Research of load and speed parameters of the health of rolling bearings

B I Kovalsky, N N Lysyannikova, K A Knyazev, V G Shram, A V Lysyannikov and E G Kravtsova

Siberian Federal University, 82 Svobodny Avenue, Building 6, 660041, Krasnoyarsk, Russia

E-mail: Nataly.nm@mail.ru

Abstract. The influence of the lubricant base and the rotation speed of rolling bearings on the formation of an elastohydrodynamic layer is studied. The method of control parameters of the formation of an elastohydrodynamic layer in rolling bearings is presented, which allows one to determine the parameters at which an elastohydrodynamic layer is formed on the surfaces of the rolling bodies. The results of a study of the effects of radial, axial and common loads are presented. As a result, the experimental data were obtained and analyzed, and graphical dependencies were constructed that clearly demonstrate the formation of an elastohydrodynamic layer.

1. Introduction

An important feature of the use of rolling bearings in various bearings is their lubricant, both liquid lubricants and greases. There are a number of devices for assessing the health of rolling bearings and methods for calculating rolling bearings for durability [1-5]. These methods and devices take into account all the friction parameters and the geometry of the rolling bodies, however, the performance of the rolling bearings depends on such parameters as the load, bearing rotation speed, lubricant properties, temperature, which provide the conditions for creating an elastohydrodynamic layer and there are still no scientifically based methods for determining a range of these parameters at which an elastohydrodynamic layer is guaranteed to form between the rolling bodies.

In this regard, the aim of the work is to determine the influence of the properties of oils of various basic bases on the conductivity range at which an elastohydrodynamic layer of lubricant is formed taking into account axial and radial loads, properties and purpose of the lubricant and design features of a rolling bearing based on the use of a device for diagnosing rolling bearings [6].

2. Method and results of research

For experiments, mineral Mobil Super 15W-40 SJ / CF, partially synthetic Spectrol GLOBAL 15W-40 SJ / CF and synthetic Havoline Energy SAE 5W-30 SL / CF motor oil were selected. As samples, a rolling bearing made of IIIX15 steel was used, the cage of which was 80 mm. During the test, a device was used to diagnose rolling bearings [7].

The research methodology was as follows. Using a frequency converter, the rotation speed of the bearing was set from 200 to 1400 rpm. The time of each experiment was 40 minutes, the temperature
was maintained in the range from 25 °C to 60 °C, the rotation speed of the rolling bearing increased to 1400 rpm with a step of 200 rpm.

Experiments were carried out without bearing load, with axial, radial, and also with the use of axial and radial (joint) loads. In an experiment using loads, an axial and radial load of 6 kg s (60 N) was applied.

Each experiment was carried out three times under the same conditions to determine the error of the readings, then we plotted the average values with the error limits at the measurement points.

The data were recorded on a computer in the form of a diagram of the transmitted current, then they were mathematically processed and graphical dependences of the current on the frequency of rotation of the bearing were constructed to determine the formation of an elastohydrodynamic layer.

Figure 1 shows the dependence of current on the frequency of rotation of a rolling bearing with mineral oil. It has been established that with an increase in the number of revolutions, a decrease in the current value occurs, which indicates the formation of an elastohydradynamic layer and an increase in its strength. In the absence of load (curve 1), the formation of an elastohydradynamic layer occurs faster at 1200 rpm, current decreased by 80%. The axial load (curve 2) has a greater effect on the formation of an elastohydradynamic layer on friction surfaces than the radial load (curve 3). The combined application of axial and radial loads (curve 4) is the most difficult combination for the formation of a lubricating layer.

![Figure 1. Dependences of current on the frequency of rotation of a rolling bearing with mineral oil: 1 - no load, 2 - axial load, 3 - radial load, 4 - joint load.](image)

In the study of partially synthetic (figure 2) and synthetic oils (figure 3), the same tendency for current values to vary with the speed of the rolling bearing is observed as in the study of mineral oil. Less influence on the formation of the elastohydradynamic layer is used when testing joint load. The thickness of the elastohydradynamic layer without load at the maximum number of revolutions of the rolling bearing (1400 rpm) exceeds by 10% the thickness with axial load, 40% thickness with radial load, and 60% thickness with joint load.
Figure 2. Dependences of current on the frequency of rotation of a rolling bearing with partially synthetic oil: 1 - no load, 2 - axial load, 3 - radial load, 4 - joint load.

The distinctive feature is that when using synthetic oil (figure 3), the radial and joint load have the same effect on the formation of the elastohydrodynamic layer to the speed of the rolling bearing at 1000 rpm, with a further increase in the number of revolutions, a more durable elastohydrodynamic layer is formed at the radial load, as evidenced by a decrease in the current index by 20%.

Figure 3. Dependences of current on the frequency of rotation of a rolling bearing with synthetic oil: 1 - no load, 2 - axial load, 3 - radial load, 4 - joint load.

Based on the studies, we can conclude that the formation of a more durable elastohydrodynamic layer, when using axial and radial loads in experiments, is affected by the rotational speed. The greatest frequency of rotation of the rolling bearing is required for the formation of an elastohydrodynamic layer under the action of a joint load than the action of each separately.
Figure 4. Dependences of current on the frequency of rotation of a rolling bearing without load (a), with axial load (b), with radial load (c) and joint load (d): 1 - mineral oil, 2 - partially synthetic oil, 3 - synthetic oil.

Figure 4 shows the dependences of current on the frequency of rotation of a rolling bearing without load (a), with axial load (b), with radial load (c) and joint load (d) of mineral, synthetic and partially synthetic oils. After analyzing the results of the study, all samples observed common signs:

- the formation of an elastohydraulic layer begins after an increase in the frequency of rotation of the rolling bearing 400 rpm;
- when using mineral oil, with an increase in the frequency of rotation of the rolling bearing, the current decreases and its values are less than when using partially synthetic and synthetic oils, which indicates the formation of a more durable layer compared to other oils.

A distinctive feature when using axial, radial and joint loads is the difference in the current values and the intensity of formation of the elastohydraulic layer. So, when using axial and radial loads, for example, when the rolling bearing rotates at 1000 rpm, the resulting film using mineral oil is about 1.4 times more durable than synthetic and partially synthetic oils.

The duration of the formation of the elastohydraulic layer is exerted by the quality of the oil and its properties, which contribute to the formation of this layer with increased electrical resistance.

During the experiment, it was proved that with the use of mineral oil, the resulting elastohydraulic layer is more stable and begins to harden at a lower speed of the bearing, in comparison with synthetic and partially synthetic oils. The dependence of the formation of an elastohydraulic layer on such parameters as axial and radial loads was also determined.

3. Conclusions
The method has been developed to control the parameters of the formation of an elastohydraulic layer in rolling bearings, which allows one to determine the range of changes in the contact conductivity of samples at which an elastohydraulic layer of lubricant is formed taking into
account axial and radial loads, properties and purpose of the lubricant, and design features of a rolling bearing. The developed method for controlling the parameters of the formation of an elastohydrodynamic layer in rolling bearings allows one to determine the parameters of rolling friction at which an elastohydrodynamic layer is formed on the surfaces of rolling bodies, at which the bearing life is maximum.

References
[1] Kovalsky B I, Sorokin G M and Efremov A P 1983 Method for determining the lubricity of oils USSR Author's certificate 1,054,732, 15 Nov 1983
[2] Korchagin Yu V, Mozolyuk V A and Golubev A P 1982 Device for monitoring the condition of a rolling bearing USSR Patent 2,217,031, 30 Mar 1982
[3] Salishchev S N, Korndorf S F and Podmasteriev K V 1982 Device for monitoring the condition of bearings USSR Patent 2,964,516, 07 Oct 1982
[4] Chechuevsky V P, Frolov V I 1991 Device for assessing the health of a rolling bearing RF Patent 2,006,019, 15 Jan 1994
[5] Podmasteriev K V 1998 Device for the diagnosis of rolling bearings RF Patent 2,113,699, 20 Jun 1998
[6] Kovalsky B I, Lysyannikova N N, Bezborodov Yu N and Derezin A N 2015 Device for the diagnosis of rolling bearings RF Patent 2,567,086, 27 Oct 2015