Evaluation of tribotechnical properties of plastic lubricants used in heavy loaded bearing units of agricultural machines

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Abstract. The resource of most of the heavily loaded bearing units of agricultural machines in the agro-industrial complex is limited by the quality of the lubricant. To ensure the operating condition of the bearing assemblies, it is necessary to evaluate the tribological characteristics of greases. The paper investigates the lubricity of greases used in agriculture, according to the criterion "scuffing index". The studies were carried out using standard and original methods for assessing the lubricity of greases. The paper proposes and substantiates a variant of assessing the tribological characteristics of greases based on the “scuffing index” criterion, which consists in determining the wear spot of balls taking into account their plastic deformation zone. It was found that LITOL and LGRT 2 greases have identical antitrust properties.

Keywords: bearing assembly, grease, seizure index, friction machine, friction torque, seizure marks, friction surface.

1. Introduction
The durability of heavily loaded bearing assemblies of agricultural machines mainly depends on the lubricants (greases) and additives used. Lubricant, along with the structural material of the bearing assembly, is an integral part of the design of the bearing assembly of machines used in the agricultural sector. In this regard, the assessment of the service properties of greases, namely their tribological characteristics, is currently a priority task. As the work of the 1st European Congress on Tribology has shown, the economic effect in mechanical engineering is achieved not only by the use of new materials, coatings, an increase in the accuracy of calculations and the successful design of friction units, but also, to a large extent, by the correct choice of lubricants. Along with the growth of requirements for the durability of machines and mechanisms, the time spent on testing them also increases. Currently, in the country as a whole, millions of working hours are spent on testing [4]; therefore, reducing the duration of such tests by improving and applying accelerated test methods is of great scientific and practical importance. One of the main performance characteristics of greases is their lubricity. Lubricants must have high lubricity and high surface activity for the formation of a strong film on the surface of rubbing parts that can prevent or reduce their wear at operating loads and speeds [1].

Studies [2, 3] describe domestic and foreign laboratory methods for assessing the service properties of greases by tribological and physicochemical tests, in particular according to IP (England), DIN (Germany), FTM and SAE (USA) standards.

Laboratory methods for assessing the service properties of greases can be roughly subdivided into methods using point contact samples (for example, four-ball test rigs) and roller test rigs. In addition,
methods are used based on determining changes in the physicochemical characteristics of greases and friction surfaces of test samples, etc.

Analysis of literature sources, as well as the practice of evaluating the service properties of greases have shown that the presented methods do not allow to reliably determine the absolute parameters of the extreme pressure and antiwear properties of greases, but allow comparative studies to evaluate the service properties of both commercial and working greases.

The main disadvantage of the above methods is the uncertainty and discrepancy in the criterion estimates of the extreme pressure and antiwear properties of greases.

Therefore, it is necessary to develop a reliable and unambiguous criterion for assessing the extreme pressure and antiwear properties of greases.

Four-ball friction machines have become widespread, but a generally accepted and scientifically grounded methodology for testing and processing experimental data when evaluating lubricants on this machine has not yet been created [3-6].

The use of a four-ball friction machine to predict the behavior of lubricants under real operating conditions is controversial, and the remarks about the limited possibilities of interpreting the results obtained, and the difficulty of comparing and transferring the research results to specific objects are true. And, nevertheless, this method is still relevant today.

Consequently, the service properties of greases are determined both by the interaction of the lubricating layer with a solid (physical or chemical) and by the molecular-mechanical properties of this layer. The deformability and strength of the surface layer of a metal can have a much greater effect on wear than the physicochemical effect of a lubricant. Based on the foregoing, an unambiguous and reliable criterion for assessing antiwear and extreme pressure properties of both commercial (fresh) and working greases can be the “scuffing index”.

The "scuffing index" evaluates the ability of a lubricant to reduce damage to rubbing parts under load due to scuffing. Determined on the basis of data obtained on a four-ball friction machine [1, 2, 3].

According to [5, 6], the “scuffing index” (SI) is determined from the ratio:

$$SI = \frac{\sum Q}{n}$$

where $Q$ – conditional load, N;
$n$ – number of determinations in a row $y 1$, $n = 3$ [3].

$$Q = \frac{P \cdot d_j}{d_{is}}$$

where $P$ – axial load, N, in a row $1$ ($P = 196 \ldots 10000\, N$);
$d_j$ – diameter of the elastic deformation zone of balls according to Hertz, mm, under axial load $P = 196 \ldots 10000\, N$;
$d_{is}$ – average diameter of the wear spots of the lower balls, mm, at axial load $P = 196 \ldots 10000\, N$.

Thus, the “scuffing index”, based on dependence (1), is determined in units of force. The concept of "scoring" (scoring, scuffing) includes the formation as a result of grasping a groove distinguishable by the naked eye with the pushing of the material both to the sides and in the direction of sliding, is a change in the topography and microrelief of the friction surface. In this work, the "scuff index" is proposed to be estimated based on the size of the scuff marks (their geometrical dimensions) and the estimation of the magnitude of the topography and microrelief of the friction surfaces.

Therefore, the "scuffing index" can be determined from the ratio:

$$SI = d_j + 0,15\, MM,$$

where $d_j$ – the diameter of the elastic deformation zone of the balls according to Hertz, mm;
$0,15\, MM$ – a value characterizing the increment of scuff marks from destruction, adsorption and passivation of surfactants and chemically active substances.
2. Materials and methods
The experimental part of the work aims to verify and clarify the results of theoretical studies and includes a laboratory experiment to study the “scuffing index” of commercial greases. Determination of the "scuffing index" was carried out on a four-ball friction machine. The general view of the machine is shown in Figure 1.

![Four-ball friction machine](image)

Figure 1. Four-ball friction machine

The study allows you to get the nature, type and amount of wear. Thus, the information obtained characterizes the lubricating and working properties of the materials used and their behavior under the influence of various loads.

The study was carried out in accordance with GOST 9490-75 [6].

Before the start of the study of the lubricant, all the parts of the machine with which it comes into contact during the test (the cup with the fastening parts of the lower balls and the fastening parts of the upper ball in the spindle) were washed with several portions of rectified ethyl alcohol in accordance with GOST R 51652-2000, until the solvent did not become transparent and was dried in air. The balls used in the test were checked for deviation from the spherical shape in accordance with GOST 3722 and the presence of external defects. The hardness of the balls was HRC 62 - 66. When determining the “scuffing index”, the friction unit of the machine was loaded with a constant force of 196 N.

The 196 N load is the main one.

The duration of the machine operation from the moment of switching on to the moment of switching off the electric motor at the current load was 60 ± 2 sec. The machine's operating time was controlled by a built-in timer. For the limiting value of the "scuffing index", according to the recommendation of work [5], the size of the wear scar is more than 0.4 mm.

During the study, the frictional moment arising in the friction unit was not recorded, since the value of the "scuffing index" was the main investigated indicator.

The diameter of the wear scar for each ball was measured in two mutually perpendicular directions with an accuracy of ± 0.01 mm.

Before measuring the size of the wear spot, the balls were removed from the friction unit cup and washed with several portions of rectified ethyl alcohol according to GOST R 51652-2000 until the solvent became transparent and dried in air. The measurements were carried out at a temperature of \(20^\circ\text{C}\).\(22^\circ\text{C}\).

The experiments were carried out using LITOL and LGRT 2 greases (SKF).
3. Results and discussion

The results of the study of the extreme pressure and antiwear properties of LITOL and LGRT 2 greases according to the “scuffing index” are shown in Figure 2.

![Image of scuffing marks and worn surface interpretations]

**Figure 2.** Three-dimensional stereographic interpretation of scuff marks during testing of LITOL-24 (a) and LGRT 2 (b) grease, digital interpretation of the worn-out surface of a ball (surface topology) when testing LITOL (c), LGRT 2 (d) grease.

Analysis of the morphology and topology of worn surfaces (Figure 2) when testing the tribological characteristics of both lubricants shows the presence of significant surface breakouts with deep cracked depressions. The friction surface, which worked in the LITOL grease, has undergone significant changes. The value of the “scuffing index” was 2.74 mm. In the tribological test of the LGRT 2 grease, the value of the “scuffing index” was 2.67 mm. Thus, the lubricants are identical in extreme pressure properties and can be interchangeable when operating in the bearing units of agricultural machines of the agro-industrial complex.

**Conclusions**

1. A variant of assessing the tribological characteristics of greases based on the “scuffing index” criterion, which consists in determining the wear spot of balls, taking into account their plastic deformation zone, has been proposed and substantiated. 2. Comparative tribological tests of LITOL and LGRT

2 Greases have been carried out, which have shown the identity of their antiwear properties according to the criterion "scuffing index".
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