the physical and mechanical properties of pads lubricated with existing pads and ultradisperse additives.

To conduct experimental studies and test experiments, a device was used that was described in the second chapter.

The experimental test unit comprises the following components (see fig. 1): an experimental rolling pad (1), a suspension rope (2), a plastic cup (3), a faucet (4), a hose (5), a plastic water container (6), a tripod (7), a support table (8), and a motor base (9).

The experimental device allows us to measure the static resistance force and friction coefficient. The process of working with the device is as follows.

First, we set the static resistance force. Then, we open the faucet (4) and allow water to fill the plastic cup (3) until it reaches a certain level. When the water level is sufficient, we disturb the equilibrium of the pad and displace the water-filled cup. After that, we abruptly close the faucet and remove the cup from the suspension rope hook.

Finally, we weigh the weight of the water and cup on an electronic balance. The measured weight will be the resistance force we are looking for**.**

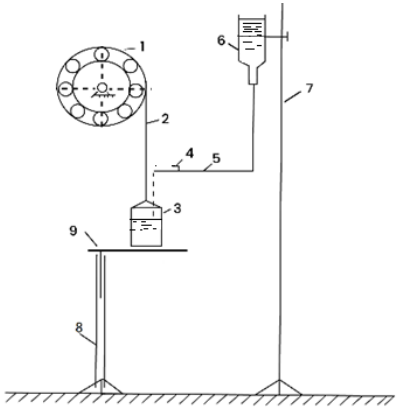


Figure 1. Diagram of an experimental setup for determining the static resistance force and coefficient of friction

The process of work on the device goes as follows: 1. First, the experimental pad is made lean. To do this, the pad is washed and cleaned, and the thread on the pad is wrapped around the pad, and its hooked end is left 45-50 cm below the pad.

Meanwhile, the plastic cup (3), which is wrapped around the pad and hung on a rope, stands in one position and does not fall down, as it is very light. Its weight or the force generated by it is not able to overcome the calm resistance force of the pad and the cup stands hanging steadily. Then the tap (4) opens and the plastic cup (3) is filled with water. As soon as the plastic cup is moved, the tap (4) closes abruptly and the plastic cup sits on the table evenly with the water.

The plastic cup is removed from the suspension and weighed on an electronic scale with water. The calm that this cushion has for the current is the resistance force. As a result, a G_1 weight is obtained, which can also be defined as:

$$G_1=m_1g\ , \qquad (5)$$

where m_1 - the billet of the glass with water, kq. This is the quietness resistance force generated in the pad for lean condition.

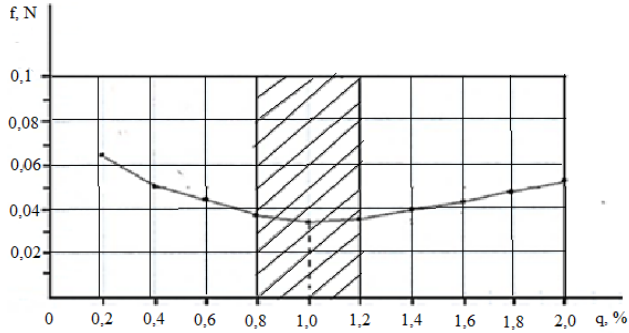
2**.** Then the pad is lubricated on both sides with serial Litol-24 oil. By rotating the pad, the oil is settled on the pad parts. The amount of oil for lubrication is taken according to the instructions of the pad according to the norm. By the same rule, the tap is opened, water is released into the plastic cup (3), and at the moment the glass is moved, the tap is closed. The flow of water is stopped and the water with the container is weighed on an electronic scale. As a result, a G_2 weight is obtained, which can be determined in the same order:

$$G_2=m_2g\ , \qquad (6)$$

where m_2 - the billet of the glass with water., kg. This is the static resistance force generated in a bearing lubricated with Litol-24 oil..

Determination of the effective amount of ultrafine diamond graphite additive in Litol-24 oil. The effective amount of ultrafine diamond graphite additive in Litol-24 oil is determined by the value of the static resistance force. To do this, various amounts of an ultrafine diamond graphite additive are added to the Litol-24 lubricant in the range of 0.2...2% in weight increments of 0.2% (i.e. 0,2; 0,4; 0,6; 0,8; 1,0; 1,2; 1,4; 1,6; 1,8 and 2.0%). Then a table of static resistance force values is compiled for each additive amount option. A graph of changes in the static resistance force is plotted depending on the amount of additive**.**

Thus, the static resistance force and the coefficient of friction were determined for the cases when the bearing was lubricated with serial Litol-24 oil and Litol-24 oil modified with an ultrafine diamond graphite additive..



Graph 1. Effect of various amounts of ultrafine diamond graphite additive in Litol-24 oil on friction resistance

Optimization of the amount of ultrafine diamond graphite additive added to Litol-24 oil in rolling bearings. The experimental data obtained and the graph based on them show that the coefficient

of friction varies according to the quadratic law depending on the amount of additive.

$$y=ax^2+bx+c \qquad (7)$$

Based on experimental data, a mathematical model of the process was constructed using the least squares method and the optimal amount of the additive equal to 1.07% was determined.

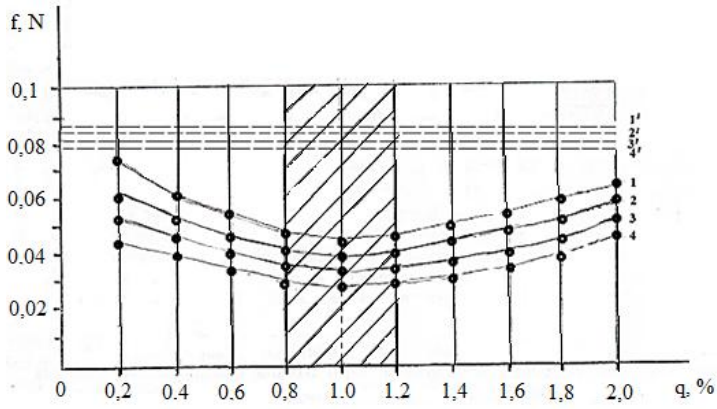
$$y^1 =0,023658\cdot x^2-0,05641\cdot x+0,070 \qquad (8)$$

However, it was taken into account that when experimenting on technical systems, an error of 0.07% is allowed. Therefore, by rounding the result, the optimal amount of additive was assumed to be ≈1%. This amount was used in subsequent laboratory studies and tests under production conditions [126][6].

Changes in the strength of static resistance with different amounts of additives in the ambient temperature regime. The effect of the additive amount on the friction process in various ambient temperature conditions has been investigated. Similar experiments were carried out under different temperature conditions, namely at temperatures of 20, 25, 30 and 35^0C and in different media (the temperature in the bearing for this medium is indicated).

It has been found that in oils with additives of ultrafine diamond graphite, both Litol-24 and Litol-24+1%, the coefficient of friction and the force of static resistance decrease with increasing temperature. In all cases, the minimum values of the coefficient of friction and the static resistance force were obtained in the range of 0.8-1.2% by weight of the ultrafine diamond graphite additive (shaded area in graph 2).

[6] Guliyev, S.S., Baghirov, B.M., Rzayeva, R.A., Aliyev, S.H., Verdiyev, B.Z., Askarova, A.A., Hasanova, K.R., Taghiyev, U.T. Determination and justification of the optimal amount of ultrafine diamond graphite additive in litol-24 oil in rolling bearings// EUREKA: Physics and Engineering – 2025, № 3 (58), p 113-129.



Graph 2. The effect of ambient temperature change on the quietness resistance force in Litol-24 and Litol-24+ultradispers diamond-graphite grease: the change in the quietness resistance force in 1-20, 2-25, 3-30 and 4-35^{0}C; for lubricating grease with 1^1, 2^1, 3^1 and 4^1 only in 20, 25, 30 and 35^{0}C according to G_1=87N; G_2=85N; G_3=82N, G_4= 80N=const.

Thus, it was found that with an increase in the amount of ultrafine diamond graphite additive in the bearing oil, the friction resistance force first decreases, reaches a minimum value at a certain limit, and then increases. This effect is explained by the thickening of the oil.

The favorable amount of the additive is taken at 0,8-1,2%, with a limit of 1%. Therefore, ultradispers diamond-graphite admixture of Litol-24 oil to serial 1% was considered an efficient amount, and it was the specified amount of ultradispers diamond-graphite admixture that was used during further studies and application (graph 2).

Determination of the force of resistance to movement. The effect of serial litol-24 and modified Litol-24 oils with ultradipers diamond-graphite admixture on the resistance force of movement in the cushion has been investigated. The determination of the resistance force of various oil materials in the pad can be carried out by

different methods, and the characteristics of these materials can be analysed comparatively. In real conditions, the friction path turns out to be different depending on the composition and quality of the oil. Of these, less oil with less friction and more suturing is considered to be of better quality and suitable for the purpose. To test these considerations, a comparison was carried out, determining the appropriate time spent on the path travelled by falling from the same height of the same pad lubricated with 1% ultradispers diamond-graphite additive Litol-24 oil and only serial Litol-24 oil.

Investigation of the effect of Litol-24 and ultradispers diamond-graphite additive Litol-24 oil on resistance force to action. As mentioned, the smallest value of the resistive strength of calm when the ultradispers diamond-graphite additive used was added in different quantities to Litol-24 oil of the series in different variants was obtained in the amount of 1% of the additive. One of the important issues is the determination of the effect of the new additive material on the force of resistance to movement during the operation of the pad. Thus, the ingress of food on the pads occurs mainly during their movement, and this not only negatively affects fatigue, reduced reliability and longevity of the pad, but also directly affects the energy expenditure on the friction processocess.

To study the listed issues, test experiments in various variants were laid on the experimental installation. To achieve the goal, the test device is placed high, or the device is placed on the ground and its rope is suspended from the block in a high place, swinging the hook down. In accordance with the research methodology, a load weighing $G=1kg$ from a height h is released to the ground from a height h in different versions and the fall time is recorded with a stopwatch. It is clear that when a load weighing G, falling from a height of h, begins to move, its initial speed is $V_0=0$. The time of its fall from the same height will be a lot when the resistance to movement on the pad is very high, and little when it is low. The speed of the time to reach the ground after overcoming the height will be $gt^2/2$, depending on the free-fall momentum. Therefore, according to the classical law of mechanics, if we determine the fall time for

each case and compare them, we will determine how different the resistance force should be compared to ultradisperse diamond-graphite+Litol-24 oil and serial Litol-24 oil for individual variators. Thus, in experiments of different types of oiled pad with the same mass load (*1kg*), the results of determining the time of falling from a height of *3,6 m* on an experimental installation are presented in table 1

Table 1

Times of falling from a height of 3.6 m of a load suspended from a rope of an experimental pad with different types of lubrication, sec.

	Pad lubrication material	1 kg mass drop time / repetitions					Total	t_1; t_2; t_3 average	t_1/t_2 average	t_2/t_3 average
		1	2	3	4	5				
t_1	Low oil	18,6	20,0	20,0	18,8	20,8	98,2	19,64	-	-
t_2	Litol-24	15,0	14,5	15,6	15,5	14,8	75,4	15,08	1,30	
t_3	Litol-24 +1% ultra dispers almaz-graffiti	11,5	11,2	11,5	11,0	11,6	56,8	11,36	-	1,33

As can be seen from table 1, in the rolling pad lubricated with ultradisperse diamond-graphite doped oil Litol-24+1%, the load drop time, the corresponding friction coefficient, and the force of resistance to movement are Litol-24 oil times or 1.33% than in the pad lubricated with serial 33 less, i.e.:

$$\frac{15,08}{11,36} = 1,33$$

This effect, that is, a 33% reduction in the force of resistance to movement in the pad lubricated with modified oil, not only allows to increase the longevity and reliability of the pads, but also reduces the energy consumption per unit operation and improves the efficiency of the pad.

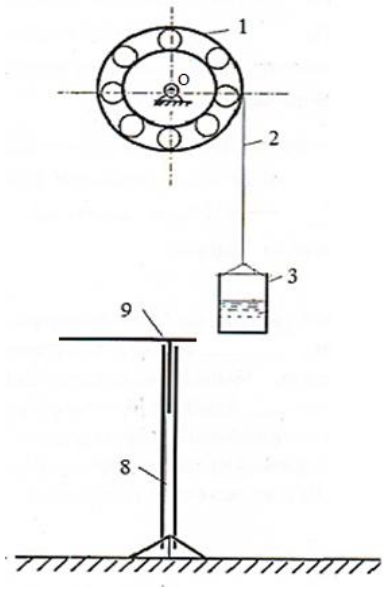


Figure 2. Scheme for determining the time of falling the load hanging on pads lubricated with various oil

Thus, it was established that the addition of ultradispersed diamond-graphite admixture to Litol-24 oil increases the antifriction properties of plastic oils, reduces the friction resistance force and the corresponding friction coefficient by 1.33 times. This effect creates the basis for improving the working capacity, reliability and longevity of rolling pads.

Determination of the tolerance of pads to be eaten. The method of resource testing and comparison was used to determine the endurance of the pads to be eaten. For this purpose, in the pressure processing and dyeing shop of Azeraluminum LLC, real operation tests were carried out on the 3616 brand pads used in the technological line for the production of aluminum sheets. 10 pairs of rolling pads are lubricated with Litol-24+1% ultradispers diamond-graphite doped oil (each pad in the same amount - 10g).

The working pads in the workshop were removed from the shaft on which they were sitting, washed, cleaned and dried, and then each of them was scraped on an electronic scale. The pads were lubricated with the rule according to the instructions and placed in their places. After 200 hours of operation, the pads were again removed from their shafts, washed and dried and each weighed on an electronic scale. Then the shafts, laid in their places. The amount of food eaten in the pads was determined and compared by the weight method. Each time the pads were removed, washed, dried and weighed, the pads were diagnosed and their current position was determined. No noticeable change was observed in the pads subjected to resource tests. The running surfaces of the pads have been in normal condition.

In the tests of Litol 24 oil of pads lubricated with serial -10 pairs, the previous dry weight G_1 and post-test dry weight G_1', the pre-test dry weight G_2 and post-test weight G_2' of lubricated with Litol-24 oil+2% pads ultradispers diamond-graphite doped oil were indicated. When such:

G_1 - G_1'- total wear on the pad lubricated with serial oil, gr;

G_1 - $G_1'/n = G_1$ - $G_1'/20$ - average eating of a pad, gr / pad;

G_2-G_2 '- available grease+1% ultradispers diamond-graphite admixture oil-lubricated overall wear on pads, gr;

G_2 - $G_2'/n = G_2$ - $G_2'/20$ - available grease+1% ultradispers diamond-graphite additive grease in a lubricated pad, gr /pad.

Therefore:

G_1 - G_1'/G_2 - G_2' the ratio will show how many times less wear on pads lubricated with ultradispers diamond-graphite-doped oil compared to serial oil.

As can be seen from Table 2, after 200 hours of resource testing in series oil-lubricated oil, the average consumption was 0.034 G, while in ultradisperse additive oil it was only 0.015 *G*. More precisely, compared to the existing oil-lubricated pads (base variant), the ingestion of modified oil-lubricated pads was 2.26 times less. This effect lays the foundation for a correspondingly 2.26-fold increase in the reliability and longevity of the pads.

Table 2

The amount of food in the lubrication of 3616 pairs of rolling pads of 10 brands with different oil

Various oil-lubricated pad options	Initial average weight of pads, G_1, G_2, q	Weight of pads after 200 hours of operation, G_1', G_2' q	The wear parameter, G_1- G_1' G_2- G_2', q	The ratio of differences G_1- G_1' / G_2- G_2'
Basic-G_1-available Litol-24	5058	5024	0,034	$\frac{0,034}{0,015}$ = 2,26
New-G_2- Lithol-24+1% ultrafine diamond graphite	5058	5043	0,015	

Determination of economic efficiency. Production tests of the research results were carried out at the pressure processing and dyeing shop of Azeraluminum LLC on 10 pairs of traction rolling pads operating in heavy operating conditions on the technological line. In the flow line of the dyeing shop of aluminium sheets with a length of 500 meters and the number of pads more than 600, 10 pairs of series of pads lubricated with Litol-24 oil were registered as the **base variant** and 24 pairs of pads lubricated with litol-1+10% ultradisperse diamond-graphite additive as the new variant. Constant control over the operation of these pads in the technological line was carried out, the base and the new version were operated in real conditions. The energy consumption of the proposed option and the economic efficiency resulting from it are determined.

For this purpose, in accordance with the requirements of the inter-state standard for determining the economic efficiency of technical systems (ГОСТ 34393-2018), a comparison of the costs of the base version and the new version was carried out. It has been established that the annual economic efficiency of the application of the developed proposal for 24 pairs of rolling pads lubricated with ultradispers diamond-graphite doped Litol-10 oil is 711 AZN.

Technical and economic indicators of the application of the research results in production are presented in table 3.

Table 3

Technical and economic indicators of the application of research results

№	Indicators	Unit of measurement	Base variant, B_b	Experimental variant, B_y
1.	Annual production volume	ton	5211	5211
2.	Productivity	ton/hour	3,375	3,375
3.	Number of shifts per day	say	1	1
4.	Duration of the shift	hour	8	8
5.	Electricity spent on painting a ton of aluminum sheets	kvt/hour	217,6	131,21
6	Annual operating costs	AZN	5635,85	4923,84
7	Annual expenses	AZN	5855,45	5144,44
8	Annual economic benefits	AZN	-	711

Results

1. Research and analysis of literature and scientific papers on improving the reliability and durability of bearing assemblies has shown that there is sufficient technical, technological, and constructive potential to enhance the performance, reliability, and durability of bearings. However, due to the lack of scientifically proven and effective lubricants and rational lubrication methods that guarantee these attributes in harsh operating conditions, it has not been possible to fully guarantee the quality of bearings. Bearing failure occurs prematurely, resulting in significant losses.

2. A study on the causes of failures of various types of bearings, including rolling bearings that commonly fail during operation in different conditions in industrial environments, has revealed that the use of traditional plastic lubricants primarily reduces contact stresses within them. However, this alone is not sufficient to ensure the reliable operation and longevity of bearings throughout

their lifespan. It has been determined that in order to significantly enhance the performance, reliability, and durability of bearings, lubricants must provide not only reduced contact stresses but also improved surface polishing and friction strength.

3. It has been determined that the fulfillment of these requirements can be achieved by adding ultrafine diamond graphite fillers to traditional oils. The addition of different amounts of fillers has different effects on the performance of the oil. Therefore, determining an effective additive for serial oil, its optimal amount, and operating parameters is an urgent scientific and technical challenge, which is the goal of this research project.

4. The quality of lubrication in bearings was investigated by adding different amounts of an ultrafine diamond graphite additive to Litol-24 oil, which is widely used in bearings at the moment. For this purpose, we determined the force of static resistance and resistance to movement on an experimental setup developed for this task.

5. It has been found that as the amount of ultrafine additive in oil increases, the static resistance force initially decreases, reaches a minimum value at 1%, and then increases again. Therefore, the optimal amount is the addition of 1% of Litol-24 ultrafine diamond graphite additive to the mass of the base oil. During further research and implementation into production, this amount of ultrafine graphite additive was used and recommended for use in production processes.

6. It has been found that when 1% of ultrafine diamond graphite is added to the existing Litol-24 oil, the static resistance decreases by 1.5-2 times or more and the resistance to movement decreases by 1.33 times compared to the standard oil. In addition to positively affecting bearing performance and other indicators, this effect also leads to a corresponding reduction in energy consumption per unit of work during operation.

7. Experiments have shown that the wear rate of bearings lubricated with Litol-24 oil + 1% ultrafine diamond graphite additive is 2.26 times lower than that of bearings lubricated with standard Litol-24 oil. This has allowed for a proportional increase in the reliability and durability of the bearings.

8. Practical research results: In the workshop for pressure treatment and painting at Azeraluminum LLC, 10 pairs of traction roller bearings were tested under severe operating conditions using Litol-24 + 1% ultrafine diamond graphite oil additive. Based on the positive results, it was planned to implement this solution in production. The expected technical and economic benefits amounted to 711 manats per 10 bearing pairs.

9. The findings were accepted by Azeraluminum management, and it was decided to implement the proposed technological and technical developments in other departments of the company.

The main content of the dissertation is published in the following scientific papers:

1. Gojaev, T.B., Guliyev, S.S. A study of dispersion depending on the forces affecting the durability of roller bearings //- Ganja: Ganja Branch of the National Academy of Sciences of Azerbaijan-2018. № 2(72), - pp. 221-225.
2. Guliyev, S.S. Methodology for calculating reliability and durability of roller bearings, reasons for failure structure and calculation criteria //- Ganja: Ganja Branch of the National Academy of Sciences of Azerbaijan-2018. № 4 (74), - pp. 247-251.
3. Gojaev, T.B., Guliyev, S.S. Research and report on the probability factors of roller bearings // - Baku, Azerbaijan University of Architecture and Construction, Theoretical and Applied Mechanics - 2018. № 1-2, - pp. 77-80.
4. Gojaev, T.B., Guliyev, S.S. Development of mathematical models for evaluation the working condition of roller bearings // - Ganja: Azerbaijan Technological University, Collection of scientific news - 2018. № 2(25), - pp. 77-83.
5. Guliyev, S.S. The main provisions of the theory of calculation of roller bearings and ways to meet the working conditions // - Ganja. Scientific papers of the Azerbaijan State Agrarian University, 2018, No. 1, pp. 111-115.
6. Guliyev, S.S. A study of the probabilistic and statistical model of uninterrupted operation of roller bearings // Baku, Azerbaijan University of Architecture and Construction, Theoretical and Applied Mechanics, 2018, No. 1-2, pp. 45-50.
7. Gojaev, T.B., Guliyev, S.S. Investigation of friction forces occurring in bearings // Ganja. Scientific Papers of the Azerbaijan State Agrarian University -2018. No. 1, pp. 79-83.
8. Baghirov, B.M., Guliyev, S.S. Analysis of rolling bearing lubrica-tion methods//-Ganja:Azerbaijan Technological University, Mate-rials of the international scientific and practical conference on "The main problems of university rating issues",

dedicated to the 98th anniversary of the birth of national leader Haydar Aliyev, part II - 2021. No. 2, pp. 58-60.
9. Guliyev, S.S. Probabilistic and statistical models of the durability of rolling bearings//-Ganja:Ganja branch of the National Academy of Sciences of Azerbaijan - 2021. № 4(83), - pp. 102-105.
10. Guliyev, S.S. An assessment of rolling hills operating conditions //-Chernihiv Polytechnic University, Technical Sciences and technologies. Chernihiv - 2021, № 4(26), - pp. 50-57.
11. Guliyev, S.S. Working capacity of rolling pads and reliability investigation. Bulletin of the priazovsky State Technical University. Collection of scientific papers, Mariupol - 2021, No. 43, pp. 93-102.
12. Guliyev, S.S. Research of the operational characteristics of roller bearings//-Scientific Research Center "Mashinostroenie"–Machi-nes, Aggregates and Processes. Design, creation and moderni-zation. Materials of the international scientific and practical conference. Saint Petersburg, 2022, No. 5, pp. 11-13.
13. Guliyev, S.S. Assessment of rolling pills operating conditions in Azeraluminum OJSC // "Current issues of modern science and education". Collection of articles of the XVI International Scientific and Practical Conference. Penza - 2022, pp. 67-69.
14. Guliyev, S.S. Determination of the current-carrying capacity and reliability of rolling bearings // - Baku, Azerbaijan University of Architecture and Construction, Engineering Mechanics - 2022, No. 1-2, pp. 31-36.
15. Guliyev, S.S. Investigation of the calculation of contact stresses in rolling bearings // - Ganja: Azerbaijan Technological University, Proceedings of the International Scientific and practical confer-ence "Design, technology and innovations in the textile and light industry", dedicated to the 99th anniversary of the birth of national leader Haydar Aliyev, Part I. Ganja - 2022, pp. 225-226.
16. Guliyev, S.S., Baghirov, B.M. Determination of the effective amount of oils with ultrafine additives in rolling bearings // -

Ganja: Azerbaijan Technological University, Collection of Scientific News - 2022, No. 4/41, pp. 9-16.
17. Guliyev, S.S., Baghirov, B.M. Determination of probabilistic and statistical assessment of bearing reliability // - Baku: Azerbaijan Technical University. Republican Scientific and Technical confer-ence of students and young researchers on the theme "Youth and scientific innovations", dedicated to the 99th anniversary of the birth of the national leader of the Azerbaijani people Haydar Aliyev. Part I - 2022, pp. 718-720.
18. Guliyev, S.S., Baghirov, B.M. Investigation of the effect of various temperature conditions on the force of static resistance in a rolling bearing lubricated with an ultrafine diamond graphite additive Litol-24//-Baku: Azerbaijan Technical University. Vll Republican Scientific and Technical Conference of students and young researchers on the topic "Advanced technologies and innova-tions", dedicated to the 100th anniversary of the birth of national leader Haydar Aliyev. Part I -2023, pp. 1076-1079
19. Baghirov, B.M., Guliev, S.S. Substantiation of a new test device and test procedure for determining the quality of oil material in bearings // Azerbaijan Technological University, International Scientific and Practical Conference on the topic "The Fourth Industrial Revolution and Innovative Technologies", dedicated to the 100th anniversary of the birth of national leader Haydar Aliyev, Part II. Ganja, 2023, pp. 411-413.
20. Guliyev, S.S., Baghirov, B.M. Prospects of using ultrafine dia-mond graphite additives to oil to improve the quality of lubrication of rolling bearings in mechanical engineering //-Ganja: Azerbaijan Technological University, Scientific News Collection - 2023, No. 3/44, pp. 90-96.
21. Guliyev, S.S., Baghirov, B.M. Investigation of the operation of a rolling bearing with an ultrafine diamond graphite lubricating groove Litol-24 oil// Publisher agency: Proceedings of the 3rd International Scientific Conference «Foundations and Trends in Modern Learning» Berlin, Germany - 2023, № 3, pp 155-158 .

22. Guliyev, S.S., Baghırov, B.M. Study of the influence of Litol -24 + oil with ultra-fine diamond graphite advantage on the wear intensity of rolling bearings // Danish Scientific Journal, Danimarka -2023, № 75, pp. 23-27.
23. Baghirov, B.M., Guliyev, S.S. A new device for determining the strength of static resistance and the coefficient of static resistance in pads // Azerbaijan Technological University, International Scientific and Practical Conference on the topic "Current state and prospects of development of science and technology in the era of the Fourth Industrial Revolution", dedicated to the 101st anniver-sary of the birth of the national Leader Haydar Aliyev, part II. Ganja – 2024, pp. 114-116.
24. Guliyev, S.S., Baghirov, B.M., Rzayeva, R.A., Aliyev, S.H., Ver-diyev, B.Z., Askarova, A.A., Hasanova, K.R., Taghiyev, U.T. Determination and justification of the optimal amount of ultrafine diamond graphite additive in litol-24 oil in rolling bearings// EUREKA: Physics and Engineering – 2025, № 3 (58), p 113-129.

Personal work of the applicant on the works performed with co-authors:

- [5, 6, 9, 10, 11, 12, 13, 14, 15] - the works were done by the applicant himself.

- [1-4, 7, 8, 16-24] - The solution of the problem and the conduct of experimental research was carried out by the applicant, and the formulation of the problem and the processing of the results obtained during the research was done jointly with co-authors.

The defense of the dissertation will be held on «03» October 2025, at «14^{00}» at the meeting of the Dissertation council ED 2.02 of under the Azerbaijan State Oil Industry University PLI.

Adress: Az 1010, the Republic of Azerbaijan, Baku city, 20, Azadlig avenue.

Dissertation is accessible at the Azerbaijan State Oil Industry University library.

Electronic versions of the dissertation and its abstract are avaialable on the official website of the Azerbaijan State Oil Industry University

Abstract was sent to the required addresses on 06 august 2025.

Signed for printing: 13.06.2025
Paper format: (60x84) 1\6
Volume:37961 characters
Number of hard copies: 100