

MODERN APPROACH TO CONDUCTING COMPREHENSIVE TESTING OF LUBRICATING MATERIALS FOR FRICTION UNITS OPERATING IN SERVICE CONDITIONS

Dmytrychenko M.F., doctor of technical science, National Transport University, Kyiv, Ukraine, dmitrichenko@ntu.edu.ua, orcid.org/0000-0003-4223-1838

Milanenko O.A., doctor of technical science, National Transport University, Kyiv, Ukraine, milanmasla@gmail.com, orcid.org/0000-0002-8197-5277

Bilyakovich O.N., associate professor State non-commercial company State university «Kyiv aviation institute», Kyiv, Ukraine, oleg65@voliacable.com, orcid.org/0000-0002-2423-2346

Bobro A.M., National Transport University, Kyiv, Ukraine, stormshadow0117@gmail.com, orcid.org/0009-0002-1193-117X

СУЧАСНИЙ ПІДХІД ЩОДО ПРОВЕДЕННЯ КОМПЛЕКСНИХ ВИПРОБУВАНЬ МАСТИЛЬНИХ МАТЕРІАЛІВ ДЛЯ ВУЗЛІВ ТЕРТЯ, ЩО ПРАЦЮЮТЬ В УМОВАХ ЕКСПЛУАТАЦІЇ

Дмитриченко М.Ф., доктор технічних наук, Національний транспортний університет, Київ, Україна, dmitrichenko@ntu.edu.ua, orcid.org/0000-0003-4223-1838

Міланенко О.А., доктор технічних наук, Національний транспортний університет, Київ, Україна, milanmasla@gmail.com, orcid.org/0000-0002-8197-5277

Білякович О.М., кандидат технічних наук, Державне некомерційне підприємство «Державний університет «Київський авіаційний інститут», Київ, Україна, oleg65@voliacable.com, orcid.org/0000-0002-2423-2346

Бобро А.М., Національний транспортний університет, Київ, Україна, stormshadow0117@gmail.com, orcid.org/0009-0002-1193-117X

Analysis of the latest research and publications.

Existing comprehensive studies on the wear resistance and lubrication efficiency (lubricity) of friction units establish the influence of external factors (load, speed, contact kinematics, temperature, etc.) on the durability and operational reliability of both the lubricant and the metal of the contacting surfaces.

Much of the complex experimental research concerns the influence of external factors on the wear resistance of metal surfaces and the efficiency of lubrication of friction units. The results of tribotechnical, rheological, and physicochemical studies are of great importance in the design, manufacture, and operation of machines and the creation of modern lubricant compositions [1, 2].

To obtain reliable test results of lubricants and materials of metal surfaces, reproduction and similarity of results during repeated experiments, a clear structure of the concept of complex design and experimental studies is required, which should contain the following components [3]:

- 1) availability of experimental facilities for conducting the research (scheme and design of the facility);
- 2) selection of research objects (microhardness, mechanical properties, contact shape and roughness of metal friction surfaces, physical, chemical and rheological properties of the lubricant);
- 3) conditions of the study (nature of the load, kinematic and temperature factors);
- 4) mathematical and statistical methods for processing the results of an experimental study.

Outline of unresolved issues.

Since Ukraine's Independence Day, there has been no sectoral technical regulation on the requirements and circulation of lubricants in our country. In European countries and the United States of America, such a document is the main one regulating the requirements for lubricants that are put into circulation and made available on the market within the country in order to ensure energy efficiency, national security, protection of human, animal and plant life and health, environmental protection and natural resources, preservation and protection of property and prevention of business practices that mislead consumers.

The requirements for lubricants (motor, transmission, universal oils) used in vehicles are still regulated either by Soviet standards or by the manufacturer's internal technical specifications. However, the main

technical problem is that the current assessment methods used in qualification tests are 90% based on Soviet standards, which have long been out of step with modern requirements for lubricants.

Only recently, the Working Group has been established to develop a draft Technical Regulation on the requirements for vehicle oils [4].

The first draft was developed taking into account the requirements of Regulation CLP (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on the classification, labelling and packaging of chemicals and mixtures, Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste (Waste Framework Directive). However, regarding the requirements for lubricants, there are certain technical problems associated with the lack of an adequate methodology for assessing tribotechnical, physicochemical and rheological properties that meet international and European standards (ISO, ASTM, DIN) in terms of quality indicators in real operating conditions.

From the point of view of energy efficiency and national security, at strategic enterprises of the oil and gas, thermal power and aerospace complexes, in the production of high-speed transport, agricultural and military hybrid equipment, predicting the lubrication efficiency and wear resistance of friction pairs, especially for friction units operating under extreme conditions, is a necessary direction to improve reliability and extend the service life in a wide range of changes in contact loads, speeds, temperatures, impact of lubricant.

Setting the task.

For operating conditions, an important factor is the extreme friction conditions, which are proposed to be investigated using contact-mechanical, rheological and physicochemical aspects for a wide range of assemblies: non-conformal friction units with a changed actual form of local contact (units with point friction contact, which are typical for various bearing friction units and units with linear friction contact, which are typical for gears and some parts of an internal combustion engine); conformal friction units (having a complete contact of surfaces under sliding friction conditions, for example, between the upper compression ring and the inner wall of the cylinder liner of an internal combustion engine).

The corresponding extreme friction conditions (i.e., in real operating conditions) for non-conformal and conformal assemblies will occur in case of insufficient lubrication (lubrication starvation), when the lubricant does not regularly enter the contact zone due to several reasons: 1) non-stationary friction conditions in the «stop-and-go» mode; 2) loss of mechanical stability of the lubricant due to the manifestation of non-Newtonian properties at high shear rates under low-temperature start-up conditions (rheological aspect); 3) insufficient structural adaptability of the modified layers under conditions of boundary friction at high loads in the contact zone (physicochemical aspect).

The characteristic friction conditions lead to the generation of contact stresses in the subsurface contact zone, especially for assemblies with a point and linear contact form. The corresponding stresses will cause deformation processes as a result of repeated microplastic shear in the zone of discrete contact areas along the tops of friction surface micro-irregularities, which generally characterize the stress-strain state of friction contact surfaces (contact-mechanical aspect).

Thus, increasing the lubrication efficiency and wear resistance of friction units under extreme friction conditions should be considered from the point of view of preventing contact fracture to prevent crumbling (pitting) for bearing friction units as a result of repeated microplastic shear and to counteract scoring for internal combustion engine units in the zone of discrete contact areas along the tops of the micro-irregularities.

For internal combustion engine components, extreme operating conditions are significantly related to unsteady friction conditions and the temperature factor of the local contact zone, especially for low-temperature starting conditions. Unsteady-state operating conditions with frequent start-stops during low-temperature starting of an internal combustion engine often lead to insufficient lubrication (lubrication starvation) in the contact zone due to the following reasons: firstly, there is not enough lubricant in the contact zone to form a lubricant layer of optimal thickness, secondly, due to non-Newtonian behavior, the lubricant layers do not have time to relax and acquire a stable structural viscosity (rheological aspect) and thirdly, to have the necessary structural adaptability of the newly formed modified layers during engine warm-up after a low-temperature start (physicochemical aspect), which ultimately leads to the appearance of scoring in the area of discrete areas of frictional contact along the tops of micro-irregularities of friction surfaces (contact-mechanical aspect).

For extreme conditions of operation of conformal friction units of an internal combustion engine under sliding friction, an important factor is the temperature factor, namely, it is important to compare the average local temperature in the friction contact zone and the critical local temperature, which will characterize the

thermomechanical stability under conditions of plastic-deformed contact in the boundary lubrication mode, which may occur, for example, in the zone of the upper dead center along the stroke of the internal combustion engine piston. Determination of the average local temperature is achieved by correlating the temperature of the oil volume temperature and the local temperature in the friction contact zone. The excess of the average temperature in the contact zone over the critical temperature gives the necessary grounds for modifying the qualitative and quantitative physicochemical composition of lubricants order to increase thermomechanical stability to ensure the structural adaptability of the newly formed modified layers to extreme friction conditions.

The necessary information about the nature of many phenomena in lubrication can be obtained only by applying a fundamentally new and modern approach to the effective creation (modification) of a lubricant for specific operating conditions and lubrication mode, establishing the optimal range of operation of friction units for modified lubricants. This is achieved by choosing an effective concept for conducting comprehensive experimental (qualification) tests, using the necessary modern and automated equipment, applying modern methods of mathematical processing of research results and implementing the results of experimental studies during bench and operational (field) tests on original equipment and machines at lubricant manufacturers and friction unit operators.

As part of this work, we propose a modern scientific and applied approach to the comprehensive evaluation of lubricants and the introduction of a new concept of comprehensive tests to improve the lubrication efficiency and wear resistance of friction pairs, which maximally approximate the conditions of qualification (experimental) studies to the real friction conditions of vehicle components in operation.

Presentation of the main material.

In Figure 1 schematically presents the proposed general concept of comprehensive testing of lubricants to improve the lubrication efficiency and wear resistance of conformal and non-conformal components (friction bearing units and internal combustion engine components) operating under extreme operating conditions, covering the full life cycle of the lubricant from the manufacture of mixtures, to the development and implementation of modified oils and to the end of the life of the used oil at operating enterprises. If the results of bench or operational tests do not show the expected positive results, the input physical and chemical parameters of the lubricants are adjusted, and all qualification tests and data processing are repeated until positive results are obtained in operational tests.

The corresponding concept provides a scheme of complex experimental and calculation studies of the mechanical properties of friction contact, contact shape, physical (rheological) properties of lubricants, thickness of the modified layer, qualitative and quantitative chemical composition of active components in the lubricants, structural adaptability and wear characteristics of the modified layers.

According to Fig. 1:

Block A – substantiation and establishment of input parameters of the physical and chemical composition of lubricating media for friction bearing units and internal combustion engine units;

Block B – justification and establishment of output parameters of the physical and chemical composition of lubricants for friction bearing units and internal combustion engine units;

Block C – processing the results of experimental and computational studies to build mathematical models for assessing the stress-strain state of the friction contact, the thickness of the lubricant layer and the wear rate of friction pairs, taking into account the shape of the contact, mechanical properties of materials, rheological properties (type) of lubricants and local temperatures in the friction contact zone of friction bearing assemblies and ICE units;

Block D – introduction of modified oils for friction bearings and internal combustion engine units;

Block E – bench and operational testing of modified oils for friction bearing units and internal combustion engine units at operating companies.

Establishing the relationship between external influences on a tribotechnical system and changes occurring in the friction contact zone is the main goal of experimental research. Expanding the range of load, speed and temperature parameters for specific operating conditions requires the development of comprehensive universal methods and express methods for assessing the performance of a friction unit in relation to various operating conditions.

Means of implementing a modern concept.

1. Stand for optical interferometric studies of the actual contact shape and lubricant layer thickness for bearing assemblies friction in the contact-mechanical aspect.

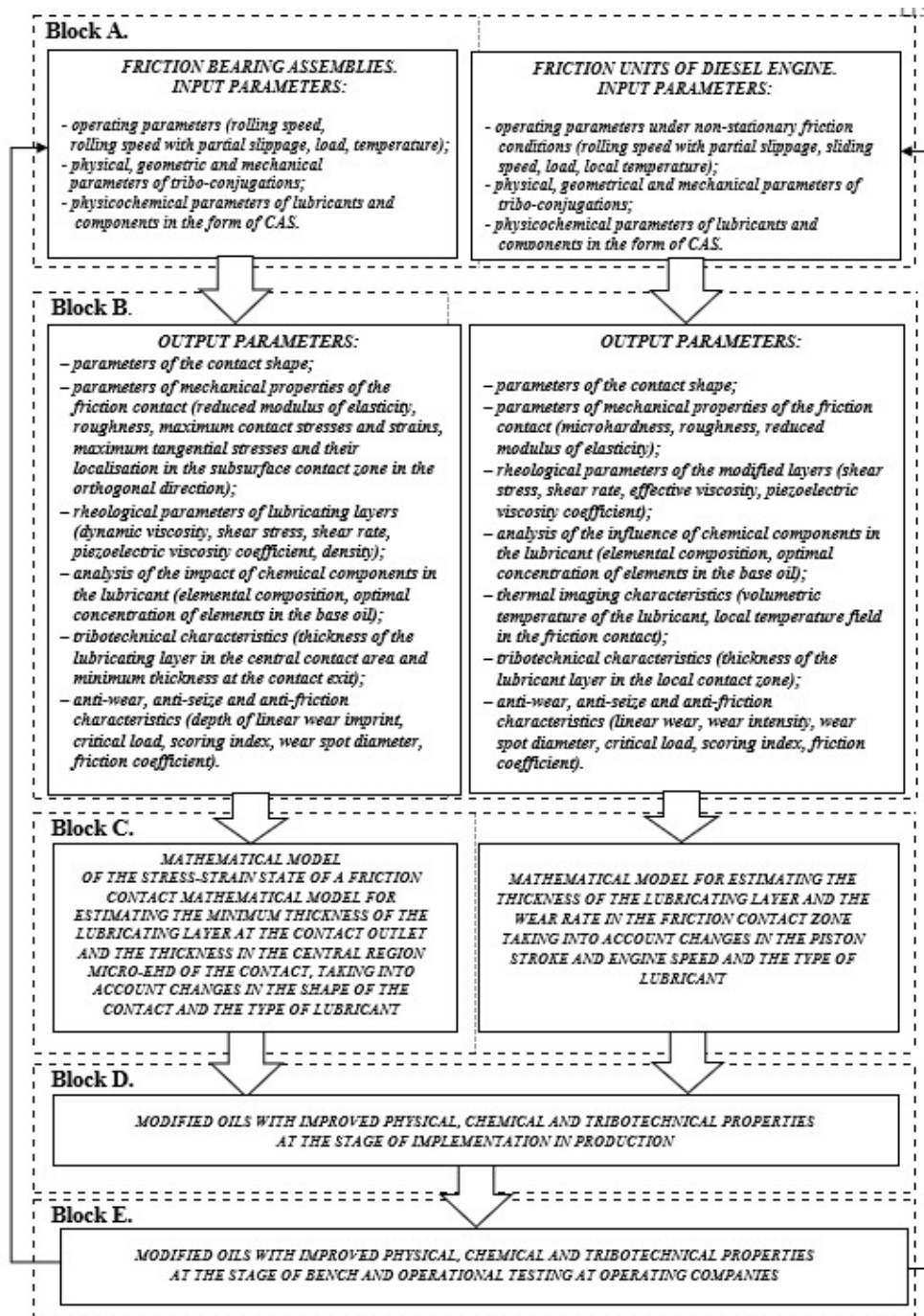


Figure 1 – The general concept of comprehensive testing of lubricants to improve lubrication efficiency and wear resistance of friction units in operation

In order to conduct experimental studies of micro-EHD lubrication in friction bearings, a stand can be used to measure the actual contact shape and thickness of the lubricant layer by optical interferometry, taking into account the pattern of lubricant supply and distribution using photo and video recording equipment.

The methodology for conducting optical interferometric studies and calibrating the necessary parameters to determine the actual thickness of the lubricating layer is described in detail in monograph [5].

The general view and schematic diagram of the stand simulating conditions similar to those that occur on the surfaces in point contacts of various friction bearing assemblies (radial, thrust, angular contact ball bearings with an outer ring or plate, tubular roller bearings, etc.) are shown in Fig. 2.

The tribotechnical contacting pair of indenter with counterbody is: steel ball – glass disc for circular contact (Fig. 3, *a*); steel ball – glass ring for elliptical contact (Fig. 3, *b*).

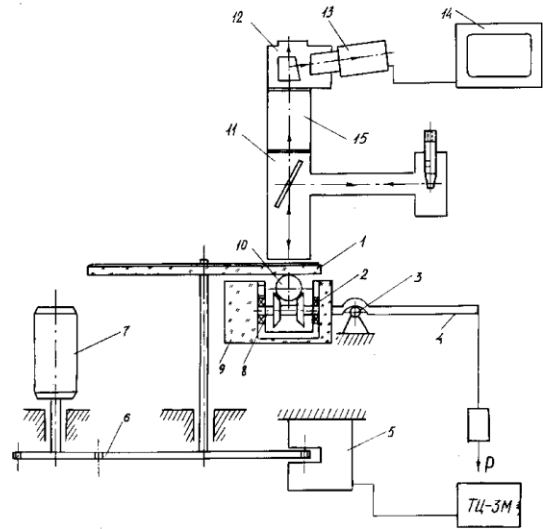


Figure 2 – General view and schematic diagram optical interferometric research stand



a



b

Figure 3, *a, b* – The contacting tribopair of the indenter and the counterbody in point contact:
a – circular contact ($\beta = 1$); *b* – elliptical contact ($\beta = 8$)

The bench thus allows for the study of the actual contact shape and lubricant layer thickness for the circular friction contact, which is typical for thrust ball bearings with self-aligning outer plates, and for the elliptical friction contact, which is typical for a wide range of ball and some roller bearings with an outer ring.

2. Evaluation of lubricating media from the rheological point of view for friction bearing units.

The main rheological characteristic of a lubricant is its dynamic viscosity (η), which is a measure of resistance to fluid flow or deformation. The dynamic viscosity of an oil (η) at temperature (t) is calculated based on the kinematic viscosity using the formula:

$$\eta = \nu \cdot \rho, \quad (1)$$

where ν – the kinematic viscosity, mm^2/s .

ρ – the density of the oil at the same temperature at which the kinematic viscosity ν was determined, g/cm^3 .

From the point of view of the rheological characteristic (viscosity-pressure-temperature relationship) of the oils under study, a more universal definition of dynamic viscosity should be used, which is equally suitable for Newtonian and non-Newtonian oils. For this purpose, the dynamic viscosity is defined as the ratio of the shear stress (τ) to the shear rate gradient ($\dot{\gamma}$):

$$\eta_0 = \frac{\tau}{\gamma} \quad (2)$$

The dynamic viscosity (η_0) at atmospheric pressure and temperature at the contact inlet at high shear rate gradients is measured by a rotational viscometer (Fig. 4) using a coaxial-cylindrical measuring device (Fig. 5).



Figure 4 – General view of the rotational viscometer REOTEST 2.1

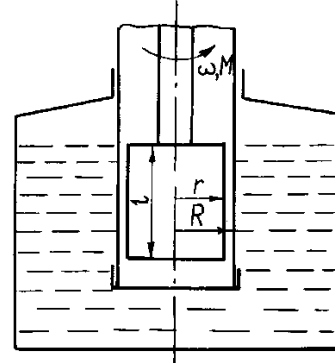


Figure 5 – Diagram of the coaxial-cylindrical system REOTEST 2.1

When determining dynamic viscosity, rotational viscometers have the advantage of measuring viscosity as a function of time at high shear rate gradients of up to $5 \cdot 10^6 \text{ s}^{-1}$ and determining the presence of elastic- viscosity hysteresis.

The shear stress (τ) and velocity gradient (γ) are determined according to the following relations:

Shear stress (τ)

$$\tau = \frac{M}{2 \cdot \pi \cdot l \cdot r^2}; \quad (3)$$

Shear rate gradient (γ):

$$\gamma = \frac{2 \cdot \omega \cdot R^2}{R^2 - r^2}; \quad (4)$$

3. A set of qualification tests to determine the tribotechnical properties of lubricants with different qualitative and quantitative chemical composition.

To carry out comprehensive experimental studies to establish the qualitative and quantitative chemical composition of lubricants and their effectiveness in terms of tribotechnical properties, it is proposed to conduct two-stage tests: at the first stage – rapid analysis of elemental chemical composition and concentration in the form of additives (friction modifiers, nanomodifiers) in a neutral base oil using an energy dispersive X-ray fluorescence spectrometer (EDXRFS) according to the European standard ASTM D7751 [6]; at the second stage – simultaneous assessment of anti-wear and antifriction properties using a tribometer from the Swiss company CSM Instruments according to the European standard ASTM G99 [7] with a high degree of accuracy of the results obtained according to the scheme shown in Fig. 6.

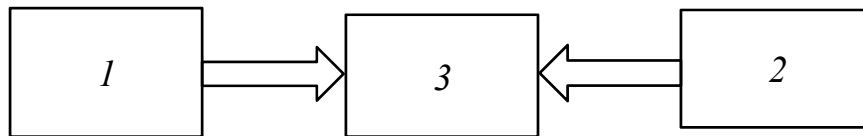


Figure 6 – Block diagram of complex two-stage experimental studies:
1 – USRFS; 2 – Tribometer; 3 – Unified software of the USFS and tribometer for PC

The EDXRFS spectrometer (Fig. 7) allows achieving the necessary flexibility and versatility in setting up the procedure for calculating the concentrations of elements in the range from sodium (atomic number 11) to uranium (atomic number 92) to record spectra for accurate assessment of the chemical composition of lubricants and the concentration of coolant components within 10 seconds.

With a resolution of up to 200 eV, the spectrometer enables you to identify chemical components and determine the optimum concentration with high accuracy thanks to its 4096-channel analogue-to-digital converter.

The spectrometer includes special software that allows you to build spectral lines of elemental composition and concentration in percent or *ppm* of the studied components of the CAS in lubricants.

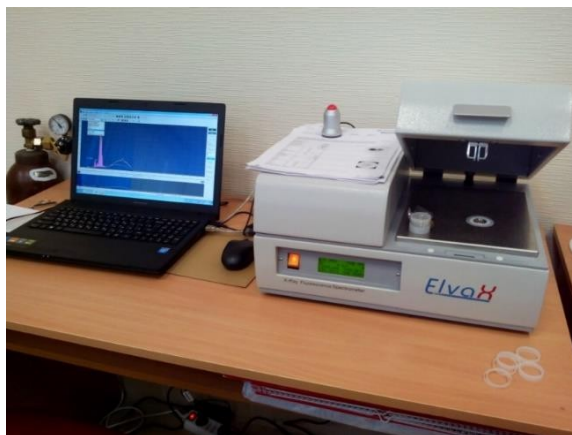


Figure 7 – General view of the spectrometer (EDRFS) and a PC with the appropriate software interface

To determine the effectiveness of the qualitative and quantitative composition of chemical components, it is advisable to simultaneously conduct tribotechnical studies to assess anti-wear and antifriction properties using a tribometer with a high degree of accuracy of the results obtained. Below is a general view of the tribometer and a schematic diagram of the test (Fig. 8).

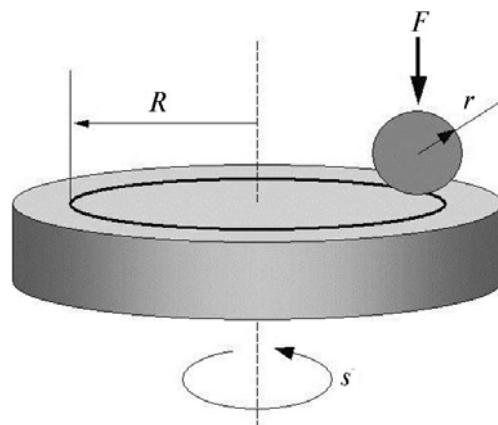
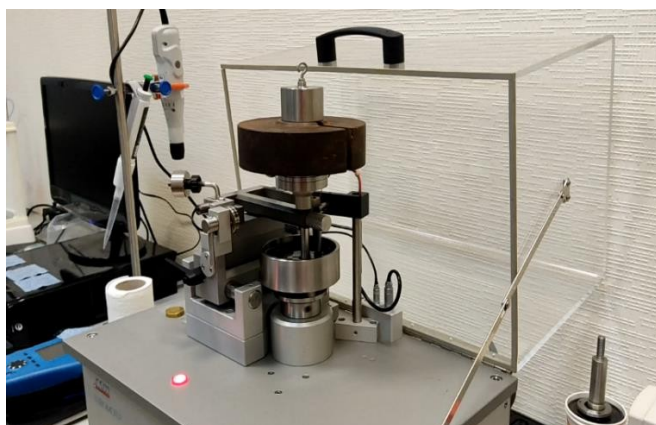


Figure 8 – General view of the tribometer with the corresponding PC and the test scheme

The principle of measuring the formation of a modified layer (if the value is above 0) or linear wear (if the value is below 0) and the friction force on the tribometer allows you to determine the thickness of the modified layer or the depth of the linear wear imprint H [nm] (anti-wear properties) of the counter body (ball) and the friction coefficient μ (antifriction properties) by the minimum deviation of the elastic lever in the vertical and horizontal directions, respectively, in real time (run), taking into account temperature changes, contact pressure, speed, moisture, and thus determine the optimal concentration of chemical components in the lubricant medium for improved anti-wear and antifriction properties.

4. Methodological support for testing of internal combustion engine components under non-stationary friction conditions.

The main principle of choosing a scheme for tribotechnical and rheological tests under non-stationary friction conditions is the maximum approximation to the actual operating conditions of the studied tribological couplings. To do this, it is necessary to ensure that the nature of the specimen movement, sliding values and speeds, as well as the materials of the friction pairs, which simulate the conditions of friction units in the so- called start-stop or stop-end-go modes, are consistent. When choosing a schematic diagram for studying the processes of friction and wear of moving joints in lubricants, it is necessary to take into

account the obtaining of a qualitative picture on the samples observed when implementing the conditions of intensive friction and wear in the parts of the cylinder-piston group of an internal combustion engine, namely when contacting the compression ring – the inner wall of the working cylinder with full contact of the contact surfaces under sliding friction (conformal units) or with a local contact zone under rolling friction with partial slippage (non-conformal units), where the relevant studies can be attributed to units with linear friction contacts operating in an internal combustion engine (for example, timing cams).

The selected research scheme (Figure. 9) allows taking into account such friction processes as the interaction of tribotechnical pair materials in the lubricant, changes in the contact shape, rheological changes in the lubricant, changes in the qualitative and quantitative chemical composition of components in the lubricant, and wear of moving joints in an automated mode on the universal automated friction test UAFT bench.

A block diagram and general view of the UAFT is shown in Fig. 9 i 10.

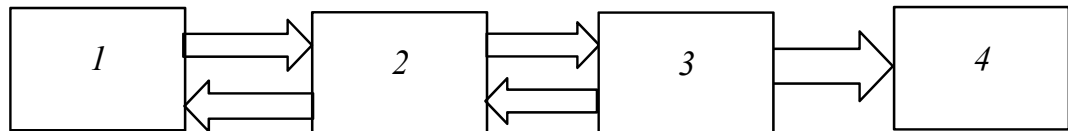


Figure 9 – Block diagram of the UAFT:

1 – Friction machine SMC-2; 2 – 4: Automated control unit with software (ACUS), which includes:
2 – Strain gauge unit; 3 – Analogue-to-digital converter (ADC); 4 – PC software



Figure 10 – General view of the UAFT

To investigate the relationship between the volumetric temperature of the oil under study, measured by a thermocouple, and the local temperature in the local contact zone, a thermal imaging method is used to measure the local temperature field under different modes of loading in the contact.

The thermal imaging method allows us to study the change in local temperatures of friction units in the contact zone and outside the contact zone using a modern portable thermal imager TESTO-875-2i at UAFT (Fig. 11).



Figure 11 – General view of the TESTO-875-2i portable thermal imager for UAFT

Conclusion.

A modern concept of comprehensive tests to improve the efficiency of lubrication and wear resistance of friction units operating under extreme friction conditions (in service) is proposed on the basis of comprehensive computational and experimental studies on contact mechanical, rheological, and physicochemical aspects.

The means of implementing complex tests that take into account: non-stationary friction conditions, the shape of the actual contact and friction kinematics, rheological properties of lubricating (modified) layers, local temperature in the friction contact zone, physical and chemical composition of components in the lubricant are determined.

REFERENCES

1. Myshkin M.K. Friction, lubrication, wear: Physical foundations and engineering applications of tribology / M.K. Myshkin, M.I. Petrokovets. – Fizmat. – 2007. – 370 p.
2. Fuchs I.G. Introduction to tribology / I. G. Fuchs, I.A. Buyanovsky. – Oil and gas, 1985. – 278 p.
3. Yevdokimov Yu.A. Planning and analysis of experiments on solving friction and wear problems / Yu. A. Yevdokimov, V.I. Kolesnikov, A.I. Teterin. – Naukova Dumka, 1980. – 227 p.
4. Order of the Ministry of Energy of Ukraine No. 331 dated 09/29/2022 in accordance with subparagraph 3 of paragraph 6 of the Regulation on the Ministry of Energy of Ukraine, approved by the resolution of the Cabinet of Ministers of Ukraine dated 06/17/2020 No. 507.
5. Dmitrichenko M.F. Lubricating effect of oils under elastohydrodynamic lubrication conditions: monograph / M.F. Dmitrichenko, O.A. Milanenko. – Kyiv: Ukravtodor, 2009 – 184 p.
6. ASTM D7751-16: Standard Test Method for Determination of Additive Elements in Lubricating Oils by EDXRF Analysis.
7. ASTM G99-17: Standard Test Method for Wear Testing with a Pin-on-Disk Apparatus.

ПЕРЕЛІК ПОСИЛАНЬ

1. Мишкін М.К. Тертя, змащення, зношування: Фізичні основи та інженерні застосування трибології / М.К. Мишкін, М.І. Петроковець. – Фізмат. – 2007. – 370 с.
2. Фукс І.Г. Вступ до трибології / І. Г. Фукс, І.А. Буяновський. – Нафта і газ, 1985. – 278 с.
3. Євдокимов Ю.А. Планування та аналіз експериментів з вирішення задач тертя та зношування / Ю.А. Євдокимов, В.І. Колесников, А.І. Тетерін. – Наукова думка, 1980. – 227 с.
4. Наказ Міністерства Енергетики України від 29.09.2022 № 331 відповідно до підпункту 3 пункту 6 Положення про Міністерство Енергетики України, затвердженого постановою Кабінету Міністрів України від 17.06.2020 № 507.
5. Дмитриченко М.Ф. Мазильна дія оливи в умовах еластогідродинамічного мащення: монографія / М.Ф. Дмитриченко, О.А. Міланенко. – К.: Укравтодор, 2009 – 184 с.
6. ASTM D7751-16: Стандартний метод випробування для визначення елементів присадок у мазильних оливах за допомогою аналізу EDXRF.
7. ASTM G99-17: Стандартний метод випробування на знос за допомогою пристрою Pin-on-Disk.

ABSTRACT

Dmytrychenko M.F., Milanenko O.A., Bilyakovich O.N., Bobro A.M. Modern approach to conducting comprehensive tests of lubricants for friction units operating under operating conditions. Visnyk National Transport University. Series «Technical sciences». Scientific, scientific and industrial journal. – K.: NTU, 2025. – Issue 1 (60).

The article is devoted to the proposed modern scientific and applied approach to the comprehensive assessment of lubricants and the introduction of a new concept of comprehensive tests to improve the efficiency of lubrication and wear resistance of friction pairs, which maximally approximate the conditions of qualification (experimental) studies to the real friction conditions of vehicle components in operation. This is achieved by choosing an effective concept for conducting comprehensive experimental (qualification) tests, using the necessary modern and automated equipment, applying modern methods of mathematical processing of research results and implementing the results of experimental studies during bench and operational (field) tests on original equipment and machines at enterprises producing lubricants and operators of friction units.

The means of implementing complex tests that consider: non-stationary friction conditions, the shape of the actual contact and friction kinematics, rheological properties of lubricating (modified) layers, local temperature in the friction contact zone, physical and chemical composition of components in the lubricant in terms of contact-mechanical, rheological and physical and chemical aspects are determined.

Thus, the general concept of comprehensive testing of lubricants to improve the lubrication efficiency and wear resistance of conformal and non-conformal units (friction bearing units and internal combustion engine units) operating under extreme operating conditions is presented, covering the full life cycle of the lubricant medium from the manufacture of mixtures, to the development and implementation of modified oils and to the final service life of used oil at operating enterprises. Relevant results of bench or operational tests, if they did not show the expected positive results, make it possible to adjust the input physical and chemical parameters of lubricants in accordance with the proposed concept scheme and achieve positive results of operational tests.

KEYWORDS: EXTREME FRICTION CONDITIONS, LUBRICANT, BEARING FRICTION UNIT, INTERNAL COMBUSTION ENGINE (ICE) UNITS, NON-CONFORMAL FRICTION UNITS, CONFORMAL FRICTION UNITS, MICROELASTOHYDRODYNAMIC (MICRO-EGD) LUBRICATION, LUBRICATING (MODIFIED) LAYER, CHEMICAL ACTIVE SUBSTANCES (CAS), STRESS-STRAIN STATE OF CONTACT FRICTION SURFACES, RHEOLOGICAL PROPERTIES OF LUBRICANTS, QUALITATIVE AND QUANTITATIVE PHYSICAL AND CHEMICAL COMPOSITION OF LUBRICANTS, FRICTIONAL CONTACT.

РЕФЕРАТ

Дмитриченко М.Ф. Сучасний підхід щодо проведення комплексних випробувань мастильних матеріалів для вузлів тертя, що працюють в умовах експлуатації / М.Ф. Дмитриченко, О.А. Міланенко, О.М. Білякович, А.М. Бобро // Вісник Національного транспортного університету. Серія «Технічні науки». Науковий, науково-виробничий журнал. – К.: НТУ, 2025. – Вип. 1 (60).

Стаття присвячена запропонованому сучасному науково-прикладному підходу щодо комплексної оцінки мастильних матеріалів та впровадження нової концепції комплексних випробувань для підвищення ефективності мащення і зносостійкості пар тертя, які максимально наближають умови кваліфікаційних (експериментальних) досліджень до реальних умов тертя вузлів транспортних засобів, що працюють в експлуатації. Це досягається вибором ефективної концепції проведення комплексних експериментальних (кваліфікаційних) випробувань, використання необхідного сучасного і автоматизованого обладнання, застосування сучасних методів математичної обробки результатів досліджень і впровадження результатів експериментальних досліджень при проведенні стендових і експлуатаційних (натурних) випробувань на оригінальному обладнанні та машинах на підприємствах-виробників мастильних матеріалів та експлуатантів вузлів тертя.

Визначені засоби реалізації комплексних випробувань, що враховують: нестаціонарні умови тертя, форму фактичного контакту та кінематику тертя, реологічні властивості мастильних (модифікованих) шарів, локальну температуру в зоні фрикційного контакту, фізико-хімічний склад компонентів в мастильному матеріалі за контактнo-механічними, реологічними та фізико-хімічними аспектами.

Таким чином, представлена загальна концепція комплексних випробувань мастильних матеріалів щодо підвищення ефективності мащення та зносостійкості конформних і неконформних вузлів (підшипникових вузлів тертя та вузлів ДВЗ), які працюють в екстремальних умовах роботи, охоплює повний життєвий цикл функціонування мастильного середовища від виготовлення сумішей, до розробки і впровадження модифікованих оливи і до кінцевого терміну експлуатації відпрацьованої оливи на підприємствах-експлуатантах. Відповідні результати стендових або експлуатаційних випробувань, якщо вони не показали очікуваних позитивних результатів, надає можливість скорегувати вхідні фізико-хімічні параметри мастильних середовищ згідно запропонованої схеми концепції, і досягати позитивних результатів експлуатаційних випробувань.

КЛЮЧОВІ СЛОВА: ЕКСТРЕМАЛЬНІ УМОВИ ТЕРТЯ, МАСТИЛЬНИЙ МАТЕРІАЛ, ПІДШИПНИКОВИЙ ВУЗОЛ ТЕРТЯ, ВУЗЛИ ДВИГУНА ВНУТРІШНЬОГО ЗГОРАННЯ (ДВЗ), НЕКОНФОРМНІ ВУЗЛИ ТЕРТЯ, КОНФОРМНІ ВУЗЛИ ТЕРТЯ, МІКРОЕЛАСТОГІДРОДИНАМІЧНЕ (МІКРО-ЕГД) МАЩЕННЯ, МАСТИЛЬНИЙ

(МОДИФІКОВАНИЙ) ШАР, ХІМІЧНО-АКТИВНІ РЕЧОВИНИ (ХАР), НАПРУЖЕНО-ДЕФОРМОВАНИЙ СТАН КОНТАКТНИХ ПОВЕРХОНЬ ТЕРТЯ, РЕОЛОГІЧНІ ВЛАСТИВОСТІ МАСТИЛЬНИХ МАТЕРІАЛІВ, ЯКІСНИЙ ТА КІЛЬКІСНИЙ ФІЗИКО-ХІМІЧНИЙ СКЛАД МАСТИЛЬНИХ МАТЕРІАЛІВ, ФРИКЦІЙНИЙ КОНТАКТ.

AUTHORS:

Dmytrychenko Nikolay F., Ph.D., Engineering (Dr.), National Transport University, professor department of Manufacturing repair and materialoved, e-mail: dmitrichenko@ntu.edu.ua, tel. (044)2808203, Ukraine, 01010, Kyiv, Omelyanovich Pavlenko str. 1, of. 318, orcid.org/0000-0003-4223-1838.

Milanenko Oleksandr A., Dr. Sc. (Eng.), National Transport University, associate Professor of Department of Manufacturing, Repair and Materials Science, e-mail: milanmasla@gmail.com, tel. (044)2801886, Ukraine, 01010, Kyiv, Omelyanovicha-Pavlenko str., of. 102, orcid.org/0000-0002-8197-5277.

Bilyakovych Oleg N., associate professor, State non-commercial company State university «Kyiv aviation institute», associate professor department of technologies of air-ports, e-mail: oleg65@voliacable.com, tel. (044)4067694, Ukraine, 03680, Kyiv, b. Cosmonaut of Komarova, 1, of. 1.409, orcid.org/0000-0002-2423-2346.

Bobro Andrii M., postgraduate, National Transport University, assistant of Department of Manufacturing, Repair and Materials Science, e-mail: stormshadow0117@gmail.com, tel. (044)2801886, Ukraine, 01010, Kyiv, Omelyanovicha-Pavlenko str., of. 102, orcid.org/0009-0002-1193-117X.

АВТОРИ:

Дмитриченко Микола Федорович, доктор технічних наук, професор, Національний транспортний університет, професор кафедри «Виробництво, ремонт та матеріалознавство», e-mail: dmitrichenko@ntu.edu.ua, тел. (044)2808203, Україна, 01010, м. Київ, вул. Омеляновича-Павленка, 1, к. 318, orcid.org/0000-0003-4223-1838.

Міланенко Олександр Анатолійович, доктор технічних наук, доцент, Національний транспортний університет, доцент кафедри «Виробництво, ремонт та матеріалознавство», e-mail: milanmasla@gmail.com, тел. (044) 2801886, Україна, 01010, м. Київ, вул. Омеляновича-Павленка, 1, к.102, orcid.org/0000-0002-8197-5277.

Білякович Олег Миколайович, кандидат технічних наук, професор, Державне некомерційне підприємство «Державний університет «Київський авіаційний інститут», професор кафедри «Технологій аеропортів», e-mail: oleg65@voliacable.com, тел. (044)4067694, Україна, 03680, м. Київ, просп. Космонавта Комарова, 1, к.1.409, orcid.org/0000-0002-2423-2346.

Бобро Андрій Михайлович, аспірант, Національний транспортний університет, асистент кафедри «Виробництво, ремонт та матеріалознавство», e-mail: stormshadow0117@gmail.com, тел. (044) 2801886, Україна, 01010, м. Київ, вул. Омеляновича-Павленка,1, к.102, orcid.org/0009-0002-1193-117X.

REVIEWERS:

Gutarevich Y.F. Engineering (Dr.), State non-commercial company State university «Kyiv aviation institute», professor department of motors and heating, Kyiv, Ukraine.

Tamargazin A.A., doctor of technical sciences, professor, head of the airport technology department of the faculty of aircraft of the State non-commercial company State university «Kyiv aviation institute».

РЕЦЕНЗЕНТИ:

Гутаревич Ю.Ф, доктор технічних наук, професор, Національний транспортний університет, професор кафедри двигунів і теплотехніки, Київ, Україна.

Тамаргазін О.А., доктор технічних наук, професор, завідувач кафедри технологій аеропортів факультету літальних апаратів Державного некомерційного підприємства «Державний університет «Київський авіаційний інститут».