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Wear resistance increase of samples tribomating "Steel 45-cast iron SCH20" with geo modifier KGMF-1

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Abstract

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) has been suggested. 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. Moreover, it was recorded that the maximum wear rate of samples in their functioning in modified oil M-10G2K + KGMF-1 was 2...3 times lower, and friction torque change law is similar to the wear rate change depending on the time of testing.

Key words: tribomating of sample, geo modifier, composite oil, friction torque, wear resistance, acoustic emission, friction area, oil M-10G_{2K}.

Introduction

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 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].

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]. 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. 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.

Purpose

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). The purpose has been achieved by solving the problem: find the laws of friction torque change and wear rate of different types of samples mating "steel 450cast iron СЧ-20" due to the use of oil composition M-10G2K + KGMF-1 according to the the scheme "ring-ring" on the friction machine 2070 SMT-1.

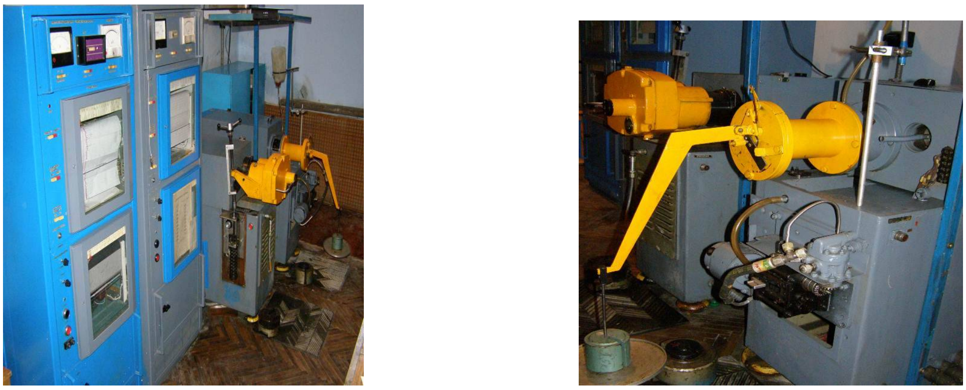
Research Methodology

Steel 45 (HRC52), cast iron СЧ20 (equivalent EN-GJL-200) (HRC40) 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-$10G_{2K}$ + KGMF-1 (4.0-4.5) were used as a lubricating environment. The preliminary results of KGMF-1 content were described in the paper [2]. We must admit that geo modifier KGMF-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 [23].

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 KGMF-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.

Before the investigation the samples had been wearing in till the complete contact areas took place. Here, the surface roughness was equal to R_a=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.



a b

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

The investigation was conducted under 150...250 N load and sliding velocity 0.5...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.

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.

Type of mating	Characteristic features of tribomated samples (parts)			
	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.

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 [24]. An acoustic-emission complex was used in the investigation. It consisted of a commercially produced instrument of Brüel & Kjear company (type 2511).

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:

$$I_u = k \cdot A \cdot 10^{-9}, \tag{1}$$

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.

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}+KGMF-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 u.

Results

The results of studying the evolution of friction torque change on friction machine 2070 SMT-1 (Table 2) and wear rate (Table 3) are shown for different tribocoupling types in base oil M-10G_{2K} and oil with geo modifier KGMF-1. Steel 45 and СЧ20 (equivalent EN-GJL-200) (analogEN-GJL-200) were used as materials of samples mating.

When an additive KGMF-1 is used in base oil M-10G_{2K} on samples mating of material steel 45 – СЧ20 (equivalent EN-GJL-200) the friction torque is getting 5–28 % decreased comparing to the base oil (Table 2) for different types of samples mating. In this case, it was found that wear rate (Table 3) 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.

Table 2

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 20 (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 3

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-$10G_{2K}$ + КGMF-1 (B) depending on the time of testing (Steel 45 - СЧ 20 (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

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.

Conclusions

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 КGMF-1 use in base oil M-$10G_{2K}$ on samples mating of the material steel 45 – СЧ20 (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.

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Аулін В.В., Лисенко С.В., Гриньків А.В., Чернай А.Є., Жилова І.В., Лукашук А.П.
Підвищення зносостійкості трибоспряжень зразків "сталь 45-чавун СЧ20" з геомодифікатором КГМТ-1

Підвищення зносостійкості трибоспряжень різних типів спряжень, що функціонують в рідинному мащені, можливе за рахунок: вибору більш якісного і вартісного матеріалу зразків, що не завжди є доцільним; нанесення зносостійких покриттів на них; підбір та формування комплексного складу добавок в оливу. З розвитком наноматеріалів в трибології створилась можливість ефективно використовувати функціональні добавки у вигляді геомодифікаторів. При впровадженні композиційних олив з геомодифікаторами не потрібно виконувати конструктивні зміни спряжень деталей машин, але їх зносостійкість збільшується. Це потребує проведення експериментальних трибологічних досліджень.

Виявлено, що модифіковані оливні середовища геомодифікатором підвищують зносостійкість робочих поверхонь різних типів трибоспряжень. Запропоновано використання геомодифікатора KGMF-1 (Катеринівський геомодифікатор тертя – 1). Були виявлені усереднені показники зносу, критичне навантаження та навантаження зварювання. Для більш точного відображення процесу зміни зносостійкості спряжень зразків, що функціонують в базовій та модифікованій оливі, запропоновано поділ зразків в спряженнях на чотири типи за характерними ознаками: рухомість, твердість матеріалу і площа зони тертя. Зменшення моменту сили тертя різних спряжень зразків в модифікованій оливі геомодифікатором KGMF-1 в порівнянні з базовою оливою М-10$Г_{2К}$ фіксували при використанні машини тертя моделі 2070 СМТ-1 з додатковим модулем "кільце-кільце". Дослідження інтенсивності зношування зразків в модифікованій оливі геомодифікатором KGMF-1 в порівнянні з базовою оливою проводили методом вимірювання амплітуди акустичного сигналу безпосередньо із зони тертя за допомогою приладу фірми Brüel & Kjear. В свою чергу зафіксовано, що максимальна інтенсивність зношування зразків, при їх функціонуванні в модифікованої оливі М10-$Г_{2К}$ + KGMF-1, зменшилась в 2...3 рази, а закономірність зміни моменту тертя аналогічна зміні інтенсивності зношування від тривалості випробування.

Ключові слова: трибоспряження зразків, геомодифікатор, композиційна олива, момент тертя, зносостійкість, акустична емісія, зона тертя, олива М10-$Г_{2К}$.