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Investigation of the phenomenon of lubrication starvation in conditions of rolling with sliding

The paper considers the problem of the occurrence of oil starvation conditions in tribocontact under conditions of rolling with sliding. It was found that when the lubricant is forcibly removed from the friction surface, the rate of destruction of the lubricating layer increases 10 times compared to the conditions when the supply of lubricant to the tribocontact is stopped.

Relevance of the topic of research.

During the operation of machines and mechanisms, the friction nodes of which transmit large loads at high sliding speeds and temperatures, jamming occurs - the process of the occurrence and development of damage to the friction surfaces as a result of adhesion and transfer of material [1].

The jamming process is significantly influenced by such parameters as load, sliding and rolling speed, roughness of contact surfaces, type and structure of metal, temperature, physical-chemical characteristics of the lubricating material and the environment, the amount and quality of additives to the base oil, the method and mode of lubrication and other factors [2].

Jamming refers to emergency types of destruction of friction surfaces, because, unlike others, once it occurs, it can lead to the complete unsuitability of the mechanism for further operation within a short time.

The destruction of the lubricating layer is a necessary condition for the occurrence of jamming. Information about the nature of the destruction of the lubricating layer and the reasons that cause this process are limited, so it is difficult to present, let alone predict, this process on a full scale based on the existing experimental and theoretical materials.

The destruction of the lubricating layer occurs due to two main reasons, which, in turn, are divided into many sub-reasons. This is the metal of the friction surfaces and the lubricating material, the interaction of which is characterized by a spectrum of mechanical, physical-chemical and thermal processes occurring at the interface of phases. However, it is generally known that jamming occurs at temperatures that do not significantly affect the properties of the material. First of all, these are volumetric properties of the material.

The existing methods of measuring the thickness of the lubricating layer make it possible to record changes at sufficiently large values. In cases where the lubricating layer is thin, these methods are not sensitive. The destruction of the lubricating layer is fixed by increasing the coefficients of friction. But it is the lubricating layers of small thickness that determine the kinetics of further processes that lead to catastrophic wear.

The purpose of the study was to find the regularity of the change in the thickness of the lubricating layer during the period of oil starvation and, especially, in the area immediately before the jamming of the contact surfaces.

Research objects and experimental conditions.

Cylindrical rollers with a diameter of 50 mm from the materials of the same name, 9ХС steel with a hardness of HRC 55 and 30ХГСА steel with a hardness of HPC 35 were used as samples. The initial roughness of the working surfaces is 0,32 μm. The contact stress was 400 MPa. The friction surfaces were lubricated by immersion in an oil bath. Aero Shell Grease 33 was used as a lubricating medium.

The tests were carried out according to the following scheme on the СМЦ-2 installation with online registration of tribocontact indicators. The moment of friction, the frequency of rotation of the rollers, the temperature of the lubricant, the voltage drop in the lubricating layer in the contact are recorded and processed on a PC (ProfiLab software) in real time with a graphical representation of their changes [3]. The rollers were run-in in rolling mode with 3, 10 and 20% sliding, respectively, the total rolling speed was 5,5, 5,1 and 4,8 m/s. After the running-in was completed, which was evidenced by the stabilization of the thickness of the lubricating layer, the bath with the lubricating material was removed and the oil starvation mode was simulated. Moreover, the mode of accelerated oil starvation (lubricant is completely wiped off the friction tracks after running in) and the mode of normal oil starvation (lubricant is not wiped off the friction tracks) were simulated.

In fig. the change in the thickness of the lubricating layer during the run-in period for the selected materials in different conditions is shown.

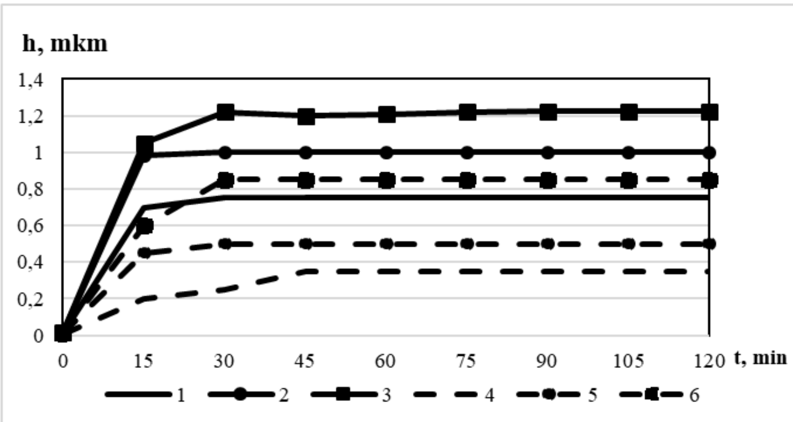

Fig. Change in the thickness of the lubricating layer during the run-in period: 1, 2, 3 – steel 9ХС; 4, 5, 6 – steel 30 ХГСА, 1.4 – sliding 3%; 2, 5 – 10% sliding; 3, 6 – 20% sliding.

The analysis of the kinetics of the formation of the lubricating layer on the contact surfaces shows that, regardless of the amount of sliding of the contact surfaces, the permanent thickness of the lubricating layer formed on the 9ХС steel after running-in is approximately 30 – 40% greater than the layer thickness recorded on the 30ХГСА steel.

Another regularity established in the experiments is the effect of the degree of sliding on the formation of the thickness of the lubricating layer in the tribotechnical contact. Regardless of the type of material of the contact surfaces, an increase in sliding from 3 to 20% causes an increase in the thickness of the lubricating layer in the contact, on average, by a factor of 2. The mechanism of this phenomenon is based on the positive influence of tangential shear stresses as a result of sliding, more intensive activation of friction surfaces, as a result of which the thickness of the lubricating layer increases.

In the process of studying the regime of oil starvation, during the study of the change in the thickness of the lubricating layer, no additional lubricant was supplied to the contact zone, which led to the absence of a hydrodynamic thickness of the lubricating layer. Oil starvation was studied in rolling mode with 20% sliding on 9XC steel. It is known that the initial thickness of the film is the boundary layers of the lubricant, which were formed on the contact surfaces activated by friction during the run-in period, the thickness of which is, on average, 0,3 μm.

Under the conditions when the lubricant was not wiped from the surfaces of the rollers, a sharp decrease in the thickness of the layer to 0,1 μm is immediately observed, but up to 8 min. during the tests, the thickness increases, later in the process of development there is a period of fluctuations in the thickness of the layer with a certain regularity. The difference in thickness is approximately 0,25 – 1 μm. At the final stage of the tests, an increase in the thickness of the lubricating layer was established, which reached an initial constant value during the run-in period. After that, the thickness of the lubricating layer begins to decrease until it is completely destroyed.

In the contact zone, smoking of the lubricating material was observed, although there were no sharp changes in the rotation frequency of the samples. It should be noted that the process of destruction of the lubricating layer does not occur like an avalanche, it seems to be stretched over time. In this experiment, the duration of this process is 55 minutes.

The next study was carried out when the grease was thoroughly wiped from the friction surfaces. In contrast to the previous experiment, when moving to critical lubrication conditions, a sharp increase in the thickness of the lubricating layer is observed to a value equal to the constant value of the layer thickness during the run-in period (the film thickness of the boundary layers increases from 0,3 to 1,21 μm). Then there is an equally sharp decline in the thickness of the layer, its destruction and adhesion of working surfaces. This process continues for 5 minutes, i.e. when the lubricant was wiped from the friction tracks, the rate of destruction of the lubricating layer increased 10 times compared to the experiment where the lubricant was not wiped.

This suggests that the forced removal of the lubricant from the contact zone leads to an increase in the rate of its destruction. Formed in the process of friction on the activated metal surface, the boundary layer of the lubricant is heterogeneous in its structure. First, the monomolecular layer immediately adjacent to the surface is connected to the metal by strong chemical bonds due to the formation of metal soaps as a result of the chemical reaction between the surface of the metal and lithium soap (the main component of the investigated lubricant). However, this layer can also be heterogeneous due to the presence of a synthetic mixture of hydrocarbons and ether, corrosion and oxidation inhibitors in the lubricant. Secondly, the boundary layer is characterized by anisotropic properties as it moves away from the metal surface, which is manifested in the weakening of the influence of the solid phase of the metal on the components of the lubricant.

Conclusions.

When the lubricant is forcibly removed from the contact zone, there is a rapid disorientation of the boundary layers due to the gradient of the shear rate, a violation of the integrity of the boundary layer, which leads to sticking of the contact surfaces.

In the case when the lubricant is not forcibly removed from the contact zone, there is an additional "reserve" of the lubricant due to the layers furthest from the metal surface, which are connected to the surrounding molecules by weak Van der Waals interaction forces and can freely migrate along the surface by itself preventing direct metal contact.

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