Study of the lifetime and lubricity of greases for rolling bearings

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Abstract. This article presents a methodology for the study of the relative lifetime of lubricating greases operating in rolling friction. An experimental assembly is described for testing lubricating greases in order to determine the friction coefficient and relative resource. A criterion for assessing the relative resource of lubricating greases has been proposed. The test results of the proposed method were obtained and presented.

1. Introduction

It is technically difficult to determine the resource of greases operating in rolling friction conditions. Resource requirements for various mechanisms are constantly growing. The performance of assemblies containing rubbing components, largely depends on the characteristics and quality of the greases used. At the moment, lifetime testing is a rather laborious and expensive process. The information about the resource of new greases not in open printing is significantly limited.

The bearing capacity, an ultimate load capacity, an anti-wear and extreme pressure properties are determined on a four-ball machine [2], which is not intended for life tests. The methodology for determining the grease resource was proposed in 1958 by K.L. Johnson. In accordance with his methodology, tests are carried out on a spiral tribometer [1,3,4]. The degradation of the lubricant greases occurs in the area of movement of the ball, which will include both rolling and spinning with slipping. There are works in which the grease resource is determined according to the “roller-plane” scheme [5].

The aim of this work is to determine the lifetime and lubricity of greases in rolling friction.

2. Materials and test procedure

The tests were carried out for four types of greases, the composition and main characteristics of which are presented in table 1.

For greases life tests a laboratory bench has been developed, the work of which is based on measuring the friction coefficient in a rolling bearing with pre-applied lubricant, Figure 1. The test rolling bearing (position 1 in Figure 1) with applied grease (20 ... 26 mg) on the lower ring is mounted on a rotating frame 2, which is driven by an electromechanical drive 3.

The resistance moment in the rolling bearing was measured by a load cell 4. The axial force on the bearing Fb was created using a pneumatic cylinder 5 and a linkage system 6. The shaft, with which the power is transmitted from the lever 6 to the test bearing, has a thrust bearing 7 in the upper part and a...
swivel joint with the mandrel of the upper bearing ring, which is secured by a pin. Thus, the load cell mounted on the shaft allows measuring the resistance moment with high accuracy.

As a data collecting instrument, myDAQ series equipment, National Instruments has been used. The test report is generated in the LabVIEW 2017 graphical programming environment. The experimental data were processed using the DIAdem 2017 program.

Table 1. The main characteristics of the LGs tested.

| Base oil                        | Thickener                        | Viscosity<sup>a</sup> at -40°…-50°C, Pa·s | Temperature range of operation<sup>b</sup> (°C) |
|---------------------------------|----------------------------------|-------------------------------------------|---------------------------------------------|
| VNII NP-274 GOST 19337-73       | Polyorganosiloxane (HS-2-1VV liquid) | 54                                       | -80…+160                                    |
| «AMETHYST» (VNII NP-284) TC 38.1011029-85 | Perfluoropolyether                | 210                                      | -110…200                                    |
| NIKA TC 38.1011032-85           | Perfluoropolyether                | 79                                       | -130…200                                    |
| «EMERALD» TC 38.401-58-92-94    | Perfluoropolyether                | 100                                      | -130…160                                    |

<sup>a</sup> According to a manufacturer  
<sup>b</sup> long term operation

Figure 1. The laboratory bench for greases life testing. 1- axial bearing test; 2- rotating bed plate; 3- electromechanical drive; 4- load cell; 5- pneumatic cylinder; 6- linkage system; 7- thrust bearing
For the tests, an axial bearing 8104 (according to GOST 7872-89) from ISB (Italy) with an internal diameter of 20 mm was used. During assembly, a predetermined amount of lubricant (20 .. 26 mg) is to be applied to the lower bearing ring. To determine the LGs mass, an Ohaus Adventure analytical balance with an accuracy of ± 0.1 mg was used. The material was taken from used bearings 52100.

The rolling resistance torque $T_r$ arising in the bearing is calculated from the condition of equilibrium of the moments acting on the axis of the bearing:

$$ T_r = F \cdot l, $$

where $F$ – force acting on the load cell, $l$ – load cell installation shoulder.

The lubricity of greases was evaluated by the coefficient of friction, which was calculated by the formula (2):

$$ f = \frac{T_r}{r_{fr} \cdot F_b}, $$

where $F_b$ – axial force acting on the bearing; $r_{fr}$ – friction radius (radius of the ball raceway); $T_r$ – rolling resistance torque, figure 1. The condition for completing the test is three times the steady-state value of the coefficient of friction.

To estimate the resource, we used the parameter of the greases relative lifetime $R$, formula (3), which is the ratio of the number of revolutions $n$ before the increase in the coefficient of friction (the corresponding moment of time $T$ is shown in figure 2) to the greases mass $M$, which was applied to the lower bearing ring.

$$ R = \frac{n}{M}, $$

where $n = \omega \cdot T$, $\omega$ - bearing rotation speed; $T$ – greases operating time, $M$ – mass, mg.

Experiment Conditions:
- Bearing rotation speed - 50 rpm;
- Axial force on the bearing - 2800 N;
- Specific pressure - 1.32 GPa;
- Ambient temperature - 22 ° C

3. Results and discussion
As a result of the work, the characteristics of the relative resource and lubricity of greases in atmospheric conditions are obtained. The results of one series of experiments for each grease are shown in figure 2.
According to the graph in figure 2, it can be seen that grease samples No. 2 and 4 («AMETIST» and «EMERALD», respectively) have not only a high friction coefficient compared to other samples, but also a relatively large amplitude of oscillations of the current value of the friction coefficient $A_f$. Samples with a high friction coefficient have a high viscosity relative to other samples (table 1) and the same base is perfluoropolyether. It is worth noting that sample No. 4 («EMERALD»), showing the maximum friction coefficient among the studied greases, includes metal-cladding additives [5].

As a result of the tests, we obtained the relative resource of each grease according to the proposed method and the average value of the friction coefficient. Figures 3, 4 show confidence intervals of the average values of the relative resource and friction coefficient (the sample size for each grease was $n = 3$).

![Figure 3. Greases relative lifetime](image)

![Figure 4. Friction coefficient in bearings according to test results](image)

The best indicators for the relative resource and friction coefficient were obtained when testing samples No. 1 (VNII NP-274) and No. 3 (NIKA). Furthermore, sample No. 1 has not only good friction coefficient and resource indicators, but also a relatively stable low amplitude of friction coefficient oscillations, figures 2,3,4. Such results are explained by the composition (liquid base - polyorganosiloxane (HS-2-1VV liquid)) and the lowest viscosity of the lubricant ST 54 (table 1), which is different from other test samples.
4. Conclusions

1. The developed experimental bench makes it possible to evaluate the relative lifetime and friction coefficient of greases working in normal climatic conditions. The repeatability of test results is observed.
2. The best indicators on the relative lifetime and friction coefficient were obtained during testing of samples No. 1 (VNII NP-274) and No. 3 (NIKA);
3. Sample No. 4 («EMERALD») with an increased range of operating temperatures and a metal-cladding additive in the composition has the lowest relative lifetime and high friction coefficient among the studied greases.

5. References

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