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Influence of temperature on the dynamics of formation of granic sleeps and connected elevation dynamics in sliding conditions

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Abstract

The running-in process is accompanied by a change in microgeometry, as a result of which some constant roughness is established, which is characteristic of given friction conditions, and the physical and mechanical properties of the surface layers also change, since plastic deformations usually predominate in the contact.

The thickness of the surface layers that have undergone changes during external friction depends on the stress state in the zones of their actual contact and heating during friction. The stress state in the zone of actual contact of the bodies is characterized by indentation or crushing of surface microroughnesses, as well as by elastic or plastic states of the latter. Surface heating during friction depends on the thermophysical properties of the contacting bodies and the friction mode. An increase in the temperature of the surface layers causes not only their softening, but also greatly increases the rate of physical and chemical processes in them. This leads to saturation of the surface layers with environmental gas molecules, oxidizing slicks, and also to an increase in the concentration of defects in these layers [1-5].

Key words: lubricating layer, wear, oil, temperature, adsorption layer, viscosity, friction coefficient

Introduction

We studied the lubricating properties of Mobil-1 0w-40 engine oil of a commercial batch and oil, the service life of which was 15 thousand km. As samples, a pair of slip block - roller was used. The sample material is 40X steel. The studies were carried out on the SMC-2 facility, in the start (3 s)–stop (3 s) mode. The cycles followed one after another, without interruption, the total number of cycles in the experiment was N=700. The studies were carried out at bulk temperatures of 20^0C and 120^0C at contact load max = 90 MPa.

In work efficiency of formation of boundary adsorption layers on contact surfaces at variable temperatures and their influence on wear resistance of elements of triboconjugation was investigated.

Lubrication properties of Mobil-1 0w-40 motor oil of commercial batch and oil with the service life of 15 thousand km were investigated. A pair of sliding pad - roller was used as samples. Material of samples - steel 40X. Researches were carried out on the SMC-2 unit, in the start (3 s) - stop (3 s) mode. Cycles followed one after another, without a break, all cycles in the experiment N = 700. Studies were carried out at volumetric temperatures of 20^0C and 120^0C at contact load max = 90 MPa.

The purpose of the work

In this paper, we studied the efficiency of formation of boundary adsorption layers on contact surfaces at variable temperatures and their influence on the wear resistance of triboconjugation elements.

Results of experimental studies

The study of load-carrying capacity of the presented samples of oils has established that in the process of start-up at rotational frequency n > 150 rpm, regardless of oil service life, conditions of hydrodynamic lubrication are realized in the contact at oil volume temperature 20^0C.

Let's follow the formation of non-hydrodynamic component of the lubricating layer thickness in the contact of commercial sample of Mobil-1 oil and the sample which operation period was 15 thousand kilometers at the temperature of 20^0C (Fig. 5.7). Firstly, irrespective of the type of grease, up to N<50 cycles of operating time in 100 % of cycles metal contact of elements of tribocouplings at standstill is observed (Fig. 1,a). With further operating time, due to the intensification of activation processes in the surface layers of the metal during their dynamic loading, their adsorption capacity increases, which leads to the formation of stable boundary layers on the contact surfaces.

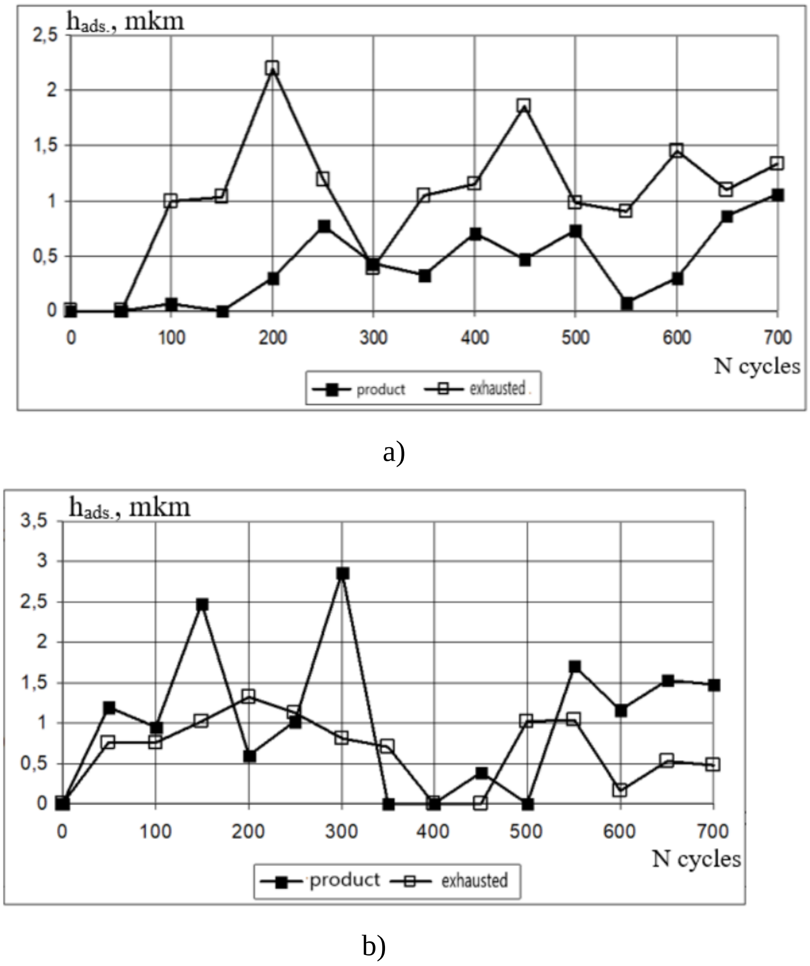

Fig. 1. Dynamics of formation of boundary adsorption layers (had.) with Mobil-1 oil at 20^0C (a) and 120^0C (b) at operating time (N)

Secondly, if a stable boundary film of a lubricant when using a commercial sample of oil is formed at N > 150 cycles, the period of formation of adapted boundary layers for used oil is three times shorter, which is caused, in our opinion, by the accumulation of surface-active substances in the process of oil operation.

Thirdly, there is a clear tendency of increasing the adsorption activity of hydrocarbon components of the oil with the lifetime of 15 thousand km, which is manifested by an increase in the thickness of the boundary adsorption layers by 30-40 %, on the average, in contrast to the similar indicator established for the commercial sample oil. This phenomenon is also intensified by agglomeration of mechanical impurities accumulated during oil operation.

Approbation of the research results

Increasing the volumetric temperature of the oil up to 120^0C leads to significant changes in the efficiency of boundary layer formation by the researched oils.

Firstly, from the first running cycles no metallic contact of surfaces at stopping is observed - up to N < (300 - 400) cycles a stable boundary film is formed, regardless of the type of oil used, reliably separating the contacting surfaces.

Secondly, a period of long breakdown of the lubricating layer at stopping (for commercial and used oil the specified period is 350 < N < 500 and 400 < N < 450 operating cycles, respectively) for both studied oil samples, after which effective formation of limiting adsorb layers in contact Gradual erasure of boundary layers is restored, leading to metallic contact of the surfaces is caused, in our opinion, by high shear rate gradients of the oil layer, reaching $0.7\text{-}10^{-6}$ s^{-1} and $1.6\text{-}10^{-6}$ s^{-1} respectively for commercial and waste oil samples. Triple reduction in the recovery period of the efficiency of formation of limiting films by long-life oil is associated with a higher concentration of surface-active substances in it, characterized by increased adsorption activity.

Third, a greater thickness of the boundary adsorption layers in the contact is traced throughout the 80% cycles of the studies when commercial oil is used. We assume that in this case, the most important parameter influencing the dynamics of boundary layer formation is the viscosity of the lubricant.

According to [6], oil in the initial state is a multicomponent homogeneous system, and in the process of oil operation it transforms into a heterogeneous system containing colloidal and suspended particles of different origin.

Let's consider main physical and chemical properties of Mobil-100-40 oil and their change during operation at 15 thousand km of run (Tab.1).

Table 1

Basic physical and chemical characteristics of Mobil-1 0w-40 engine oil

	Kinematic viscosity $\upsilon_{100}{}^{0}C$	Flash point,^{0}C	Alkaline number, mg КОН/г	Acid number	Ash content	Coking	Active elements of the additive	
							Ca	Zn
Oil sample	13,64	216	10,04	Відсутн.	0,92	1,23	0,32	0,96
Used oil sample (15 thousand km)	14,32 (+5%)	192 (-12%)	6,18 (-39%)	2,38	1,06 (+13%)	2,92 (+68%)	0,32	0,95
Maximum permissible values of the parameter	± 20 – 25% from the commercial oil indicator	< 170	- 50% from the commercial oil indicator	> 2,0	-	> 2,0	-	-

According to the results presented, the commercial synthetic motor oil is characterized by a high quality margin of SAE viscosity class, alkali number, flash point and meets all the requirements for this operational type of oil.

During operation, the oil is aging, which leads to a change in its physical and chemical characteristics. One of the main insufficient parameters is viscosity, however by results of our researches the value of the given parameter is stable enough parameter. This fact contradicts the change of another parameter - flash temperature, which tends to decrease, indicating the presence of two oil aging processes: partial penetration of fuel into the lubricant or partial degradation of hydrocarbon components under the influence of high speed gradients in the contact, which leads to the formation of lighter and volatile compounds. The established contradictions are explained by accumulation of mechanical impurities of organic and inorganic origin in the oil during operation, which are in the dispersed state, which is provided by effective properties of detergent-dispersing additive. The growth of mechanical impurities of organic origin, which indicates chemical transformations of the oil base, causes a significant increase in the acid number and degree of coking of the lubricant; the presence of mechanical impurities of inorganic origin is evidenced by increased ash content and stability of additive active elements (Ca and Zn), despite its intensive actuation, which is explained by effective dispersion of mechanical impurities constantly circulating in the lubricant, with their dilution, and the fact that their dispersion of mechanical impurities in the lubricant is not limited to the operating condition.

Consequently, the accumulation of a significant portion of mechanical impurities in the engine oil leads to significant changes in its initial physical state, which manifests itself in the transformation of a homogeneous multicomponent liquid of commercial oil into a colloidal heterogeneous solution of waste oil. This process causes stabilization of engine oil viscosity during operation, despite the fact that viscous additive is subject to temperature and mechanical degradation, fuel ingress dilutes oil, formation of light fractions during high-temperature cracking reduces the initial oil viscosity.

Thus, the absolute value of kinematic viscosity of commercial and waste oil does not reflect the change in the physical state of the lubricant, which must be taken into account when analyzing the kinetics of formation of the lubricating layer in the contact.

We assume that the established phenomenon of increase of efficiency of formation of boundary layers in contact in the conditions of increase of volume temperature of the oil at use of a commodity sample Mobil-1 0w-40 reveals potential possibilities both of base components of oil, and polyfunctional components of additives on increase of degree of adsorption. processes on elements of the tribocoupling Application of the used oil in these conditions also provides formation of stable boundary layer, but the basic role in this process belongs According to the work of Wenzel S.V. [7], highly dispersed mechanical impurities, adsorbed on friction surfaces, show effective antifriction and antiwear properties. We found that at the moment of friction coefficient stabilization, corresponding to operating time N > 500 cycles, this parameter for the used oil is 15% lower than the friction coefficient recorded when lubricating with commercial oil (Fig. 2).

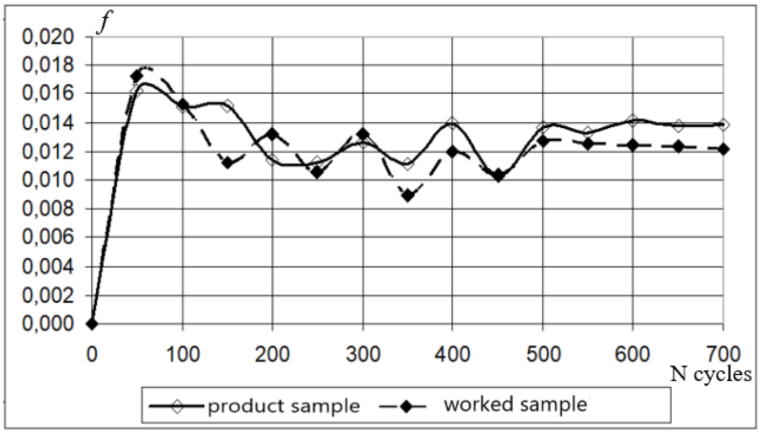

Fig. 2. Kinetics of friction coefficient change at operating time for commercial and used Mobil-1 0w-40 oil at 120^{0}C lubricant volumetric temperature

Note that at 20^{0}C volumetric oil temperature no increase in antifriction properties has been found with used oil (f for used oil is 40% higher than f established in contact with commercial oil lubrication), which is probably due to increased shear stresses in highly dispersed mechanical impurities due to increased thickness of adsorption layers by 30 - 40%, compared to commercial oil (fig. 3).

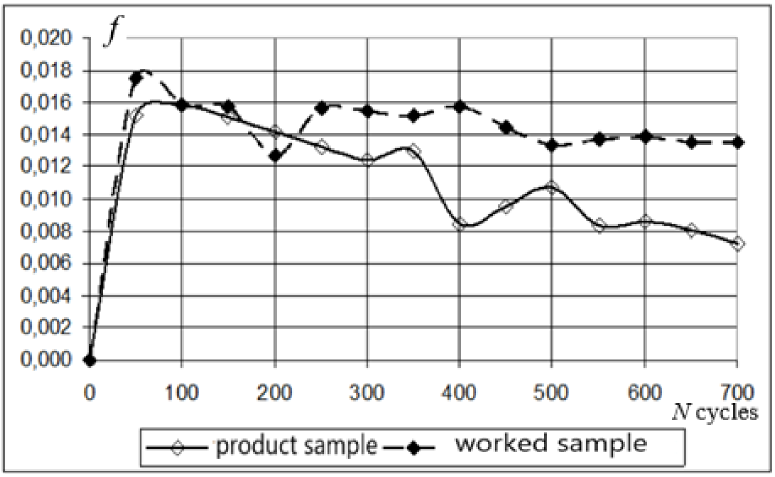

Fig. 3. Dependence of friction coefficient on working life at volumetric temperature of oils 20^{0}C

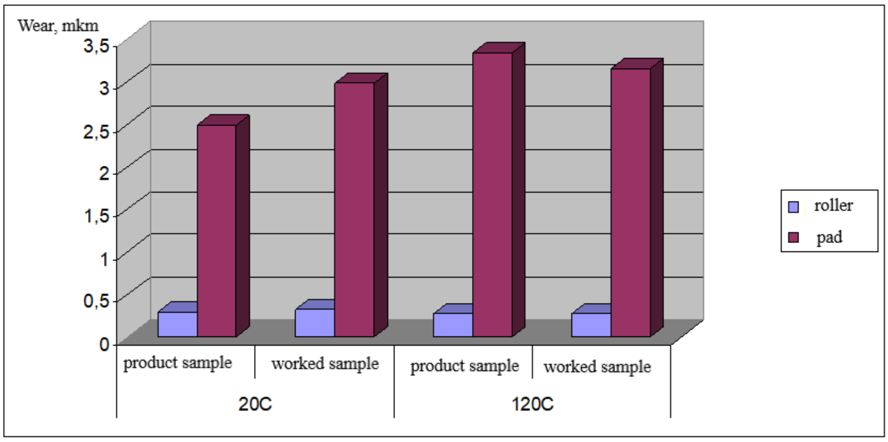

Fig. 4. Linear wear of the Cane friction surfaces (roller - shoe) at 700 operating cycles at volume temperatures of the lubricant 20^{0}C and 120^{0}C

The analysis of antiwear properties of oils showed that at 120^{0}C linear wear of steel 40X is on 5 % lower at use of used oil, and at 20^{0}C this parameter on 15 % exceeds indicators of wear, established at use of a commercial oil (fig. 4).

Conclusions

Consequently, increase of temperature causes growth of wear at use of commodity sample of Mobil-1 0w-40 oil due to oil "running-in", as a result of which colloid mechanical impurities and oxidation products which lead to stabilization of wear intensity are accumulated in it due to increase of additives activity and oxidation-polymerization processes. At 20^{0}C the intensity of the given activation processes probably essentially decreases that provides increase of wear resistance of contact surfaces, unlike at lubrication of elements of tribocoupling by the used oil containing the raised concentration of products of oxidation and colloidal mechanical impurity which form low-temperature deposits. intensifying their wear.

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Дмитриченко М.Ф., Савчук А.М., Туриця Ю.О., Міланенко О.А., Косенко М.І. Вплив температури на динаміку формування граничних плівок та знос контактних поверхонь в умовах ковзання.

В роботі досліджувалась ефективність формування граничних адсорбційних шарів на контактних поверхнях при змінних температурах та їх вплив на зносостійкість елементів трибоспряження.

Дослідження несучої здатності представлених зразків олив встановило, що в процесі пуску, при частоті обертання n > 150 об/хв., незалежно від терміну експлуатації оливи, в контакті реалізуються умови гідродинамічного мащення при об’ємній температурі оливи 20^0С.

Встановлено, що накопичення значної частини механічних домішок в моторній оливі призводить до суттєвих змін її початкового фізичного стану, що проявляється в перетворенні гомогенної багатокомпонентної рідини товарної оливи в колоїдний гетерогенний розчин відпрацьованої оливи. Даний процес обумовлює стабілізацію в’язкості моторної оливи при експлуатації, незважаючи на те, що в’язкістна присадка схильна до температурної та механічної деструкції, попадання палива розріджує оливу, утворення легких фракцій при високотемпературному крекінгу знижує початкову в’язкість оливи. Абсолютне значення кінематичної в’язкості товарної та відпрацьованої оливи не відображує зміну фізичного стану мастильного матеріалу, що необхідно враховувати при аналізі кінетики формування мастильного шару в контакті.

Аналіз протизношувальних властивостей олив показав, що при 120^0С лінійний знос сталі 40Х на 5% нижче при застосування відпрацьованої оливи, а при 20^0С даний параметр на 15% перевищує показники зносу, встановлені при використанні товарної оливи.

Підвищення температури обумовлює зростання зносу при використанні товарного зразка оливи Mobil-1 0w-40 за рахунок „припрацьовування” оливи, в результаті чого, внаслідок підвищення активності присадок та окислювально-полімеризаційних процесів, в ній накопичуються колоїдні механічні домішки та продукти окислення, які призводять до стабілізації інтенсивності зношування. При 20^0С, імовірно, інтенсивність даних активаційних процесів суттєво знижується, що забезпечує підвищення зносостійкості контактних поверхонь, на відміну при змащуванні елементів трибоспряження відпрацьованою оливою, яка містить підвищену концентрацію продуктів окислення та колоїдних механічних домішок, які утворюють низькотемпературні відкладення та спричинюють абразивну дію на контактні поверхні, інтенсифікуючи їх знос.

Ключові слова: мастильний шар, знос, масло, температура, поглинаючий шар, в'язкість, чутливість