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ADHESION PROPERTIES OF RECYCLING GREASES

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Abstract

The results of the study of the adhesion properties of recycling greases expressed in terms of the residual amount of grease that is stored on a metal plate after testing in a laboratory centrifuge are presented. It was established that the investigated samples of recycling greases in the range of the thickness of the deposition layer up to 1.0 mm, by their adhesion properties, are fully suitable for using in all types of bearings operated with a rotation speed of up to 2500 rpm. From the number of investigated grease samples, samples with a deposition layer thickness of 0.1 mm o have evidence of fairly high values of the rotational speed when the threshold value of the residual amount of grease is reached.

Keywords*: Recycling grease; Adhesive properties; Layer thickness; Rotational speed; Waste oil; Centrifuge.*

1. Introduction

Adhesive properties are among the most important performance properties of greases. Lubricating greases, in particular anti-friction, are operated in special conditions, as compared with other lubricants, characterized by significant speeds of surface rotation as well as an increase in the operating temperature. Only oils that have adhesion to the metal surface, that is, do not slip from it under the action of various physical forces; can ensure reliable and durable operation of the unit assembly, due to its constant lubrication in such conditions.

2. Research objective

Modern global trends in the chemical industry are based on the principle of involving various types of industrial and household waste as a raw material in the technological process. Such technologies are called recycling, and are quite successfully implemented in the United States and other developed countries of the world [1], helping to improve the environmental situation in these countries and reduce the cost of the final product. Using this principle in the production of plastic lubricants, as one of the most popular lubricating products, it is possible to propose to obtain recycling plastic lubricant based on used lubricating oils. The annual amount of these oils, formed in Ukraine, allows them to be used as a raw material for the technological process on an industrial scale. In order to significantly reduce the cost of production of recycled oils, thickeners, they can be crushed polymer waste, in particular high and low pressure polyethylene, which, in addition to its low cost and significant amount, will allow obtaining lubricants, which by their properties do not flow to foreign analogues [2]. However, to use the obtained greases practically in the sliding bearings, it is necessary to examine in detail their adhesive properties [3].

Among the existing theories of adhesion, the most common is the adsorption-molecular theory, which considers adhesion as a result of the formation of molecular interaction forces between the oil and the metal surface [4]. In general, the whole mechanism of adhesion of grease to the metal surface of the bearing can be divided into several stages. The initial stage is characterized by the movement of the molecules of the dispersion phase of the oil to the metal surface with a certain orientation within the phase layer and ends in close contact between the molecules of the oil and the surface. The main factors contributing to the contact of the molecules of the oil and the metal surface is the temperature and the force with which the lubricant is applied to the metal surface. The distribution of lubricant over the surface is accompanied by surface diffusion and migration of the molecules of the dispersion medium of the lubricant.

In the second stage, an intermolecular interaction arises between the metal surface and the grease applied to it, due to various chemical and physical forces. This stage begins when the distance between the molecules of the oil and the surface becomes less than 5 Å. Then between molecules of oil and the surface intermolecular forces of interaction start to act, they include hydrogen forces, Van der Waals forces and others. Thus, an oil film will be formed on the metal surface; it consists of a layer of adsorbed molecules and a layer of molecules adjacent directly to the metal surface.

In the technical literature for determining the adhesive properties of greases, various methods are proposed. Thus, in the work [5], the adhesion properties of greases, which contain various polymers, are used in sliding and rolling bearings and are determined by using the ASTM D2979 method, which is based on the determination of the force of material separation from the surface.

Also, there is a method for determining the adhesion properties of the grease according to the time during which the test oil contained a wooden block weighing 450 g to its detachment. A piece of sheet steel, 36.0 x 76.0 mm in size, was attached to the block on which the test oil was applied, so that its volume in the containment zone for each test was constant at 8.2 cm^3 [6].

Known work [7], in which to determine the adhesion properties of greases, it is proposed to use an automatic device that allows measuring the force that is applied to the measuring head with a diameter of 10 mm. This head consists of the lower and upper parts, between which there is a layer of the test oil. Parts of the head are driven by an electric motor.

It is proposed to determine adhesion of plastic grease in the work [8] using the adhesive tape on polyethylene terephthalate basis and it was determined on two parallel samples and at least three sites of each sample (plate). On the surface of the sample at a distance of at least 10 mm from the edge of the plate, at least five parallel cuts were made to the metal at a distance of 1.2 or 3.0 mm from each other using a cutting tool. Then, a perpendicular incision was made of a strip of adhesive tape measuring 40x100 mm and pressed tightly, leaving one end of the strip free. With a quick movement, the tape was ripped perpendicular to the coating. Adhesion by the method of parallel incisions was evaluated visually on a three-point scale.

Note that the main disadvantage of the methods described above is the determination of the adhesion ability of grease without regard to the conditions that are stored during the actual operation of the oil in the assembly unit.

The closest to the actual operating conditions of the grease in a sliding bearing is a method for determining the adhesion properties of greases. This method includes fixing the rotational speed of a metal surface at which the test oil slips out and determines the residual amount of grease on the surface [9].

3. Results and discussion

Using the method of testing the adhesion properties of oil using a centrifuge, we will try to investigate the adhesion properties of the samples of recycling greases in which hydraulic oil HLP-46, engine oil SAE 15W-40 API SL/CI-4 and transmission oil SAE 80W-90 GL-5 were used as a dispersion medium. Samples of oils, using a set of punches that had a thickness of 0.1, 0.5 and 1.0 mm, were applied to the prepared metal plates and placed in the slots of a laboratory centrifuge. It should be noted that for maximum compliance with the operating conditions of grease in a sliding bearing, the plates with oil samples applied on them were located in the centrifuge slots parallel to the axis of rotation. The results of the determination of the adhesion properties of the samples of recycling oils under study, which are expressed in mass percent of oil, remained on the plates after rotation at a certain speed, are shown in Fig. 1-3.

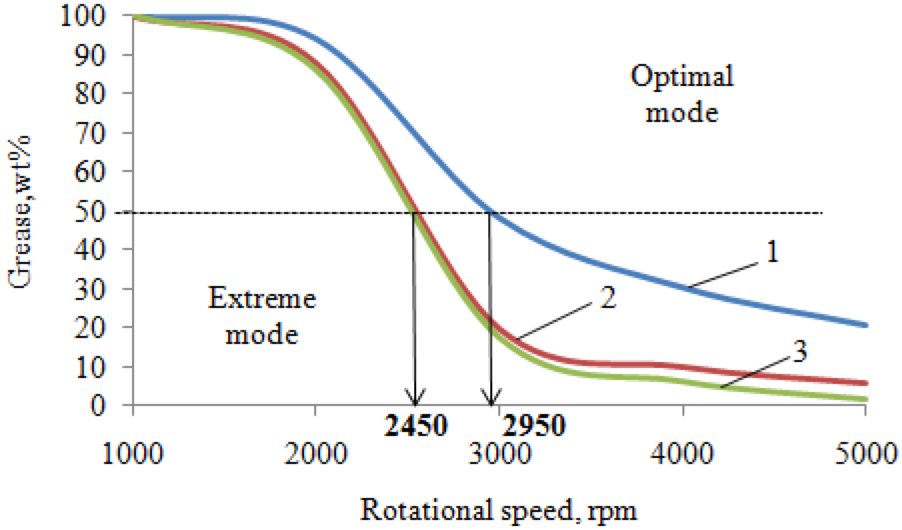

Fig. 1. Dependence of adhesion ability of grease based on used hydraulic oil HLP-46 on the rotation speed: 1 – 0.1 mm; 2 – 0.5 mm; 3 – 1.0 mm

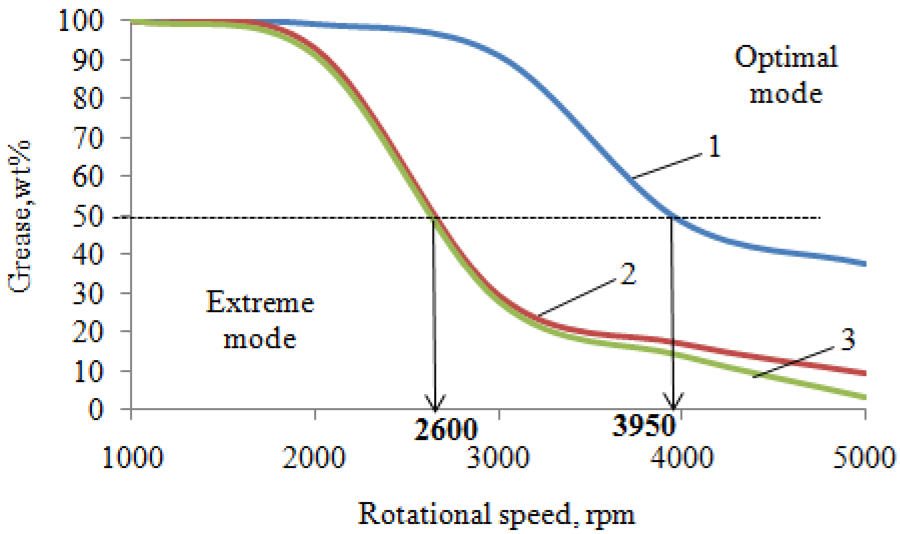

Fig. 2. Dependence of adhesion ability of grease based on used engine oil SAE 15W-40 API SL/CI-4 on rotational speed: 1 – 0.1 mm; 2 – 0.5 mm; 3 – 1.0 mm

To determine the optimal (normal mode) and extreme (mode of rapid reduction of grease in the bearing, which in the final stage can lead to lubricant starvation and bearing failure), the threshold value of the tested oil samples was set to a 50 % loss of initial the mass of the sample of oil that was applied to the metal plate. This value was taken in accordance with many years of practical experience in the use of greases during the operation of sliding bearings. Thus, the recommended amount of lubrication stuffing for angular support ball bearings for spindles of high-speed machine tools is 15 ± 2 % of the internal space and for engines 20–30 % of the internal space [10].

Analyzing the data obtained, we have noted that all the studied oil samples in the rotational speed equal to 2000 rpm and they are fully preserved on metal plates. With a further increase in the speed of rotation in the oil samples on the basis of HLP-46 oil (Fig. 1), there is a rapid decrease in the residual amount of grease on the plates. So, a sample with a layer thickness of 0.1 mm reaches a threshold value of 50 wt%. At a rotation speed of 2950 rpm and samples with a layer thickness of 0.5 and 1.0 mm reach this value only at 2450 rpm.

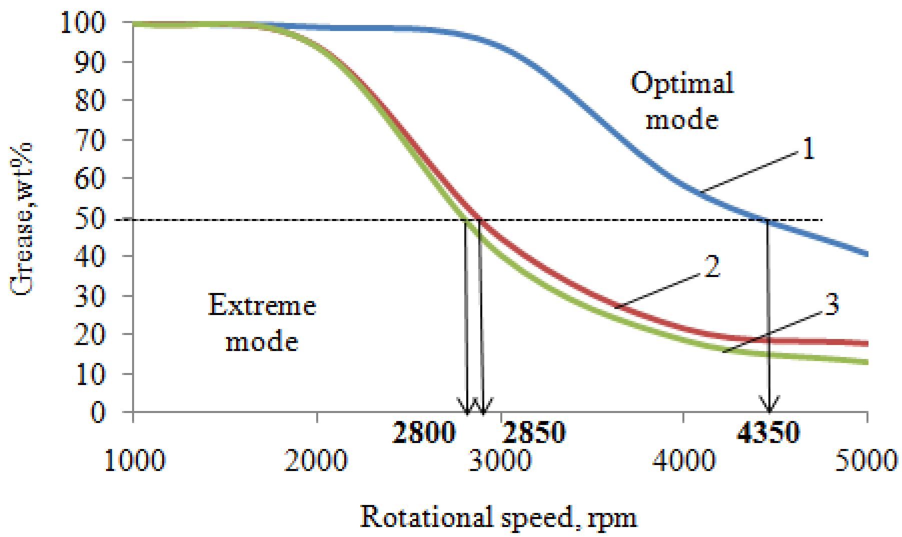

Fig. 3. Dependence of adhesion ability of grease based on used transmission oil SAE 80W-90 GL-5 on the rotational speed: 1 – 0.1 mm; 2 – 0.5 mm; 3 – 1.0 mm

A sample of oil based on SAE 15W-40 API SL/CI-4 oil (Fig. 2) with a layer thickness of 0.1 mm reaches a threshold value of 50 wt%. At a speed of wrapping equal to 3950 rpm, and samples with a layer thickness of 0.5 and 1.0 mm reach this value at 2600 rpm. So, it can be seen that these samples, compared to oil samples based on HLP-46 oil, have better adhesion properties.

As to the oil samples based on SAE 80W-90 GL-5 transmission oil (Fig. 3), they are characterized by an even greater value of wrapping speed, which remains 50 % of the original mass of the oil sample than all pre-reviewed samples. For the samples with a layer thickness of 0.1 mm, this value is 4350 rpm, while attempts with a layer thickness of 0.5 and 1.0 mm are 2850 and 2800 rpm.

Oils samples on the basis of the transmission oil SAE 80W-90 GL-5, regardless of the thickness of the deposition layer on the metal surface, should have the highest values of the rotational speed when the threshold value of the residual amount of lubricant is reached, therefore, they have the highest adhesive properties, which greatly expands their range use in bearings of various types.

If according to a mathematical point of view to characterize the receipt of experimental data for each mode of operation it is obvious that the most adequate of all mathematical functions is the change in the adhesive properties of a lubricant, expressed in the amount of lubricant, and it remains on the metal plate after the study, depending on the speed of rotation, and describes a second-degree polynomial, as evidenced by the high data of the coefficient of reliability of approximation R^2 (Table 1).

Table 1. The results of the laboratory studies

Sample grease	Regression equations for operation modes at p=0,95 Optimal	Extreme	R^2
Oil on the basis of oil HLP-46 at layer thickness:			
0.1 mm	$y = -2E-05x^2 + 0.0643x + +58.44$	$y = 4E-06x^2 - 0.0487x + +155.86$	0.99
0.5 mm	$y = -5E-05x^2 + 0.1532x + +1.1877$	$y = 8E-06x^2 - 0.0802x + +195.82$	0.99
1.0 mm	$y = -5E-05x^2 + 0.1425x + +9.0115$	$y = 9E-06x^2 - 0.0852x + +204.02$	0.99
Oil on the basis of oil SAE 15W-40 API SL/CI-4 at layer thickness:			
0.1 mm	$y = -2E-05x^2 + 0.0635x + +52.713$	$y = 2E-05x^2 - 0.1839x + +476.41$	0.99
0.5 mm	$y = -4E-05x^2 + 0.1263x + +17.5$	$y = 7E-06x^2 - 0.0678x + +181.11$	0.99
1.0 mm	$y = -4E-05x^2 + 0.1174x + +24.083$	$y = 6E-06x^2 - 0.0645x + +176.18$	0.99
Oil on the basis of oil SAE 80W-90 GL-5 at layer :			
0.1 mm	$y = -9E-06x^2 + 0.0344x + +74.958$	$y = 4E-06x^2 - 0.0522x + +197.04$	0.99
0.5 mm	$y = -2E-05x^2 + 0.0661x + +57.632$	$y = 1E-05x^2 - 0.0971x + +244.34$	0.99
1.0 mm	$y = -2E-05x^2 + 0.0696x + +55.292$	$y = 1E-05x^2 - 0.1x + +250.94$	0.99

4. Conclusions

The laboratory studies have shown that of all the methods for determining the adhesion properties of greases, which are described in the technical literature, the most adequate, that is, taking into account the effect on a lubricant of forces similar to those acting in actual operation, for example in a bearing, is the method for determining the residual amount of grease deposited on a metal plate after its rotation at certain speeds in a laboratory centrifuge.

Based on the references, it was assumed that the threshold value of the residual amount of grease, which determines the normal or extreme mode of operation of the sliding bearing, is 50 wt% of the original amount of grease.

As the layer of lubricant increases, which is applied to the metal surface, a significant deterioration in the adhesive properties is observed. So, for lubrication on the basis of HLP-46 with an increase in the lubricant layer from 0.1 to 1.0 mm, the rotation speed at which the limit value of the residual amount of lubricant is reached, it is reduced by 500 rpm, for lubrication on the basis of SAE 15W-40 API SL/CI-4 decreases by 1350 rpm, for lubrication based on SAE 80W-90 GL-5 decreases by 1500 (1550) rpm.

So, apparently, that are given above, we can conclude that the samples tested recycling greases in the range of the thickness of the deposition layer up to 1.0 mm, by their adhesion properties, are fully suitable for use in all types of bearings operated with a speed of up to 2500 rpm When increasing the speed of rotation of the bearing, it is necessary to reduce the thickness of the layer of lubrication. Thus, the most effective, that is, high adhesion properties are samples with a deposition layer thickness of 0.1 mm o, indicating sufficiently high values of the rotation speed when the threshold value of the residual amount of lubricant is reached: 2950 rpm for greasing on the basis of HLP-46, 3950 rpm for lubrication based on SAE 15W-40 API SL/CI-4 and 4300 rpm for lubrication based on SAE 80W-90 GL-5.

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