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RESEARCH

Wear Resistance Increase of Samples Tribomating in Oil Composite with Geo Modifier KGMF-1

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A B S T R A C T

Increase of wear resistance of different types of tribomating which are functioning in fluid lubrication is possible due to: choosing more expensive and high quality material of samples that is not always sensible; applying some wear resistant coatings on them; selection and formation of complex composition of oil additives. Due to nanomaterials development there is a possibility of efficient use of functional additives such as geo modifiers in tribology. Due to geo modifier-based oil composites use it's not necessary to make any structural changes of machines mated parts though their wear resistance is increased. It requires the conducting of some experimental tribological research. It was found that oil media modified by a geo modifier increase the wear resistance of working surfaces of different types of tribomating. The use of geo modifier KGMF-1 (Katerynivka friction geo modifier -1 (patent of Ukraine №69657)) has been suggested. Lubrication quality of oil compositions based on M-10Г$_{2K}$ (M-10G$_{2K}$) (motor oil of 10th viscosity grade, of group Г$_{2K}$ (G$_{2K}$), for the CIS countries the oil grade conforms SAE 30) + KGMF-1 (4.0 - 4.5%) has been studied on a computer modernized four-ball friction testing machine ЧШМ-К1 (CHMK-K1). To evaluate the lubrication quality of the oil composite with the suggested geo modifier and to use the comparative analysis of the obtained results the research was conducted on commercial samples of base oil M-10G$_{2K}$ and oil composites M-10G$_{2K}$ + XADO Maximum for Diesel Truck (2.0 - 2.3%) (agent 2D sliding revitalization factor (RF) 100, revitalizant 1 Stage RF 100, metal conditioner RF 5.5), M-10G$_{2K}$ + cuprum glycerate (3.7 - 4.5%). Some average indices of wear, critical load, and welding load have been found. Samples division into 4 types of mating according to the following characteristic features: mobility, material hardness and friction area has been suggested for more accurate picture of wear resistance changes of samples tribomating which are functioning in base and modified oil. Lower friction torque of different samples couplings in modified oil by geo modifier KGMF-1 in comparison with base oil M-10G$_{2K}$ was recorded while using Friction machine 2070 SMT-1 with add-on module "ring-ring". The samples wear rate in modified oil by geo modifier KGMF-1 in comparison with base oil M-10G$_{2K}$ was studied by method of acoustic signal amplitude measurements directly from the friction zone by a commercially produced instrument of Brüel & Kjear company.

It was found that efficiency increase of the oil compositions under investigation is taking place in the following order: M-10G$_{2K}$ + XADO Maximum for Diesel Truck, M-10G$_{2K}$ + cuprum glycerate, M-10G$_{2K}$ + KGMF-1. Wear index due to the use of modified oil M-10G$_{2K}$ + KGMF-1 was 19 - 20 % lower comparing to the obtained data of the base oil, critical load value was 27 - 29 % larger, and welding load – 24 - 25% larger respectively. Moreover, it was recorded that the maximum wear rate of samples in their functioning in modified oil M-10G$_{2K}$ + KGMF-1 was 3 times lower, and friction torque change law is similar to the wear rate change depending on the time of testing.

1. INTRODUCTION

One of the ways to increase the wear resistance of machine parts tribomating is their use with more functionally adaptable lubricants with different synthetic additives and geo modifiers. Nowadays the lubricating properties of oils are improved mainly due to commercial additive complexes. Oil additives based on natural minerals after their pretreatment are called geo modifiers. Some papers describing the effect of geo modifiers use admit that surface-active substances of a metal-ceramic reconditioner being used on friction areas with some oil provoke the process of formation of a highly wear resistant metal-ceramic coating with lower friction coefficient on the mated surfaces. Due to these additives in oil medium some friction surface texturing takes place with simultaneous hardening of the main material at great depth on the samples tribomating surfaces. While tribomating is taking place some rational micro relief is being created on the samples surfaces which are correspondent to the actual operating conditions. The most popular additives on the Ukrainian market are those represented by trade mark XADO which have shown good results for power-supply units of transport vehicles.

The distinctive feature of friction geo modifiers from other additives consists in adding some substances to the samples tribomating which launch the self-organization processes [1-4]. At the same time, mainly by adding some additives into oil, mated surfaces are being separated by soft metals [5] and long hydrocarbon chains, synthesized film. It contributes to the surface optimal structure developing, especially in the contact areas with maximum number of available bonds resulting in increased oil confinement ability and equilibrium roughness [6]. Moreover, the development of matters dealing with geo modifiers use in oil compositions enables us to increase the tribomating samples wear resistance and their further commercial use to obtain various positive effect under machines maintenance conditions.

2. LITERATURE REVIEW

Nonstationary maintenance conditions and high requirements to the machines efficiency along with high level of reliability and limited financial expenditures on their maintenance demand from the tribological research to seek for new more efficient ways of wear resistance improvement of different types of oil medium mating [1-3]. The use of oil additives classification and development of a methodical complex of their choice are highlighted in many papers [4-6], but it was necessary to study some mating complexes aimed at tribomating wear resistance increase. To decrease the internal friction and to control the laws of external friction of tribomating samples materials it's possible to use soft metals and their derivative coatings with further highly efficient treatment [7-9], but those coatings do not create the possibility of their wear resistance dynamic regulation but they only can control it under certain maintenance conditions. Different types of additives of synthetic and natural origin change the oil physical thermal-oxidative ability due to the formation of materials surface layers enabling to decrease the friction coefficient and additional dissipation of friction energy [10-12], resulted in increased oil lubrication ability but wear resistance does not change greatly. That why it is necessary to seek for some new compositions with more positive characteristics for tribomating. A wide range of tribological characteristics and repairing compositions with additives of natural origin which are based on serpentinite-based powder properties have been studied in the papers [13-16]. The data of conducted investigation haven't shown the real comparative picture of wear with existing synthetic additives. Although, the authors in papers [13-16] gave some theoretical substantiation of oil compositions use with some friction geo modifiers of this type in tribomating under investigation.

Geo modifiers stimulate mechanical and chemical reactions, oil components pyrolysis and tribo catalytic carbonization, graphitization and creation of hard carbon containing oil compounds [16,17]. The conditions of coatings formation, low friction and heat conductivity coefficient, high hardness and corrosion resistance of geo modifiers have been found. These conclusions can be made due to the study of geo modifiers $Mg_6Si_4O_{10}(OH)_8$ properties [18]. It was found that friction geo modifiers were based on a large group of minerals with similar chemical formula where Mg can be replaced by iron and nickel [2,13,16]. Serpentinite rock includes several types of serpentinite, magnetite and chromium and various chemical elements used as geo modified composition mixture [10,14]. The study of various geo modified compositions have been highlighted in papers [5,6,10,19], some recommendations have been given dealing with their efficient use in wear-reversing tribo technologies development [15-16].

Chemical constituent of metal-ceramic layer formation from geo modifiers has been developed to a certain extent in the paper [20], but there is no information on physical-mechanical and rheological properties of these layers. There is no practical evidence. Some published papers assume the possibility of occurring an elastic-hydro-dynamic effect characterized by high pressure in an oil-film wedge causing the elastic deformation of samples materials which are in contact. Due to this a gap size between parts is getting bigger. Apparently, this happens while a layer is being formed when geo modifiers are in the oil [17,21,22]. Deep investigation of surface and pre-surface layers formed on the friction surfaces under treatment by geo modifiers conditions haven't been found in open sources. There has been no study of wear resistance increase dynamics of oil compositions with some friction geo modifiers so far. Wear resistant coatings, definitely, have dissipative and metastable structures [23]. Tribotechnical oil compositions with some geo modifiers aren't systematized and need some further research of their efficiency for tribomating concerning wear resistance increase.

The purpose of the paper is to increase the wear resistance of samples couplings in oil medium with Katerynivka friction geo modifier-1 (KGMF-1) and to make the comparative analysis according to tribotechnical characteristics of base oil and oil composites with adding the commercial sample of XADO [24] Maximum for Diesel Truck additive and cuprum glycerate respectively. The purpose has been achieved by solving the problems:

- study on the 4-ball friction machine ЧШМ-К1 (CHMK-K1) the wear index, critical load, welding load for the base oil М-10$Г_{2К}$ (M-10G_{2K}), oil compositions motor oil of 10th viscosity grade, of group $Г_{2К}$ (G_{2K}), for the CIS countries the oil grade conforms SAE 30), M-10G_{2K} + cuprum glycerate, M-10G_{2K} + XADO Maximum for Diesel Truck, M-10G_{2K} + KGMF-1;
- according to the obtained results analyze the lubrication capability of oil composite with geo modifier KGMF-1 and compare it with the efficient oil composites M-10G_{2K}, + cuprum glycerate, M-10G_{2K} + XADO Maximum for Diesel Truck,
- find the laws of friction torque change and wear rate of different types of samples mating due to the use of oil composition M-10G_{2K} + KGMF-1 according to the the scheme "ring-ring" on the friction machine 2070 SMT-1.

3. MATERIALS AND METHODS

Steel 45 (HRC52), cast iron СЧ 18 (equivalent EN-GJL-200) (HRC40) and bronze Бр.АЖ 9-4 (CuA19Fe3) (HB95) were used as material samples. The criteria of material choice were their wide use and similarity in parts mating of internal combustion engines of KamAZ-family lorries which are widely represented in central regions of Ukraine and hydraulic units [16].

Motor oil M-10G$_{2K}$ (base oil) widely used for KamAZ-family lorries maintenance and oil composites: M-10G$_{2K}$ + КGMF-1 (4.0 - 4.5) were used as a lubricating environment. The preliminary results of КGMF-1 content were described in the paper [2], M-10G$_{2K}$ + cuprum glycerate (3.7 - 4.5%) - in the paper [14]. For the comparative study the oil composition M-10G$_{2K}$ + XADO Maximum for Diesel Truck (made in Ukraine), (2.0 - 2.3%) concentration was according to the manufacturer's requirements. We must admit that geo modifier КGMF-1 mixture was obtained from clay-based natural substances, it's main physical properties were recorded and described by the group of authors of Central Ukrainian national technical university in the patent of Ukraine № 69657 [25].

Due to the point contact of the samples four-ball wear test system ЧШМ-К1 is quite a reliable instrument for determining the lubrication capability of base oils and their composites, lubricants additives efficiency. The study of wear-reversing mixture КГМТ-1 (KGMF-1) use efficiency in base oil M-10G$_{2K}$ has been carried out on ball samples by point or line contacts. As comparative study some tests on base oil M-10G$_{2K}$ and oil composition M-10G$_{2K}$ + XADO have been done. Tribomating process itself took place in four-ball wear test system СНМК-К1 where oil environment was tested. In fact, the mating itself took place in a pyramid of 4 balls where three lower balls were fixed solid in a cup filled with tested oil and the upper ball was rotating in a vertical spindle. Four-ball wear test system СНМК-К1 was used in investigating the lubrication capability of base and composite lubricants [26]. The average values of critical load, welding load and wear index characterized by a wear scar diameter-applied load ratio for certain oil media were measured in the investigation. The use of four-ball wear test system СНМК-К1 is specified by GOST 9490-75, in Germany – by DIN 51350, and in the USA – by ASTM D2783 [27].

Friction machine 2070 SMT-1 (a) with add-on module of "ring-ring" type (Fig. 1) has been used for the study of laws of friction torque change and wear rate of samples mating to find their wear resistance increase and prove the efficiency of oil composites use with geo modifier КGMF-1. Base and composite oils were supplied to the friction zone by a gear pump through a nozzle. A fine filter till particles of 10 mcm size was installed in lubrication system to avoid wear particles impact on friction and wear parameters.

(a) (b)

Fig. 1. (a) Friction machine 2070 SMT-1, (b) with add-on module "ring-ring".

An add-on module was mounted to implement the model. General view of the samples is given by Fig. 2.

(a) (b)

Fig. 2. (a) Experimental models for "ring-ring" tester on friction machine 2070 SMT-1: Бр. АЖ 9-4 (CuA19Fe3) (HB95), and (b) СЧ 18 (equivalent EN-GJL-200) (HRC40).

Before the investigation the samples had been wearing in till the complete contact areas took place. Here, the surface roughness was equal to $Ra = 0.2$ mcm that corresponds to wear-in mating of resources defining mating of power units of transport and hydraulic machines. The roughness measurements were made according to GOST 27964-88 using a profilometer (roughness indicator) of make 283. The investigation was conducted with the coefficient of mutual overlap $K_{b3} = 0.5$, caused by involving more types of samples mating. The samples size and testing procedure were specified by GOST 23.210.

The investigation was conducted under 200 N load and sliding velocity 0.7 m/sec that practically corresponds to the contact area of the samples according to GOST P 51860-2002 of friction machine 2070 SMT-1. The samples of "ring-ring" type have the outer diameter 12 mm, and inner diameter 6 mm.

To have more accurate picture of changes of mated samples wear resistance due to their functioning in base and modified oil their division according to the samples features has been suggested. For the friction machine 2070 SMT-1 the mating is divided into 4 types according to the characteristic features: mobility, material hardness, friction zone area (Table 1).

Table 1. Types of tribomated samples (parts) and characteristic features.

Characteristic features of tribomated samples (parts)				
Type of mating	Movable sample (part)		Stationary sample (part)	
	Material hardness, H_p	Friction area, S_p	Material hardness, $H_н$	Friction area, $S_н$
I	$H_m > H_f$	$S_m > S_f$	$H_f < H_m$	$S_f < S_m$
II	$H_m < H_f$	$S_m > S_f$	$H_f > H_m$	$S_f < S_m$
III	$H_m > H_f$	$S_m < S_f$	$H_f < H_m$	$S_f > S_m$
IV	$H_m < H_f$	$S_m < S_f$	$H_f > H_m$	$S_f > S_m$

The first type of tribomated samples is widely used where the material of a movable sample (part) is harder (H_p) and friction zone area (S_p) is larger, whereas a stationary sample is less hard ($H_н$) and its friction zone area ($S_н$) is smaller. $H_p<H_н$, $S_p>S_н$ is a characteristic feature of the second type of tribomating, $H_p>H_н$, $S_p<S_н$ is for the third type, and $H_p<H_н$, $S_p<S_н$ is for the fourth one. Wear rate of hard and soft materials of mated samples (parts) of the fourth type is the same.

The first type of tribomating is mating of a steel shaft and a soft bushing that is widely used in systems and units of mobile agricultural and motor transport vehicles and are quite popular due to their performance characteristics. Tribomating of hard chrome-plated cylindrical samples and a soft steel movable disc belong to the second type. Hydro cylinder and its mated steel piston (here the cylinder is made of softer steel) represent the third type of mating. Tribomating "cylinder liner-piston" is of the fourth type.

During the investigation the friction torque change was found by the friction force and a sample size, and wear rate – by the acoustic signal amplitude from friction zone.

The processes of tribomated parts and samples wear were studied by method of acoustic emission [28]. An acoustic-emission complex was used in the investigation. It consisted of a commercially produced instrument of Brüel & Kjear company (type 2511).

Fig. 3. A set for wear rate study by measuring the acoustic signal amplitude.

A piezoelectric element made by Brüel & Kjear company fixed on the stationary sample was used as a transducer. The complex allows for transducing the acoustic signals of tribomated samples under the tests conditions. The choice of acoustic emission parameters is very important in conducting tribological investigation as it reflects adequately the wear processes taking into account the specific features of the signal formation. An amplitude signal from the friction zone area correlated with the wear rate value was chosen as an information characteristics of acoustic emission to study the dynamics of the wear resistant layer formation and damage. A calibrated diagram was built to transform the values of signal acoustic emission amplitude from the friction zone into wear rate values.

To convert the values of acoustic emission amplitude of the signal formed in the friction zone into the wear rate values the following formula was used:

$$I_u = k \cdot A \cdot 10^{-9}, \qquad (1)$$

where k = 0.4 mV^{-1} – a conversion factor found by the calibrated diagram for the device of Brüel & Kjear company (type 2511); A – acoustic signal amplitude, mV.

The device of Brüel & Kjear company (type 2511) conditioning was done by means of acoustic signal frequency selection which showed the wearing processes of the tribocoupling samples under study the most adequately. The conditioning under consideration was in fact the acoustic evaluation of movable units and elements of the friction machine 2070 SMT-1 hydraulic system without any contacts of the samples and the obtained results of acoustic signals amplitude were neglected as noises. The values of their amplitudes were set at threshold quantity, so in wear rate estimating by means of the device of Brüel & Kjear company (type 2511) they were neglected. The rational frequency of the samples' wear rate estimation due to the surface layers formation and failure in base and modified oil media with the samples under consideration being in contact was equal to 4 kHz. This value corresponds to the maximum amplitude of acoustic signal within range of frequency 3…6 kHz of acoustic spectrum neglecting the noises. The above-mentioned frequency of acoustic signals corresponds to the most accurate and adequate results of wear rate evaluation of the samples under consideration by acoustic emission comparing to the gravimetric method.

Experimental research of different types of samples mating was conducted to obtain the values of wear rate I_u and friction torque M_{fr} in base M-10G$_{2K}$ and composite M-10G$_{2K}$+КGMF-1 oils. The overall time of the experiment was 100 - 110 min. In each case a diagram of acoustic emission amplitude and friction torque changes was recorded by a self-recording device.

4. RESULTS

Oil composite M-10G$_{2K}$ with geo modifier КGMF-1 was compared with base oil М-10Г$_{2K}$ and oil compositions M-10G$_{2K}$ + cuprum glycerate, M-10G$_{2K}$ + XADO Maximum for Diesel Truck. Lubrication capability of the oil samples under consideration was testing on CHMK-K1 by the following indices: wear, critical load and welding load. The results of the study are given in the Table 2.

Table 2. Average results of tests on the four-ball wear test system CHMK-K1 in different lubrication media.

Average indices	M-10G$_{2K}$	M-10G$_{2K}$ + cuprum glycerate	M-10G$_{2K}$ + XADO	M-10G$_{2K}$ + КGMF-1
Wear index, mm	0.56±0.03	0.48±0.02	0.52±0.03	0.45±0.02
Critical load, N	1236±1.0	1520±2.0	1490±2.0	1570±3.0
Welding load, N	1962±15.0	2420±25.0	2350±10.0	2452±10.0

According to results of investigation on the four-ball wear test system CHMK-K1 the low layers wear scar of average diameter-vs-applied load curves were plotted. Time period per test according to GOST 9490-75 is equal to 10 sec.

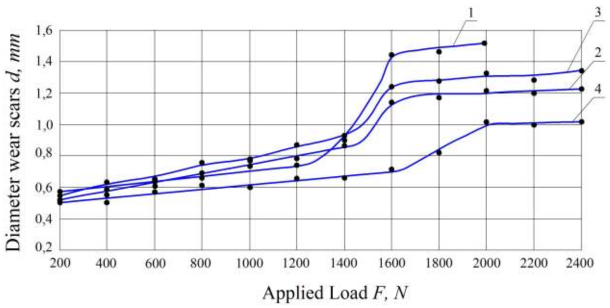


Fig. 4. Wear scars average diameter-vs-applied load curves for different lubricants: 1 – motor oil M-10G$_{2K}$ (base lubricant); 2 – M-10G$_{2K}$ + cuprum glycerate; 3 – M-10G$_{2K}$ + XADO Maximum for Diesel Truck; 4 – M-10G$_{2K}$ + КGMF-1.

The results of studying the evolution of friction torque change on friction machine 2070 SMT-1 (Table 3) and wear rate (Table 4) are shown for different tribocoupling types in base oil M-10G$_{2K}$ and oil with geo modifier КGMF-1. Steel 45 and СЧ 18 (equivalent EN-GJL-200) (analogEN-GJL-200) were used as materials of samples mating.

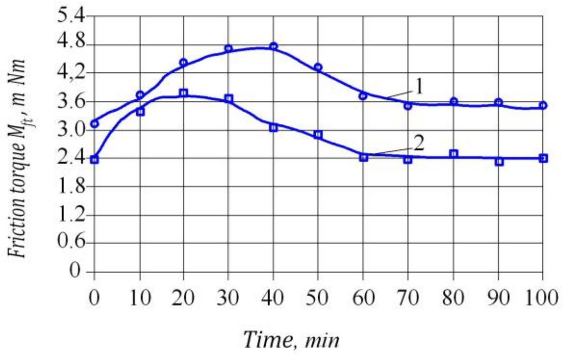
The results of study of regularities of friction torque change and wear rate change of the I - IV types of samples tribomating from steel 45 - Бр.Аж 9-4 (CuA19Fe3) are given on Figs. 5-8 respectively.

Table 3. Regularities of friction torque change M_{fr} (10^{-3}N·m) in different types of samples mating in base oil M-10G$_{2K}$ (A) and composite M-10G$_{2K}$ + КGMF-1 (B) depending on time of testing (steel 45 and СЧ 18 (equivalent EN-GJL-200) as samples materials).

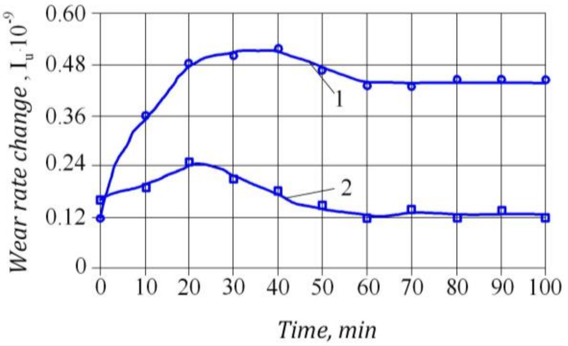
Type of mating	Oil	Time of test, min.										
		0	10	20	30	40	50	60	70	80	90	100
I	A	1.2± ±0.09	2.4± ±0.11	2.7± ±0.13	2.7± ±0.14	1.8± ±0.11	1.8± ±0.10	1.8± ±0.11	1.7± ±0.09	1.7± ±0.09	1.8± ±0.09	1.8± ±0.08
	B	1.2± ±0.07	2.7± ±0.13	2.8± ±0.14	2.7± ±0.12	2.2± ±0.09	2.0± ±0.09	2.0± ±0.10	1.9± ±0.11	1.8± ±0.07	1.8± ±0.1	1.7± ±0.09
II	A	1.2± ±0.07	1.8± ±0.10	2.3± ±0.11	2.1± ±0.10	2.5± ±0.15	2.5± ±0.14	2.5± ±0.13	2.5± ±0.14	2.5± ±0.13	2.1± ±0.10	2.1± ±0.12
	B	1.7± ±0.07	2.2± ±0.09	3.0± ±0.13	2.9± ±0.14	2.8± ±0.13	2.9± ±0.12	2.9± ±0.11	2.9± ±0.11	2.9± ±0.12	2.9± ±0.09	2.9± ±0.15
III	A	0.9± ±0.01	2.5± ±0.13	2.4± ±0.10	2.3± ±0.12	2.3± ±0.13	2.3± ±0.12	2.3± ±0.11	2.3± ±0.13	2.3± ±0.1	2.3± ±0.09	2.3± ±0.12
	B	1.0± ±0.02	2.1± ±0.11	1.9± ±0.08	1.9± ±0.07	1.8± ±0.08	1.8± ±0.07	1.8± ±0.1	1.8± ±0.08	1.8± ±0.09	1.8± ±0.11	1.8± ±0.08
IV	A	2.3± ±0.12	4.1± ±0.18	4.2± ±0.2	4.2± ±0.19	4.0± ±0.21	3.7± ±0.14	3.6± ±0.16	3.6± ±0.14	3.5± ±0.12	3.7± ±0.16	3.7± ±0.15
	B	2.2± ±0.07	2.6± ±0.09	3.0± ±0.14	3.1± ±0.16	3.6± ±0.13	3.6± ±0.15	3.6± ±0.15	3.5± ±0.12	3.4± ±0.14	3.1± ±0.14	3.1± ±0.12

Table 4. Regularities of wear rate change I_u (10^{-9}) in different types of samples mating in base oil M-10G$_{2K}$ (A) and oil composite M-10G$_{2K}$ + KGMF-1 (B) depending on the time of testing (Steel 45 - СЧ 18 (equivalent EN-GJL-200) as samples material).

Type of mating	Oil	Time of test, min.										
		0	10	20	30	40	50	60	70	80	90	100
I	A	0,20± ±0,01	0,55± ±0,01	0,59± ±0,03	0,58± ±0,25	0,57± ±0,04	0,57± ±0,04	0,58± ±0,03	0,57± ±0,02	0,57± ±0,01	0,57± ±0,02	0,57± ±0,03
	B	0,28± ±0,03	0,4± ±0,02	0,39± ±0,04	0,38± ±0,18	0,30± ±0,01	0,24± ±0,02	0,22± ±0,01	0,21± ±0,01	0,2± ±0,01	0,2± ±0,02	0,2± ±0,01
II	A	0,4± ±0,03	0,6± ±0,03	0,75± ±0,03	0,83± ±0,05	1,0± ±0,06	1,12± ±0,06	1,15± ±0,06	1,18± ±0,06	1,19± ±0,05	1,19± ±0,05	1,2± ±0,05
	B	0,2± ±0,01	0,45± ±0,02	0,45± ±0,02	0,45± ±0,03	0,5± ±0,03	0,55± ±0,02	0,55± ±0,02	0,57± ±0,03	0,58± ±0,01	0,6± ±0,01	0,6± ±0,02
III	A	0,5± ±0,02	1,1± ±0,02	1,2± ±0,05	1,21± ±0,05	1,21± ±0,05	1,21± ±0,04	1,21± ±0,04	1,21± ±0,06	1,21± ±0,03	1,21± ±0,04	1,21± ±0,03
	B	0,5± ±0,03	0,65± ±0,03	0,2± ±0,01	0,2± ±0,01	0,2± ±0,01	0,2± ±0,01	0,2± ±0,01	0,29± ±0,02	0,2± ±0,01	0,2± ±0,03	0,2± ±0,01
IV	A	0,5± ±0,01	0,64± ±0,03	1,0± ±0,01	1,21± ±0,06	1,38± ±0,06	1,43± ±0,05	1,54± ±0,08	1,58± ±0,04	1,59± ±0,03	1,6± ±0,05	1,6± ±0,02
	B	0,4± ±0,02	0,6± ±0,02	1,2± ±0,05	1,15± ±0,02	3,6± ±0,18	1,22± ±0,03	1,21± ±0,05	1,21± ±0,04	1,2± ±0,02	1,2± ±0,03	1,2± ±0,05

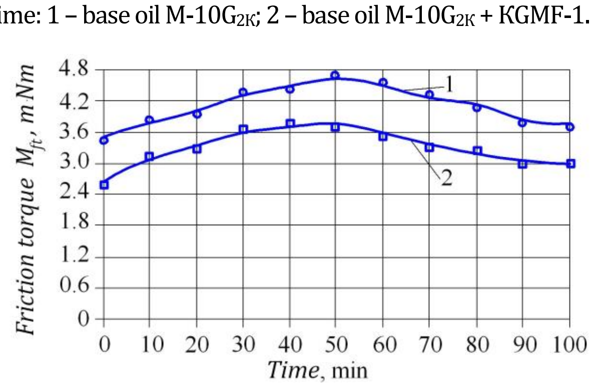


(a)



(b)

Fig. 5. (a) Evolution of friction torque in time, and (b) wear rate of the tribocoupling samples of the 1st type in time: 1 – base oil M-10G$_{2K}$; 2 – base oil M-10G$_{2K}$ + KGMF-1.



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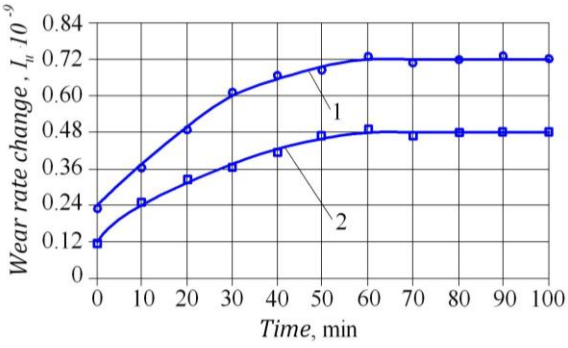
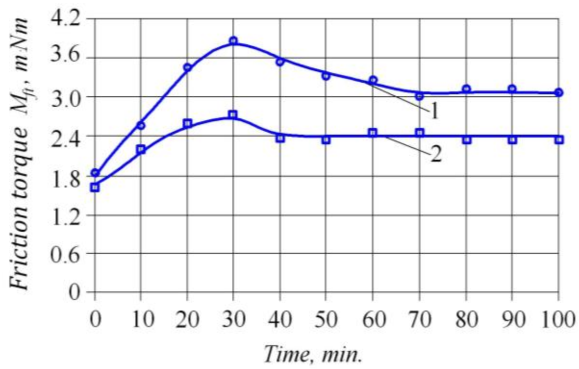
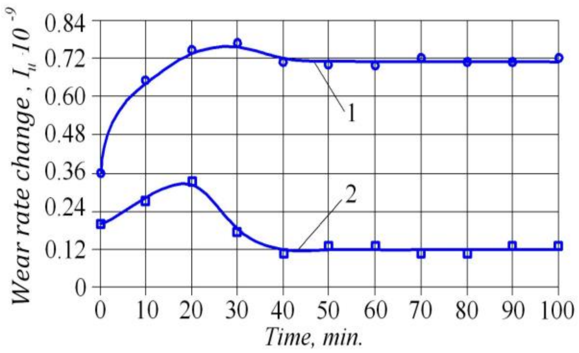


(b)

Fig. 6. (a) Regularities of friction torque change, and (b) wear rate change of tribocoupling samples of the 2nd type, in time, with different lubricants: 1 – base oil M-10G$_{2K}$; 2 – base oil M-10G$_{2K}$ + KGMF-1.

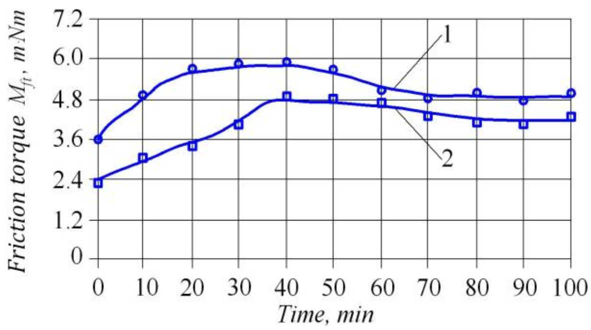


(a)

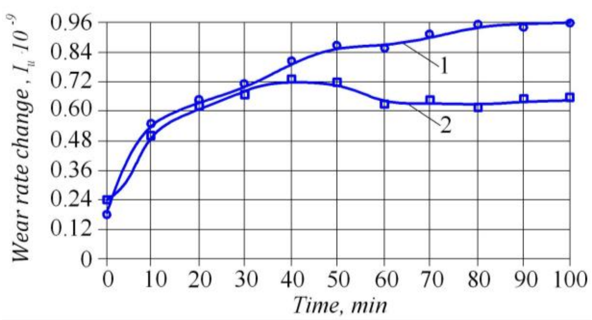


(b)

Fig. 7. (a) Regularities of friction torque change, and (b) wear rate of tribocoupling samples of the 3rd type with runtime: 1 – base oil M-10G$_{2K}$; 2 – base oil M-10G$_{2K}$ + KGMF-1.



(a)



(b)

Fig. 8. (a) Regularities of friction torque change, and (b) wear rate of tribocoupling samples of the 4th type in time: 1 – base oil M-10G2K; 2 – base oil M-10G2K + КGMF-1.

5. DISCUSSION

According to the obtained results of tests on the four-ball wear test system СНМК-К1 (Table 1) the lubrication capability of oil composites M-10G2K + cuprum glycerate, M-10G2K + XADO Maximum for Diesel Truck, M-10G2K + КGMF-1 has been improved comparing to the base oil: the wear indes became lower, critical load and welding load values got increased. Oil composite with geo modifier КGMF-1 has proved to obtain the best results comparing to the base oil: wear index became 19 - 20 % lower, though critical load became 27 - 29 % larger. Scuff-resistance characteristics determined by welding load were 24 – 25 % improved. It can be explained by the fact that geo modifier КGMF-1 helps to improve the lubrication capability of oil composite as its particles in oil on the ball samples surfaces in friction zone act as additional lubricants.

Positive properties of oil composites M-10G2K + cuprum glycerate, M-10G2K + XADO Maximum for Diesel Truck, M-10G2K + КGMF-1 comparing to the base oil M-10G2K can be observed on Fig. 4. This is proved by low balls wear scar diameter-vs-applied load curves on СНМК-К1. It was found that most of additives such as cuprum glycerate – curve 2, XADO Maximum for Diesel Truck – curve 3, КGMF-1 – curve 4 make the welding load P_w higher. Thus, while being added into base oil the above-mentioned additives will improve the scuff-resistance characteristics of base oil. Moreover, all above-mentioned additives increase the critical load value P_c characterizing the anti-wear additives operation range. In general, the proposed additive КGMT-1 is similar to the blend XADO Maximum for Diesel Truck and cuprum glycerate by scuff-resistance characteristics but it provides more efficient performance of the oil composite.

The study has proved that the efficiency increase of lubrication capability of lubrication media of base and composite oils can be presented in the following ordered series: M-10G2K, M-10G2K + XADO Maximum for Diesel Truck, M-10G2K + cuprum glycerate, M-10G2K + КGMF-1. Having compared the obtained results, we came to the conclusion that further study of tribotechnical characteristics will be effective on base and composite M-10G2K + КGMF-1 oils.

When an additive КGMF-1 is used in base oil M-10G2K on samples mating of material steel 45 - СЧ18 (equivalent EN-GJL-200) the friction torque is getting 5 – 28 % decreased comparing to the base oil (Table 3) for different types of samples mating. In this case, it was found that wear rate (Table 4) is getting smaller on different types of samples mating in a different way: 1.5 - 2.5 times smaller for the I type of mating; 1.3 - 2.1 times smaller for the II type of mating; 4.2 - 5.7 times smaller for the III type of mating; 1.2 - 1.3 times smaller for the IV type of mating.

Wear rate is changing while operating in oil composite with geo modifier КGMF-1 adding. It was found that friction torque in different types of samples mating of material steel 45 – Бр.АЖ 9-4 (CuA19Fe3) had 15 - 33% smaller values comparing to the base oil (Figs. 5a - 8a). We came to the conclusion that composite oil with КGMF-1 use made wear rate 3.0 - 3.4 times lower for the I type of mating (Fig. 5b); 1.5 - 1.6 times lower for the II type of mating (Fig. 6, b) and IV type (Fig. 8b) respectively; 5.0 - 6.0 times lower for the III type of mating (Fig. 7b).

This wear process behavior can be explained by the fact that the particles of КGMF-1 are charging into soft surface of the samples. After charging is over the friction torque value is getting smaller. The further behavior corresponds to the friction torque change respective to the base oil but with a smaller value. In this case, wear rates of samples mating in base oil and composite oil with КGMF-1 are completely different.

Due to the obtained results of lubrication capability and tribotechnical characteristics whilst geo modifier КGMF-1 use in base oil we may assume that the further development of additives formation technologies on its basis is a promising direction for heavily loaded mated parts maintenance.

6. CONCLUSIONS

1. The study of lubrication capability of base and composite oils M-10G$_{2K}$ + cuprum glycerate, M-10G$_{2K}$ + XADO Maximum for Diesel Truck, M-10G$_{2K}$ + KGMF-1 has proved the positive effect in comparison with base oil M-10G$_{2K}$. The improvement of such characteristics as welding load P_w, and critical load P_c, behavior CHMK-K1 low balls wear scar diameter respective to the applied load are the evidences. The composite oils under consideration can be used for tribomating wear resistance improvement.
2. It was found that among oil composites under consideration M-10G$_{2K}$ + cuprum glycerate, M-10G$_{2K}$ + XADO Maximum for Diesel Truck, M-10G$_{2K}$ + KGMF-1 the oil composite with geo modifier KGMF-1 has shown the best result comparing to the base oil: wear index became 19 - 20 % lower, though critical load became 27 - 29 % larger. Scuff-resistance characteristics determined by welding load were 24 - 25% improved.
3. Regularities of friction torque change and wear rate of the samples respective to the time of testing on friction machine 2070 SMT-1 depend on their material, mating type and lubrication medium. Due to geo modifier KGMF-1 use in base oil M-10G$_{2K}$ on samples mating of the material steel 45 - СЧ18 (equivalent EN-GJL-200) the friction torque is getting 5 - 28% smaller for different types of mating comparing to the base oil. Moreover, it was found that maximum decrease (4.2 - 5.7 times) of wear rate was obtained for the III type of mating, whereas minimum value (1.2 - 1.3 times) was obtained for the IV type of mating.

It was found that friction torque in different types of samples mating of material steel 45 – Бр. АЖ 9-4 (CuA19Fe3) in composite oil M-10G$_{2K}$ + KGMF-1 medium had 15 – 33 % smaller values comparing to the base oil. The maximum wear rate decrease (5.0 - 6.0 times) was observed for the III type of samples mating, and the minimum decrease (1.5 - 1.6 times) was observed for the II type of samples mating.

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