UDC 621.891

R. G. Mnatsakanov, Dr.sc., O.Ye.Yakobchuk, A.M. Khimko, PhD,
M.S. Khimko, V.V. Tokaruk
(National Aviation University, Ukraine)

Analysis of the changes in the load-bearing capacity of lubricating layers of lithium greases at contact load changing

The paper presents the results of the investigation the bearing lubricating layers capacity of lithium greases. The paper presents the results changes in the thickness of the lubricating layer, the coefficient of friction of lithium greases ВНИИНП-286М and Aero Shell Grease 33 as a result of load changing pairs of friction.

Friction units lubrication.

Grease is widely used in various friction nodes of mechanical systems. Grease prevents its leakage from the friction unit, simplifies its use and gives good sealing properties. Such properties make possible to ensure optimum performance of the lubricant. The lubrication process can be dynamic and, accordingly, the lubrication must satisfy all modes of the robots. Lubricant has self-healing properties, at which fresh lubrication is supplied in case of film destruction and self-induced heat [1]. Lubrication is defined as a semi-liquid solid dispersion of the thickener in the liquid (base oil). It consists of a mixture of up to 90% mineral or synthetic oil and thickener. In almost 90% of all lubricants, the thickener is a metallic soap, which is formed by metal hydroxide to react with a carboxylic acid. As an example of this is lithium stearate, also called lithium soap. By changing the proportions of soap, oil and additives, it is possible to produce various lubricants for a wide range of applications [2].

The decision to use lubricant for the lubrication of the friction knods should be taken only after careful consideration of several factors, which include: demonstrating chemical resistance to oxidation and formation of deposits, easily separated from water, maintain the level of viscosity in the unit, resistance to foaming [3].

Investigation of the lubricants lubricity.

In this paper, we present the results of a study of the change in the bearing capacity of lubricating layers of lithium greases when the contract load changes and the characteristics of the lubricating film change depending on operating conditions.

These experiments were carried out at the СМЦ-2 facility with registration of tribocontact indicators in *online* mode. The experiments were performed under non-stationary conditions of friction: in the start-up mode (4 s) - stationary operation (7 s) - braking (3 s) - stop (3 s). Rolling mode with a slip of 20% was reproduced. The contact load for Hertz was 250, 400, 550 and 700 MPa. The first 300 cycles of operating time were carried out by dipping the lower roller into a tray with lubricant and periodically lubricating the roller. This facilitated a sufficient supply of lubricant to the contact zone and prevented the transfer of the tribosystem into a boundary lubrication regime.

As well as at choosing of lubricant for lubrication, it is necessary to take into account some characteristics. At lubrication, a stable lubricating film must be formed, which ensures that the friction unit is operable. Accordingly, the lubricant must have sufficient viscosity to ensure the formation of lubricant films at a shear rate that is predominant but not so high that friction losses are excessive. Lubricants must have good low-temperature properties, especially if the friction unit needs to be lubricated at low ambient temperatures. Further studies were conducted under conditions in which the supply of the lubricant was stopped. With 300 operating cycles, the bath was removed, the lubricant was removed from the contact surfaces (wiped with rags). Thus, the tribotechnical properties of the lubricant in the created experimental conditions of oil starvation are due to the lubricating, antifriction and anti-wear properties of the boundary films formed in the process of friction on the activated metal surfaces.

For the investigations, the samples were made of steel 30ХГСА (HRC 35). Lubrication of surfaces was carried out with lithium greases on a synthetic basis of Aero Shell Grease 33 and on a mineral basis Era ВНИИНП-286М.

The results of the studies were presented and analyzed only after 300 operating cycles. With the increasing of σ_{max} from 250 to 700 MPa, the bearing capacity of the lubricating boundary layer significantly reduced, the thickness decreases in 15 and 3.5 times, at lubricating surfaces with lubricants ВНИИНП-286М and Aero Shell Grease 33, cprrespondently (Fig. 1).

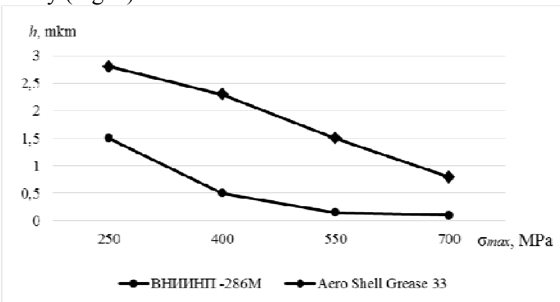

Fig. 1. Effect of contact loading on the thickness of the boundary lubricating layers

Synthetic grease Aero Shell Grease 33 is characterized by more effective lubricating properties, compared to the mineral oil under investigation. This is especially evident with loads exceeding 400 MPa. If, at σ_{max} 250 MPa, the thickness of the boundary films formed by synthetic lubricant components is 1.9 times greater than the thickness of the boundary films of the mineral grease, then at σ_{max} 550-700 MPa this value increases by 8-10 times.

Reducing the thickness of the lubricating layer determines, first of all, the correlation decrease in the antifriction properties of the lubricants under study. However, changes in the friction coefficient with increasing load are not so significant. In the investigated load range, the coefficient of friction is reduced by 3.4 and 2.5 times for mineral and synthetic lubricants, respectively (Fig. 2). First of all, this is provided by the local destruction of structured boundary lubricating layers, a decrease in the effective viscosity of the lubricant and the manifestation of hydrodynamic effects during mechanical and thermal melting of the film in frictional contact [4].

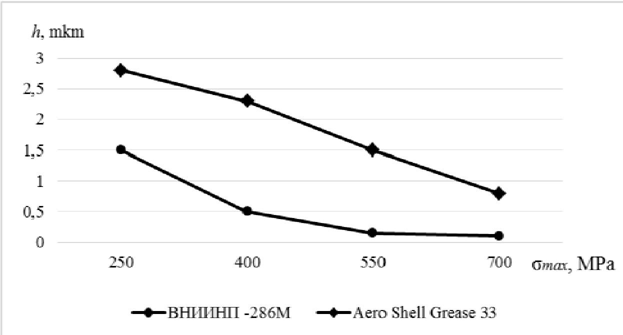

Fig. 2. Effect of contact loading on the change in the friction coefficient in the conditions of oil starvation

The mechanical destruction of the boundary layers occurs due to a sharp increase in the gradient of the shear rate of the lubricating film, which, according to [5], represents the ratio of the slip velocity in contact to the thickness of the lubricating film. If the gradient of the shear rate of lubricating layers increases for a mineral lubricant with a load increase from 250 to 700 MPa 20 times, then for a synthetic lubricant this parameter increases by 3.5 times (Table 1).

Table 1.

The change in the shear gradient rate of the lubricating layers and the number of cycles of operating the friction pairs before the indicating of the seizure

Lubricant materials	Contact loading, MPa			
	250	400	550	700
	Gradient of shear rate of lubricating layers, s-1			
Era ВНИИНП-286М	1,4·105	4,2·105	1,4·106	2,9·106
Aero Shell Grease 33	7,5·105	9,1·104	1,4·105	2,6·105
	Number of operating time cycles before seizure of friction pairs			
Era ВНИИНП-286М	300	80	50	20
Aero Shell Grease 33	900	150	130	100

Consequently, Aero Shell Grease 33 lubricant characterized by more effective lubricating properties, and its synthetic components by rheological characteristics are more stable to increase the shear rate gradient, in comparison with the mineral components of ВНИИНП-286М lubricant. The resistance of the lubricating film to mechanical degradation due to an increase in the shear rate gradient is the determining factor ensuring the normal performance of friction pairs under critical conditions. Table 1 shows the number of cycles of operating tribocells under oil starvation conditions prior to the appearance of the first signs of setting, which appeared visually on the friction track, with an increase in noise and stopping of the friction machine. Analysis of the results shows that with increasing load, the period of operating the tribosystem is acutely reduced: in the investigated range of contact loads, the efficiency of friction pairs is reduced by 15 and 9 times, respectively, at lubricating the contact surfaces of ВНИИНП-286М and Aero Shell Grease are lubricated.

At σ_{max} 250 MPa, according to the calculated dependence of the lubrication regime evaluation $\lambda = h / \sqrt{R_{a1}^2 + R_{a2}^2}$ [6], the elastohydrodynamic (λ = 3.13) and hydrodynamic (λ = 5.83) lubrication modes are realized in the contact using lubricants ВНИИНП-286М and Aero Shell Grease 33 respectively. Consequently, the contact surfaces are separated by a sufficient layer of lubricant, which ensures the localization of tangential shear stresses in the thin boundary layer of the lubricant, which helps to reduce both external force impacts and surface deformation of thin metal layers.

Conclusions. The destruction of a lubricating film in friction is one of the leading factors responsible for the intensification of the energy processes occurring in the contact zone. First of all, this develops itself in the violation of structural adaptability of contact surfaces and lubricant under critical friction conditions, the destruction of previously formed metastable structures. The transition of the tribosystem into a thermodynamically unstable state first of all is characterized, by the sharp activation of the metal due to the stress concentration at the local sections of the frictional contact at the places of destruction of the screening film of the lubricant, which is shown in the increasing of the specific friction work.

References

1. N. DeLaurentis, A. Kadiric, P. Lugt, P. Cann The influence of bearing grease composition on friction in rolling/sliding concentrated contacts Tribol Int, 94 (2016), pp. 624-632.

2. Grease lubrication – bearings [Електронний ресурс] // tandwiel.info – Режим доступу до ресурсу: http://www.tandwiel.info/en/gearboxes/grease-lubrication-bearings/.

3. When to Use Oil or Grease for Bearing Lubrication [Електронний ресурс] // WP Group. – 2015. – Режим доступу до ресурсу: www.thewp-group.co.uk/iqs/dbitemid.500/rp.10/sfa.view/wpgroup_news.html.

4. Ляшенко Я. А. Феноменологическая теория плавления тонкой пленки смазки между двумя атомарногладкими твердыми поверхностями / Я. А. Ляшенко, А. В. Хоменко, Л. С. Метлов // Журнал технической физики. – 2010. – Т. 80, № 8. – С. 120-126.

5. Порохов В. С. Трибологические методы испытания масел и присадок / В. С. Порохов. – М.: Машиностроение, 1983. – 183 с.

6. Дмитриченко М. Ф. Триботехніка та основи надійності машин: навч. посібник / М. Ф. Дмитриченко, Р. Г. Мнацаканов, О. О. Мікосянчик. – К.: ІНФОРМАВТОДОР, 2006. – 216 с.