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Compatibility of Recycling Plastic Lubricants

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Abstract

The compatibility of recycled greases thickened with 5 % (wt.) polyethylene and polypropylene solid waste was studied. It was found that according to the values of the dropping point and adhesive properties, recycled greases, regardless of the base oil and thickener, are compatible. However, when 10 % (mass) of recycled lubricants are added to Solidol "Zh", its adhesion properties deteriorate by 300-400 rpm, due to the negative effect of the aging products of base oils on its structure, which indicates their incompatibility.

Keywords: *Compatibility; Grease; Dropping point; Adhesive properties; Polymer thickener; Base oil; Thermal degradation.*

1. Introduction

One of the main problems arising in the development of new types of lubricants is their compatibility with already successfully used counterparts, which they are intended to replace. In practice, when operating greases in various mechanisms, they inevitably occur as a decrease in the initial level of quality, due to aging processes, and a decrease in the amount of the grease itself. At the same time, to ensure normal operation, it is necessary to replenish the amount of lubricant in a timely manner, instead of the lost one, but it is not always possible to do this using the same brand of lubricant that was originally filled into the mechanism. In this case, in order to ensure a reliable operation of the mechanism, it is necessary either to completely remove the remnants of the old grease from it, followed by flushing the mechanism with a solvent and refilling with a new one, or select a compatible grease that can be used to refill the mechanism without removing the old grease.

The first approach leads to an unreasonable overspending of the lubricant, the second is a more rational approach to the use of lubricants, but almost always, it is associated with the risk of premature loss of the lubricant's performance properties. Therefore, work in the field of determining the compatibility of lubricants, in particular greases, is very relevant, and should be carried out in parallel with the work to determine the level of performance properties and predict their changes during the operation of the lubricant in the mechanism.

In the case of incompatibility of greases, due to a change in their structure (hardening or softening of a mixture of greases), they are not able to perform their functions, the main of which is the lubrication of rubbing surfaces, which ultimately can lead to premature failure of the mechanism in which the mixture of lubricants was used [1]. Thus, in a mixture of two lubricants, there is a change in the ratio of base oil, thickener and additives, which existed in each lubricant separately, which will undoubtedly lead to a change in their properties, which means that when determining the compatibility of greases, their composition must be taken into account.

Considering base oils, we note that mineral oils obtained by oil refining are compatible with polyester and polyolefin oils, but not compatible with the base stock, silicone and polyglycol oils. Polyolester oils are well compatible with polyglycolic and polyphenyl ether oils. Silicone oils are well compatible with each other, and poorly, or not at all, are incompatible with other oils, in particular with mineral ones [2].

Compared to the nature of the base oil, the thickener and additives have a greater influence on grease compatibility. Thus, lubricants thickened with calcium soap are well compatible with lubricants containing lithium soap and are not compatible with lubricants containing an aluminum complex and bentonite. Bentonite, an aluminum complex and polyuria are generally incompatible with other thickeners [3]. When lubricants thickened with metal soaps are mixed with lubricants containing bentonite in their composition, reactions between the soap cations, additives and quaternary ammonium ions of bentonite will begin, which will lead to the destruction of the gel of the system and softening of the lubricant. When mixing lubricants, it should be taken into account that lubricants thickened with calcium soap function well in a weakly acidic environment, and calcium complex ones - in an alkaline environment. When calcium soap is added to a complex lubricant, the functions of the lubricant will not change; when a complex calcium lubricant is added to a calcium lubricant, the pH of the mixture will change, which can lead to significant structural changes.

It is known that the role of additives in greases is to improve the properties of the base oil [4]. For each base oil, depending on the operating conditions, an individual additive package is selected. Therefore, in the case when two greases have the same base oil, they may not be compatible due to a different additive package in their composition. This can be expressed in chemical reactions between additives, which leads to their destruction or neutralization, and as a consequence, a negative change in the properties of the grease mixture [5].

Considering the information given above, we note that the industrial use of recycled greases [6], that are designed to become analogs of greases that are widely used today, involves determining their compatibility with each other and greases thickened with metal soaps.

In the work [7], the studies were carried out on the compatibility of greases, which showed that when greases are mixed on different thickeners, the structure of the grease can soften, the dropping point and colloidal stability can decrease. Also, the research was carried out to study the compatibility of greases when operating in real and model friction units of machines and mechanisms, where the change in their structure and lubricating properties was investigated [8]. Based on the data given in these works, it was decided, in this work, to evaluate the compatibility of recycled greases in terms of dropping point ($t_{d.p.}$, °C) and adhesive properties (x_a, rpm).

2. Materials and methods

The dropping point characterizes the temperature intervals for the use of a grease, and the adhesion properties determine the ability of the grease to stay on vertical surfaces when exposed to certain loads, which is one of the main indicators of a grease that determine its performance properties.

Then, any two greases are considered compatible if the expression is the following:

$$t_{d.p.1} \geq t_{d.p.mix} \text{ or } t_{d.p.2} \geq t_{d.p.mix}$$

(1)

$$x_{a.pr.1} \geq x_{a.pr.mix} \text{ or } x_{a.pr.2} \geq x_{a.pr.mix}$$

where $t_{d.p.1}$; $t_{d.p.2}$; $t_{d.p.mix}$ – the dropping point of the first grease, the second grease, and their mixture, respectively, °C; $x_{a.pr.1}$; $x_{a.pr.2}$; $x_{a.pr.mix}$ – the indicator of adhesion properties (rotation speed), rpm.

A laboratory study of the compatibility of recycled greases was carried out on the samples in which the ratio of greases corresponded to: 10:90, 50:50, 90:10.

At the first stage, two greases were tested for compatibility, obtained using different used base oils (SAE 80W-90 and HLP 46) and one thickener (5 % (wt.) Low-pressure polyethylene).

The dropping point was determined by the standard method GOST 32394-2013, and the adhesion properties were determined graphically (see Figures), by reducing the mass of the grease to 50 % applied to a metal plate, after testing it in a centrifuge, relative to the initial value.

3. Results and discussion

The results obtained showed that regardless of the concentration of lubricants in the mixture, the dropping point, which depends mainly on the properties and concentration of the thickener in the tested mixtures, is at the level of 110°C. However, as the concentration in the mixture of lubricants based on SAE 80W-90 (x_a=4350 rpm, $t_{d.p.}$=112°C) decreases from 90 to 10%, the adhesion properties deteriorate at 950 rpm. However, the lubricants considered are compatible because satisfy inequality (1).

At the second stage, two greases were tested for compatibility, obtained using one used base oil (SAE15W-40) and different thickeners: 5 % (wt.) HDPE and 5 % (wt.) polypropylene (PP). The results of studies of the adhesive properties of the mixtures obtained are shown in the Figures 1 and 2.

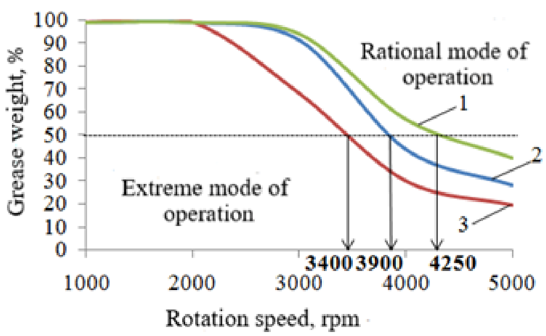

Figure 1. Adhesion properties of grease mixtures with different bases (SAE80W-90 and HLP46) and thickener: 1–90: 10; 2-50: 50; 3-10: 90

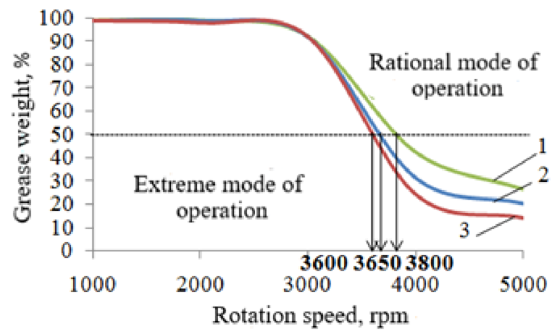

Figure 2. Adhesion properties of grease mixtures with one base (SAE15W-90) and different thickeners: 1–90: 10; 2-50: 50; 3-10: 90

Adding 10 % grease with PP (x_a=3550 rpm, $t_{d.p.}$=140°C) to grease with HDPE (x_a = 3950 rpm, $t_{d.p.}$== 112°C), slightly worsens the adhesive properties (by 150 rpm) and improves (by 4°C) the dropping point. Adding 10% HDPE grease to PP grease insignificantly (by 50 rpm) improves the adhesion properties and does not affect the dropping point. A 50:50 mixture has a higher dropping point (136°C) compared to a grease containing HDPE and slightly better adhesion properties (at 100 rpm) compared to a grease containing PP. When adding grease with HDPE, regardless of concentration, to grease with PP, the latter becomes more homogeneous (Figure 3). The results obtained indicate the compatibility of the tested greases.

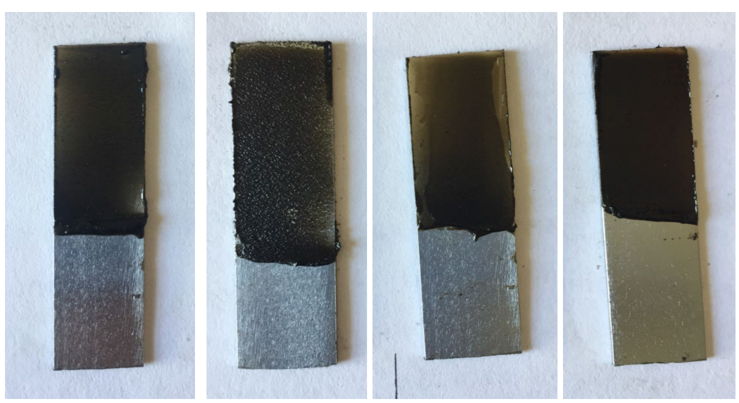

Figure 3. A snapshot of the surfaces of lubricants and their mixtures: a) lubricant with 5% (mass.) HDPE; b) grease with 5% (wt.) PP; c) a 50:50 mixture; d) mix 10:90

Then, using thermal destruction at atmospheric pressure and temperatures up to 350°C, wide fractions were obtained from PP waste and polystyrene (PS), from which, later, fractions were isolated (for PP t_{boil} > 300°C and for PS t_{boil} > 200°C), which by their consistency (the penetration for the PP fraction is 189 mm^{-1}; the penetration for the PS fraction is 265 mm^{-1}) can be used as greases. A grease made from PP is more uniform in appearance and has better application properties to a metal surface than grease made from PS, which has a granular structure (see figure). The yield of these fractions for PP was up to 15% (wt.), and for PS up to 25 % (wt.) for the feedstock. Further, for the obtained greases, their adhesion properties were checked (see Figure 5).

The lubricants obtained using the technology of thermal destruction at atmospheric pressure have high adhesion properties (for PP x_a > 8000 rpm, for PS x_a = 5000 rpm) and admissible values of the dropping temperature (for PP $t_{d.p.}$ = 56°C, for PS $t_{d.p.}$ = 110°C), it allows them to be used as conservation lubricants to protect metal surfaces from atmospheric corrosion. A 50:50 mixture has a higher dropping point (105°C) compared to PP grease and slightly better adhesion properties (at 700 rpm) compared to PS derived grease, which indicates grease compatibility.

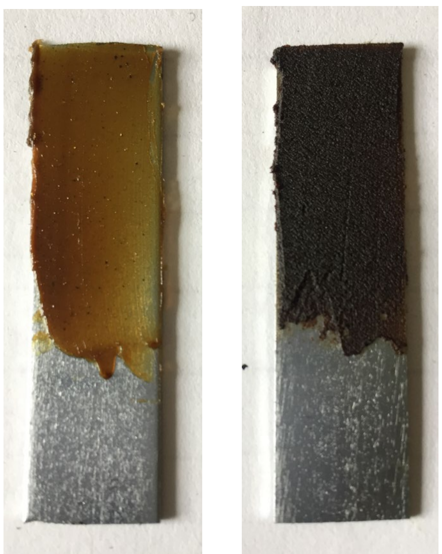

Figure 4. A snapshot of the surfaces of lubricants obtained by thermal degradation of polymers: a) PP lubricant; b) grease from PS

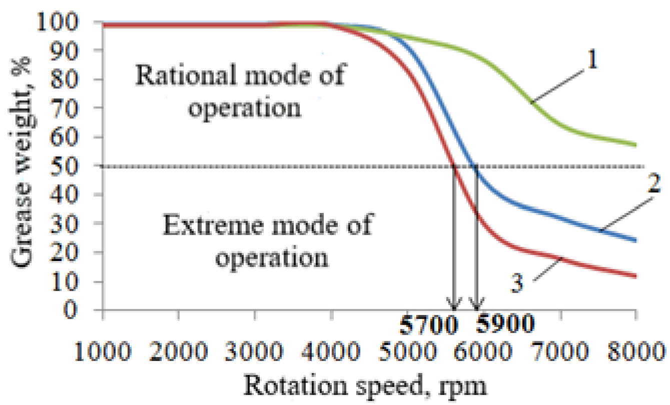

Figure 5. The adhesive properties of grease mixtures obtained from polymers (PP and PS): 1–90: 10; 2-50: 50; 3-10: 90

At the final stage of the research, the compatibility of recycled greases based on SAE 15W-40 waste oil, thickened with 5 % (wt.) HDPE and PP with antifriction grease Solidol "Zh" (Figures 6 and 7), which today is one of the most demanded lubricants.

When 10% Solidol "Zh" is added to a lubricant based on SAE 15W-40 (HDPE) (x_a = 3800 rpm, $t_{d.p.}$ = 98°C), there is a deterioration in adhesion properties (by 150 rpm) and a slight drop in the dropping point (by 1°C). A 50:50 mixture has worse adhesion properties compared to the original lubricants and a slightly higher dropping point ($t_{d.p.}$= 102°C) compared to Solidol "Zh".

A similar picture is observed in the case of mixing recycled grease based on SAE 15W-40 (PP) and Solidol "Zh". So, grease SAE 15W-40 (PP), containing 10% Solidol "Zh", has worse adhesion properties and a lower dropping point (x_a = 3350 rpm, $t_{d.p.}$ = 135°C), in comparison with the original grease. The addition of 10% SAE 15W-40 (PP) grease to Solidol "Zh" increases the dropping point (by 2°C), but worsens the adhesion properties (by 400 rpm), compared to the original grease. A 50:50 mixture has worse adhesion properties compared to the original lubricants and a slightly higher dropping point ($t_{d.p.}$ = 123°C), compared to Solidol "Zh".

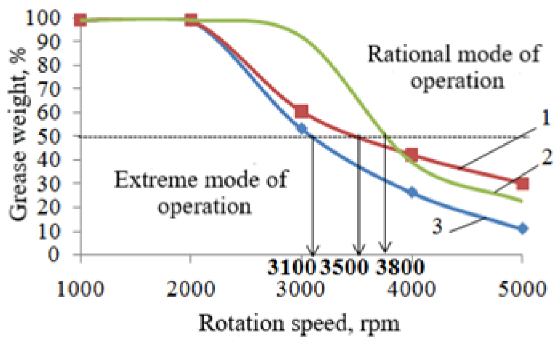

Figure 6. Adhesion properties of grease mixtures based on SAE 15W-40 (HDPE) oil and Solidol "Zh": 1–10: 90; 2–90: 10; 3-50: 50

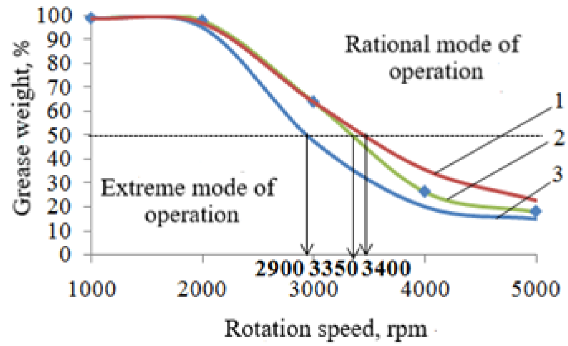

Figure 7. Adhesion properties of grease mixtures based on SAE 15W-40 (PP) oil and Solidol "Zh": 1–10: 90; 2–90: 10; 3-50: 50

A noticeable deterioration in adhesion properties when mixing recycled lubricants with Solidol "Zh" is directly related to a change in the structure of the lubricant. Thus, acidic products of oxidation of oil hydrocarbons and degradation products of detergent-despergative additives, which are found in the used oils - the dispersion medium of recycled greases, weaken the structure of greases thickened with metal soaps [9-10]. As a result of this action, the consistency of the mixed grease changes, which causes its transition to lower classes according to (NLGI) and, as a result, the mixed grease breaks off the metal surface under lower loads. Therefore, the tested recycling greases can be considered incompatible with Solidol "Zh".

4. Conclusions

The issue of the compatibility of greases, along with predicting changes in their initial properties and the ability to perform their functions is one of the main issues on the solution which depends on the reliable operation of various mechanisms where greases and the rational use of the greases themselves are used.

As the main indicators for determining the compatibility of greases, you can use the dropping point of the grease and the indicator of its adhesion properties. Also, it should be noted that these indicators, if necessary, can be supplemented by an indicator of penetration and colloidal stability.

The studies have shown that the change in the quality indicators of mixtures of recycled greases, both obtained on the basis of different waste oils (SAE 80W-90 and HLP46) and having one thickener (HDPE), and obtained on the basis of one SAE 15W-40 oil, but thickened 5 % (wt.) HDPE and PP, is in a narrow range, limited by the properties of the original lubricants, which indicates their compatibility. A similar picture is observed when mixing lubricants, which are high-boiling fractions isolated from the products of thermal degradation at 350 °C and atmospheric pressure, polymer waste represented by PP and PS.

However, recycled greases are not compatible with greases thickened with metal soaps, for example with Solidol "Zh", as evidenced by the deterioration of adhesion properties. So, when adding 10 % (mass.) of recycling lubricants to Solidol "Zh", its adhesion properties deteriorate by 300-400 rpm.

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