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RESEARCH OF LUBRICANT PROPERTIES OF USED TRACTOR MOTOR OILS

Summary. This work considers and analyses the existing technical requirements for motor oils during the operation of mobile agricultural machinery, as well as quantitative and qualitative changes in indicators when they are used. The effect of aging and contamination of motor oils on the operation of the main components of mobile agricultural machinery was experimentally studied, and criteria for evaluating the lubricating effect of motor oils were determined. It has been established that due to the significant demand for motor oils for agricultural production, it is a serious issue to prolong their service life in the operation of agricultural machinery. It was recognized that the aging processes of motor oils in a certain range positively affect their functional properties, but the methods for finding this range and criteria for their evaluation are practically absent.

Key words: motor oil, lubricating properties, quality indicators, agricultural machinery, reconstituted oil, mobile module, service life.

Formulation of the problem. The economical use of fuel and energy resources is an indispensable and most important condition for the effective development of agricultural production.

In the context of a shortage of lubricants in Ukraine, a very urgent problem is the optimization of the timing of their use.

The use of oils that do not meet the technical requirements of operation leads to a decrease in the reliability of equipment, but at the same time, the use of oils with an unjustified reserve of quality properties leads to their irrational costs, while reducing their service life by more than half.

The increase in the service life of engine oils largely depends on their initial chemical properties, the rate of aging processes, operating conditions, as well as the limiting values of certain quality parameters, upon reaching which the oils lose their operational functions. Unfortunately, today there are no reliable criteria to predict the quality of oils in the process of their use. Based on the foregoing, the relevance of research lies in the fact that in order to solve the tasks, in particular, the effective use of motor oils, it is necessary to develop such methods and criteria that would significantly increase the terms of their use during the operation of mobile agricultural machinery.

Analysis of recent research. When using motor oils, during the operation of mobile agricultural machinery, their initial functional properties are lost. Part of the oil is consumed for waste in the cylinder-piston group of the engine. Chemotological parameters also change, which ultimately leads to the so-called "Oil Aging". Qualitative changes can be so profound that the oil becomes unsuitable for further ensuring reliable engine lubrication and must be replaced with fresh one. From the complex of physical and chemical processes that make up oil aging during engine operation, the following can be distinguished first of all: oxidation, contamination and additive consumption. It should be noted that the separation of certain areas from the complex aging process is conventional, since they are actually all closely related to each other, and it is difficult, for example, to consider the process of oil pollution in isolation from the process of its oxidation and the operation of additives [1-7] .

Most researchers, until recently, considered the long-term use of oils to be inappropriate, but in recent years it has been established that with an increase in the service life of oils, its operational properties not only do not deteriorate, but even improve [8-17].

As for any structural element, the engine oil is characterized by the running-in process, accompanied by an intensive change in the parameters of the qualitative state in the initial period and the subsequent period of stabilization of properties [18].

The use of oils that do not meet the quality requirements leads to a decrease in the reliability of equipment, but at the same time, restoration of the main quality indicators can extend their service life and thereby save expensive oil products [19-21].

S.V. Wenzel explains the insufficient substantiation of the oil service life established until recently by the absence of a theory explaining the relationship between aging and the wear rate of tribo-couplings [22].

The increase in the resource largely depends, on the one hand, on the initial properties of oils, the rate of aging processes, operating conditions, as well as on the limiting values of certain quality parameters, upon reaching which the oils cease to effectively perform their functions [23].

Existing methods for assessing quality, various kinds of rejection criteria do not always objectively determine the timing of their replacement and take into account the effect of lubricants on the state of rubbing surfaces of machine parts and mechanisms, and most importantly, this is currently not technically ensured [24, 25].

The conducted literary review testifies to the significant problematicity of issues related to the establishment of rational terms for the use of lubricating oils.

This problem is especially relevant in relation to engine oils, since the work related to the optimization of the resource of this class is extremely insufficient [26-29].

Formulation of the objectives of the article. The aim of the research is to study the influence of the quality of motor oils on the effectiveness of their lubricating action during friction.

Main part. The studies were carried out using commercial mineral motor oil M-10G_2K, which was produced by SP YUKOIL (Ukraine).

According to the research objectives presented, the experiments were carried out with M - 10G_2K oil in the following qualitative states:

- in the delivery state (contamination with mechanical impurities-0.027%);

- the used resource in highly accelerated engines operated during agricultural operations (contamination with mechanical impurities - 0.91%);

- a used resource in the same engines and cleaned by the UVOM-200 installation, designed by the Tauride State Agrotechnological University (TGATU) (contamination with mechanical impurities - 0.06%);

- the used resource in the same engines and cleaned with a mobile module, the design of TSTU (contamination with mechanical impurities - 0.015%).

The lubricating properties of the studied oils were evaluated using friction machines. Tests with point contact were carried out on a MAST-1 friction machine (Russia) under the “sphere-ring sample” scheme. The following materials were selected as friction pairs: special cast iron CHN1KHMD and Steel 45, which corresponds to the tribo-coupling “piston ring-cylinder liner” and “cam-pusher of the gas distribution mechanism”.

Tests with local contact were carried out on a friction machine SMC-2 (Russia) according to the “shaft-bushing” scheme. The following materials were selected as friction pairs: Steel 20X and OF bronze OF 6.5-0.15, which corresponds to the operating conditions of tribological conjugations “crankshaft-liner” and “bushing of the upper connecting rod head - piston pin”

To control the degree of contamination of motor oils, the PKZH-904V device (Russia) was used. This device is designed to control the amount of particles contained in a controlled volume of fluid. The results of measuring the number of particles were induced on the digital display of the device in six size ranges (5-10, 10-25, 25-50, 50-100, 100-200, more than 200 microns).

The methodology for the experimental assessment of the temperature stability of motor oils on a MAST-1 friction machine was as follows: The test oil was poured into a 50-ml bath and samples of tribological conjugations were inserted. Prototypes, as well as real units were subjected to the necessary heat treatment.

After filling the oil on the load lever set the load depending on the selected load for testing. The oil was heated to the required temperature using an electric furnace. A chromel-kopel thermocouple was used to measure the temperature of the studied oils, and the value was controlled by an EPV-2 potentiometer.

Chart paper was fixed on the chart drum, and the recorder's pen was filled with ink for self-cleaning devices. After that, the tumblers were turned on to drive the samples and the chart drum. The value of the coefficient of friction was recorded by a recorder on a chart drum. The test time corresponded to 60 seconds.

An experimental assessment of the temperature resistance of motor oils was carried out in three temperature conditions:

- moderate temperatures, when the oil is heated to a temperature of 100 °C, which corresponds to the temperature of the oil in the crankcase of a running engine;
- working temperatures, when the oil is heated to a temperature of 300 °C, which corresponds to the temperature regime of the tribo-coupler “piston ring-cylinder liner”;
- elevated temperatures, when the oil is heated to a temperature of 350 °C, to simulate extreme temperature conditions at which tribological coupling “upper compression ring-cylinder liner” can work. Each test was carried out with a new portion of oil and new samples. The criterion for evaluating the lubricity at boundary friction of materials was adopted:
- the critical temperature, that is, the minimum volumetric temperature at which the friction coefficient and its spasmodic change sharply increases. This temperature characterizes the process of physical desorption of surface - active molecules of the boundary layer;
- the temperature of the chemical modification, that is, the minimum volumetric temperature at which the abrupt change in the coefficient of friction ceases and smooth sliding occurs, while the coefficient of friction is significantly reduced and stabilized. This temperature characterizes the process of chemical modification of the layers on the friction surface as a result of the decomposition products of chemically active substances contained in the lubricant with the metal of the friction surface.

After taking all readings, the oil was drained, and the samples and all parts in contact with the lubricant were washed with gasoline and dried in air.

The methodology for the study of the lubricating ability of motor oils on the SMTS-2 friction machine, unlike the MAST-1 friction machine, allowed to expand the functionality, and thereby contributed to:

- set the rotation frequency of the test samples for steady-state operation from 300 to 1500 rpm and a duration of 1 minute to 10 hours;
- maintain a stable speed of the samples when the load changes;
- set repeatedly recurrent cycles "start - stop" or "start - steady state" in identical conditions.

The temperature was measured with a chromel-kopel thermocouple; an electronic potentiometer EPV-211A was used as a temperature indicator.

Forced temperature increase at a certain speed was carried out using a special container with an incandescent element.

The methodology for controlling the degree of contamination and purification of motor oils with the PKZh-904V device included the following. To determine the class of liquid purity according to GOST 17216, the readings of the device in the appropriate size ranges should be assigned to 100 cm^3 of the controlled liquid.

The operation of the device is based on the registration by a sensitive element (photodiode) of a change in the light flux from the light source (LED) during the overlapping of a part of the light flux with an individual particle moving with the flow of the controlled fluid. The electrical signals of the photodiode are amplified, stabilized in amplitude and distributed over the corresponding size ranges indicated on the instrument panel. The device was used in two modes: control of purity in a stream and control of purity of a liquid by separate samples.

The kinetics of the change in the coefficient of friction for the four high quality states of the above M - $10G_2K$ oil is shown in Fig. 1.

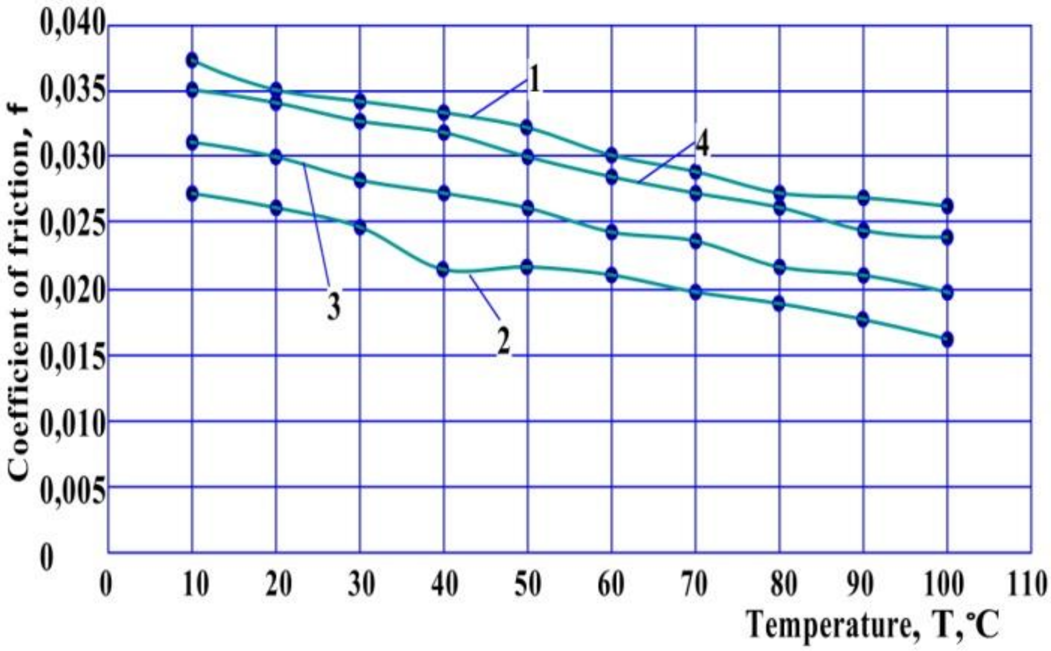

Fig. 1 The dependence of the coefficient of friction on the volumetric temperature of the oil at a load of 300 N: 1 - in the delivery state, 2 - the used resource, 3 - after cleaning the UVOM-200, 4 - restored by the module

As can be seen from fig. 1, with an increase in the volumetric temperature of the oil, the friction coefficient decreases. At the end of the running-in process of rubbing surfaces, the oil temperature in the volume is stabilized for all four lubricating oils.

It is known that foreign substances entering the oil during its operation undergo changes, which in some cases bring significant benefits. In particular, particles up to 5 μm contribute to the optimization of the surface microrelief and their antifriction separation.

Artificially contaminated oil was supplied instead of the rubbing contact of the tribo-conjugation from the activator.

Such phenomena occur only in the actual operating conditions of tribological conjugations simultaneously with the process of oil aging and stabilization of the content of oxidation products and solids.

An analysis of the results shows that the degree of contamination of motor oils during their operation in this temperature range does not significantly affect the effectiveness of the lubricating action, as evidenced by the values of the friction coefficients.

A significant influence on the performance of the lubricating action, as it turned out, has a method of cleaning lubricating oils.

An insignificant effect on the performance of the lubricating effect is exerted by the load factor, as can be seen from Figures 2 and 3.

With increasing load, the friction coefficient at the initial moment increases for all four lubricating oils, and then gradually decreases and begins to stabilize. As can be seen from fig. 1, 2 and 3, the patterns of change in the coefficient of friction are similar at different loads.

The experimental results also indicate a noticeable superiority of the lubricating performance of used oil in the units of tractor engines.

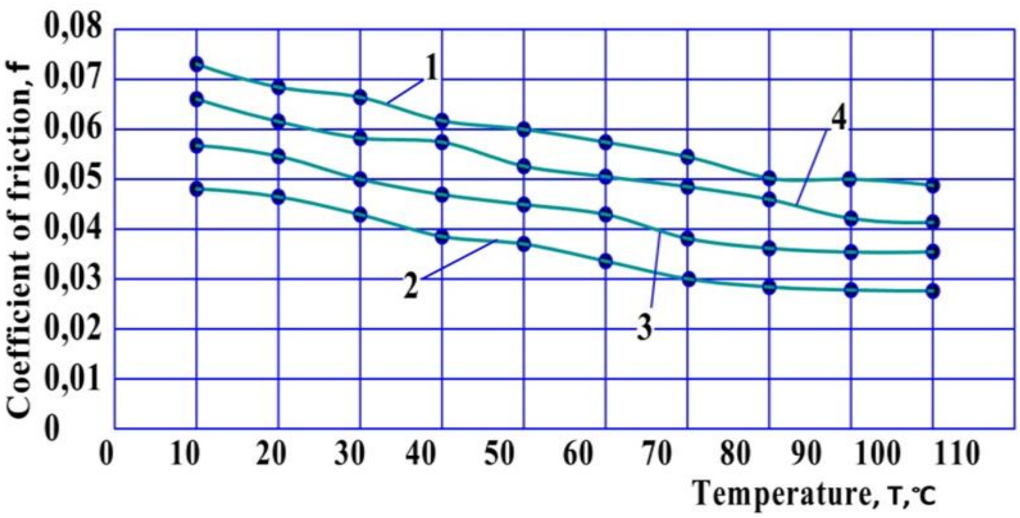

Fig. 2 The dependence of the coefficient of friction on the volumetric temperature of the oil at a load of 2000 N: 1 - in the delivery state, 2 - used resource, 3 - after cleaning UVOM-200, 4 - restored by the module

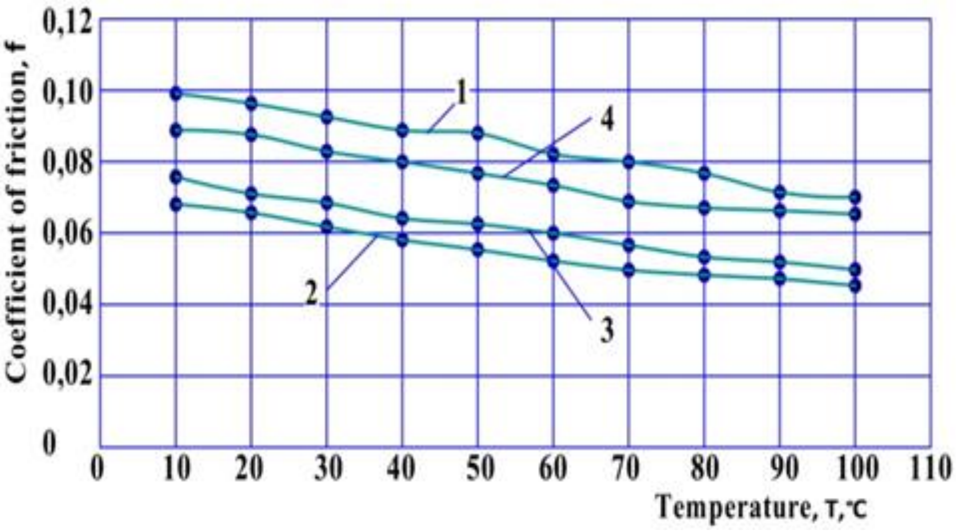

Fig. 3 The dependence of the coefficient of friction on the volumetric temperature of the oil at a load of 5000 N: 1 - in the delivery state, 2 - used resource, 3 - after cleaning UVOM-200, 4 - restored by the module

Therefore, in the conditions of the boundary lubrication regime, when using M-10G2K engine oil with a different content of contaminants, the active formation of lubricant layers begins at an oil volumetric temperature of 85 ... 100 °C.

It should be noted that the adsorption processes forming the boundary lubricating layers in oils of various qualitative states are very diverse.

In fig. 4 and 5 shown the dependences of the coefficient of friction on temperature and load for oils in various qualitative conditions.

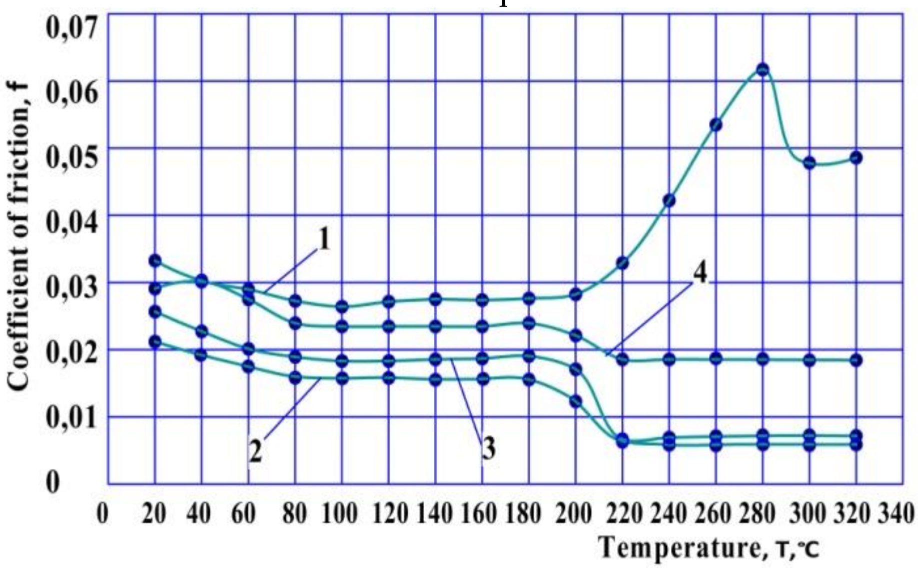

Fig. 4 The dependence of the coefficient of friction on the volumetric temperature of the oil at a load of 300 N: 1 - in the delivery state, 2 - the used resource, 3 - after cleaning the UVOM-200, 4 - restored by the module

As is well known, in the actual operating conditions of tractor engines, the volumetric temperature of the oil reaches sufficiently high values until it stabilizes. In particular, in the area of the upper compression ring, the oil temperature reaches 300 °C or more.

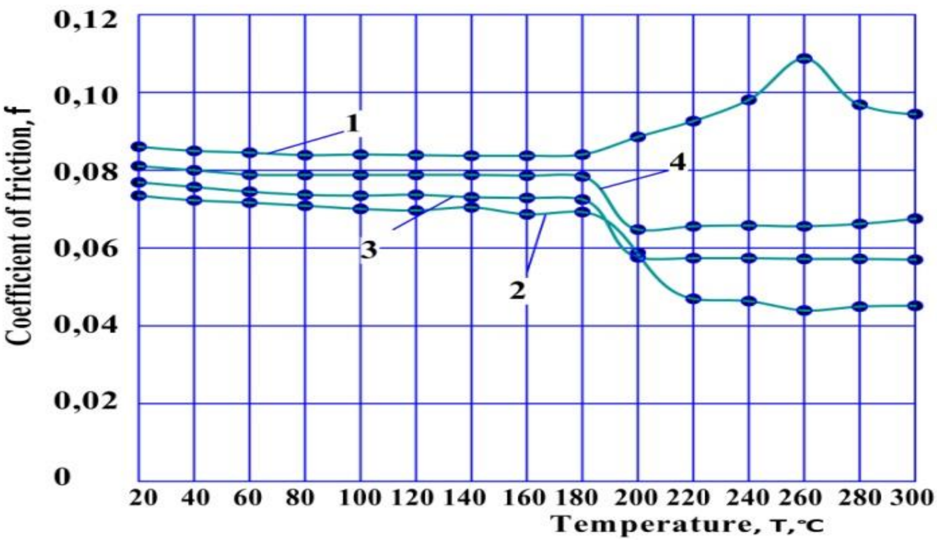

Fig. 5 The dependence of the coefficient of friction on the volumetric temperature of the oil at a load of 2000 N: 1 - in the delivery state, 2 – used resource, 3 - after cleaning UVOM-200, 4 - restored by the module

Therefore, the above temperature conditions are true for motor oils and require more detailed consideration.

Studies have shown that the lubricating effect of the restored used oil surpasses that of the oil in the delivery state.

When the oil was heated to a temperature of 100 °C, the friction coefficient decreased at various loads, while further heating to a temperature of 180 °C, its value stabilized and remained unchanged. In our opinion, this indicates an insignificant effect of this temperature factor on the processes of formation of the initial boundary layer.

At the same time, with a further increase in temperature (from 180 °C to 300 °C), there is an unconditional influence of the volumetric oil temperature on the intensity of the formation of boundary lubricating layers.

In particular, the steady-state values of the coefficient of friction during testing in oil, a used resource, and oil purified using UVOM-200 and the module were lower than at moderate temperatures.

The obtained coefficient of friction values during the test period changed differently with increasing temperature.

Therefore, ceteris paribus, the temperature factor in the evaluation of the lubricating effect of motor oils is very significant.

An analysis of the results indicates that, under conditions of heating the oil to 300 °C at nominal load conditions, P = 5000 N, the oil that has spent its life in the engine forms a stable, significant in thickness, boundary lubricating layer localizing shear deformations on the friction surface and reducing friction losses.

In our opinion, the low values of the coefficient of friction obtained during the tests are explained by the presence of a significant amount of oil aging products in motor oils that have spent their resources, which, due to their polar activity, are adsorbed on the friction surfaces and have an anti-wear effect.

In addition, oil oxidation products are adsorbed on foreign particles, which are wear products and external pollutants (dust, sand, etc.).

They, in turn, become complexes with multilayer colloidal protection, playing the role of anti-friction, anti-wear additives(fig. 4 and 5).

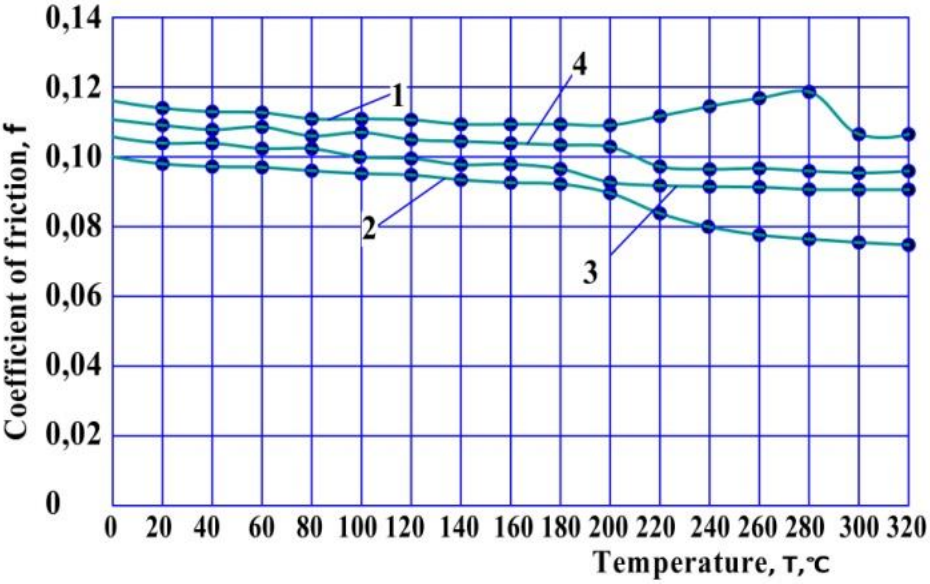

Fig. 6 The dependence of the coefficient of friction on the volumetric temperature of the oil at a load of 5000 N: 1 - in the delivery state, 2 - used resource, 3 - after cleaning UVOM-200, 4 - restored by the module

Therefore, during the operation of motor oils, particles of external contaminants of a certain size up to $5 \cdot 10^{-6}$m are reliably isolated by oxidation products, which protect the friction surfaces from the destructive effects of the latter.

During the operation of mobile agricultural machinery, due to violation of the conditions of normal operation of tractor engines, the operating temperature of lubricating media can significantly change in the direction of increasing the volumetric temperature of the oil.

In this regard, it is of certain interest to study the indicators of the lubricating effect of motor oils of various SZs during their gradual heating to 350 °C.

An increase in temperature from 300 °C to 350 °C had practically no effect on the value of the coefficient of friction when using oil in the delivery state, which remained at the same level.

For lubricating oil cleaned using UVOM-200 and the module, a slight decrease in the coefficient of friction was observed with subsequent stabilization.

For used oil, the friction coefficient decreased and its value did not stabilize when the oil was heated to a temperature of 350 °C. In our opinion, this is due to the continuation of the chemical reaction of the lubricating oil with the surface of the material, which entails the wear of the interface, as mentioned earlier.

The kinetics of changes in the coefficient of friction for these experimental conditions at nominal load conditions is shown in Fig. 7.

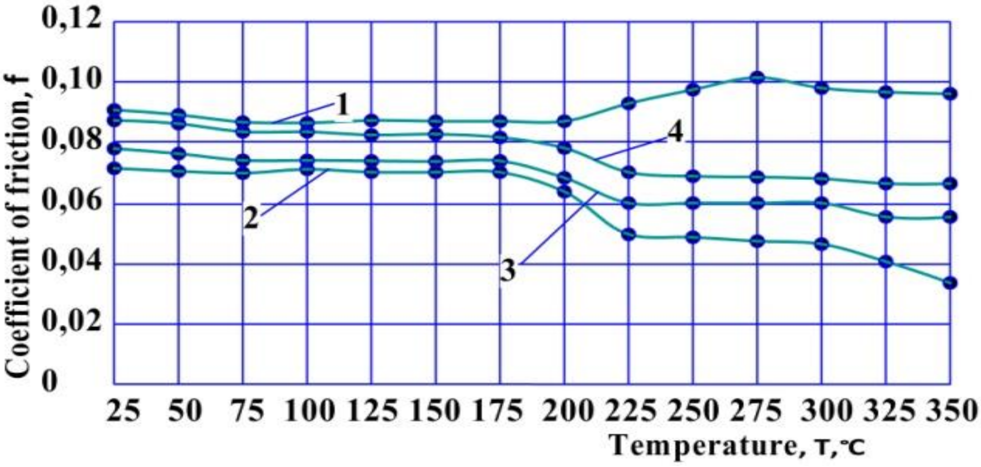

Fig. 7 The dependence of the coefficient of friction on the volumetric temperature of the oil at a load of 5000 N: 1 - in the delivery state, 2 - used resource, 3 - after cleaning UVOM-200, 4 - restored by the module

Thus, the results of studies conducted under conditions of gradual heating of lubricating media to a temperature of 350 ° C indicate a significant effect of the volumetric temperature of the oil in the range of 180 - 260 °C and 300 - 350 °C on the performance of on the lubricating performance of engine oil of varying degrees of contamination.

In order to determine the effect of the degree of purification of motor oils on their anti-wear properties, the M-10G2K oil was tested in the delivery state, purified using UVOM-200, restored by the module.

The experiments were carried out on a MAST-1 friction machine at a load of 6500 N for one hour. Samples - from ШХ 15 steel.

The analysis of the research results showed that the diameter of the wear spot obtained as a result of running in a clean oil environment significantly exceeds this value than when tested in oil, purified UVOM-200 and restored by the module, respectively 0.65 mm and 0.5 and 0.45 mm (Fig. 8). The research results confirmed the better anti-wear properties of the restored oil than in the delivery state, as evidenced by the numerical values of the friction coefficients.

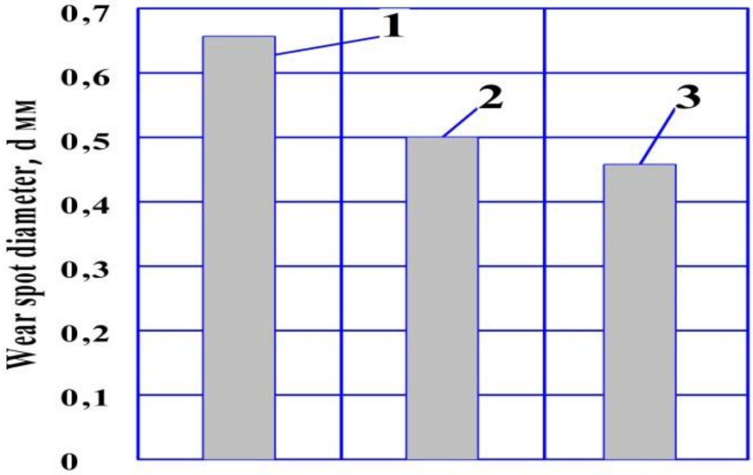

Fig. 8 Histogram of the values of the diameter of the wear spot of the studied oils: 1 - in the delivery state, 2 - after cleaning the UVOM-200, 3 - restored by the module

The main components that determine the nature and speed of the processes during friction and wear include a combination of many factors, namely the type and nature of the friction, the magnitude of the applied load, the speed of mutual movement of the rubbing surfaces, the change of modes speed over time, temperature conditions and duration of work.

Crucial to the nature and speed of the tribological processes during friction and wear are the properties of the lubricating medium.

The results of previous studies have shown that the value of the specific load during friction in the environment of lubricating oils of various qualitative conditions does not significantly affect the value of the friction coefficient, and therefore the wear rate.

The value of the specific load can have a sharp effect only if its critical values are reached, when a transition to wear by setting is observed.

The sliding speed of the rubbing parts of tractor engines operating in a hydrocarbon fluid environment in a wide range from tenths to several meters per second, therefore, studies of the influence of the high-speed regime on the lubricity of the oil aroused some interest.

The tests were carried out on a SMC-2 friction machine in the speed range from 0 to 15 m / s with axial loads on a friction pair of 300, 2000, 6000 N, which corresponds to the nominal contact stresses of the main joints of tractor engines operating in a lubricating oil environment.

The oil temperature was constant and amounted to 180 °C. This is the maximum oil temperature that separates the surfaces of the rubbing parts with a local contact.

The dependence of the coefficient of friction on the sliding velocity under load is shown in Fig. 9, 10 and 11.

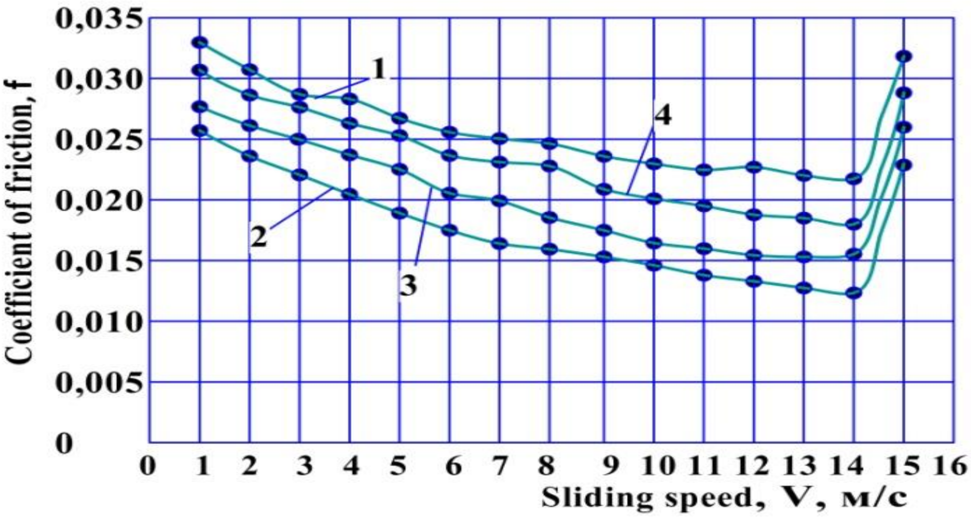

Fig. 9 The dependence of the coefficient of friction on the sliding speed at a specific load of 300 N for oils: 1 - in the delivery state, 2 - used resource, 3 - cleaned UVOM-200, 4 - restored by the module

With an increase in the sliding velocity from 0 to 15 m / s, each combination of the joint surfaces and oil has its own critical sliding velocity, at which the quantitative characteristics of the friction process change stepwise. A sharp increase in the coefficient of friction occurs. The nature of the ongoing processes on the friction surfaces and in the surface layers of metals also changes stepwise.

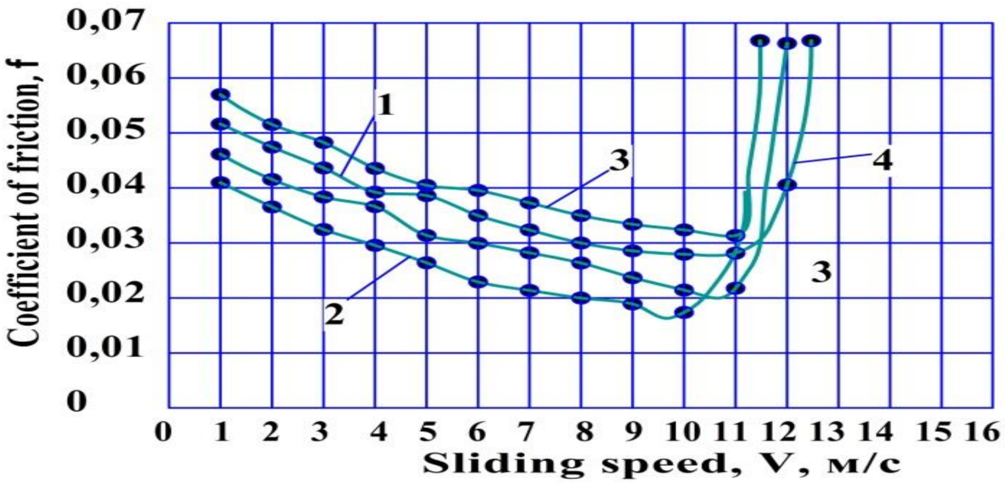

Fig. 10 The dependence of the coefficient of friction on the sliding speed at a specific load of 2000 N for oils: 1 - in the delivery state, 2 - used resource, 3 - cleaned UVOM-200, 4- restored by the module

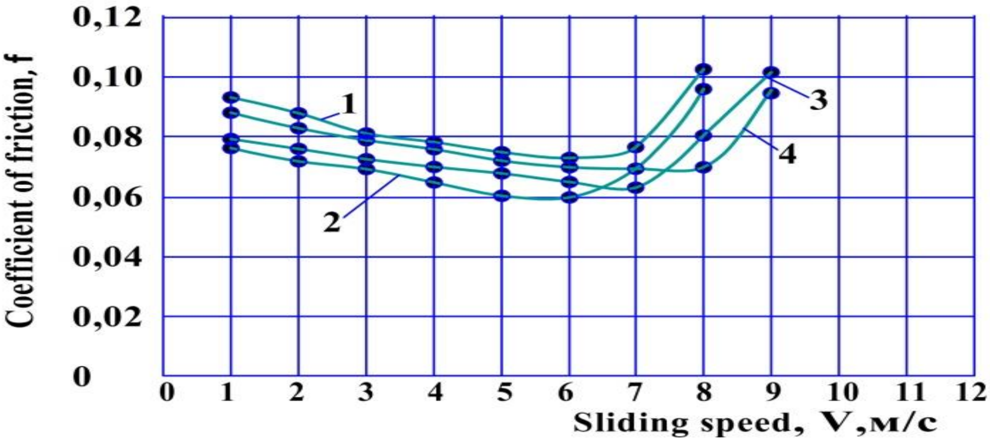

Fig. 11 The dependence of the coefficient of friction on the sliding speed at a specific load of 5000 N for oils: 1 - in the delivery state, 2 - used resource, 3 - cleaned UVOM-200, 4 - restored by the module

At nominal slip speeds, processes of physicochemical interaction of metals and a liquid medium are observed. As a result, protective films (organic and inorganic) are formed on the friction surfaces, which act as lubricants. When the critical sliding speed is reached, these films are destroyed, and on the friction surfaces, the processes of setting of metals become predominant, as a result of the simultaneous formation of strong adhesive bonds between the metal surfaces.

The research results allowed us to conclude that the speed of the process of regeneration of protective films becomes less than the speed of the process of their destruction.

A decrease in the sliding velocity from critical to 0.1 m / s leads to an increase in wear and friction coefficient.

In the process, with an increase in the sliding speed, a decrease in the critical load occurs, which further leads to gripping.

Conclusions. As a result of the studies, it was found that under conditions of loading of samples close to the operating conditions of the main parts of tractor engines under steady-state conditions, a mixed type of lubricant occurs with a significant predominance of the boundary component.

It has been established that reduced oil forms a stable, significant in thickness boundary lubricating layer on the friction surface, which localizes shear deformations and reduces friction losses.

The degree of purification of motor oil has a significant impact on the performance of the lubricating oil, while the diameter of the wear spot obtained when testing the M-10G2K engine oil on the MAST-1 friction machine was 0.65 mm for marketable oil; purified UVOM-200 - 0.5 mm and restored by the module - 0.45 mm.

Characteristics of the lubricating action of motor oils are significantly affected by the temperature of the oil, in the intervals of 180-260 and 300-350 ° C.

The effect of the degree of purification of motor oils on their anti-wear properties at various speeds and specific loads has been established, in particular, restored oil has higher anti-wear properties than oil in the delivery state.

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ДОСЛІДЖЕННЯ ЗМАЩУВАЛЬНИХ ВЛАСТИВОСТЕЙ ВІДПРАЦЬОВАНИХ АВТОТРАКТОРНИХ МОТОРНИХ ОЛИВ

Анотація

В роботі розглянуто і проаналізовано існуючі технічні вимоги до моторних олив при експлуатації мобільної сільськогосподарської техніки, а також кількісні та якісні зміни показників при їх використанні. Експериментальним шляхом досліджено вплив процесів старіння і забруднення моторних олив на роботу основних вузлів мобільної сільськогосподарської техніки, визначені критерії оцінки мастильної дії моторних олив.

Встановлено, що внаслідок значної потреби в моторних оливах для сільськогосподарського виробництва є актуальним питанням збільшення терміну їх служби при експлуатації сільськогосподарської техніки.

Встановлено, що процеси старіння моторних олив в деякому діапазоні позитивно впливають на їх функціональні властивості, але методи знаходження цього діапазону і критерії їх оцінки практично відсутні.

Існуючі методи оцінки якісних показників олив за фізико-хімічними та вибраковочним критеріям, як правило, не враховують їх триботехничні властивості, які характеризують надійність роботи трибосистеми.

Лабораторні дослідження проводились на машинах тертя МАСТ-1 і СМЦ-2 переобладнаних з урахуванням умов випробувань. В якості основних показників, які характеризують вплив ступеня очищення і забрудненості моторних олив на їхні змащувальні дія були прийняті: питоме навантаження в контакті, лінійна швидкість, а також коефіцієнт тертя і об'ємна температура оливи.

Для отримання дослідного зразка оливи використовувалися розроблені нами установка УВОМ-200 і мобільний модуль для відновлення автотракторних олив.

Дослідження показали, що значний вплив на хіммотологічні властивості моторних олив має ступінь їх очищення. Це дає можливість розробити методику збільшення терміну використання моторних олив із застосуванням деякої кількості відновленої оливи, яка дозволить порівняти терміни заміни оливи з періодичністю технічного обслуговування мобільної сільськогосподарської техніки, що в свою чергу зменшить час простою техніки і збільшить при цьому ефективність її використання за рахунок збільшення терміну їх служби.

Ключові слова: моторна олива, змащувальні властивості, якісні показники, сільськогосподарська техніка, відновлена олива, мобільний модуль, термін служби.

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ИССЛЕДОВАНИЕ СМАЗОЧНЫХ СВОЙСТВ ОТРАБОТАННЫХ АВТОТРАКТОРНЫХ МОТОРНЫХ МАСЕЛ

Аннотация

В работе рассмотрены и проанализированы существующие технические требования к моторным маслам при эксплуатации мобильной сельскохозяйственной техники, а также количественные и качественные изменения показателей при их использовании. Экспериментальным путем исследовано влияние процессов старения и загрязнения моторных масел на работу основных узлов мобильной сельскохозяйственной техники, определены критерии оценки смазочной действия моторных масел.

Установлено, что вследствие значительной потребности в моторных маслах для сельскохозяйственного производства является актуальным вопросом увеличения срока их службы при эксплуатации сельскохозяйственной техники.

Установлено, что процессы старения моторных масел в некотором диапазоне положительно влияют на их функциональные свойства, но методы нахождения этого диапазона и критерии их оценки практически отсутствуют.

Ключевые слова: моторное масло, смазывающие свойства, качественные показатели, сельскохозяйственная техника, восстановленное масло, мобильный модуль, срок службы.