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Study of the Influence of Base Oil on the Lubricating Properties of Greases Obtained from Secondary Raw Materials

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Abstract

The article presents the results of a study of the effect of base oil on the lubricating properties of plastic lubricants obtained from secondary raw materials - used lubricating oils and crushed solid polymers (LDPE and HDPE, PP). It was established that the viscosity of the base oil and the type of polymer thickener significantly affect both the colloidal stability of the plastic lubricant and its lubricating properties. The best lubricating properties were demonstrated by plastic lubricants obtained from SAE 85W-90 transmission base oils (v100=30.0 mm2/s) thickened with crushed HDPE products. Moreover, when comparing these two-component greases with industrial analogues, it was found that their lubricating properties significantly exceed those of companies Agrinol Solidol G0, G1; Agrinol Fiol 1, 2) and are at the level of plastic lubricants Mobil Grease Special; NESTE MP Grease; Shell RETINAX Grease CMX1,2; Mobilux EP.

Keywords: *Greases; Recycled materials; Polymers; Base oil; Thickener; Viscosity; Colloidal stability; Lubricating properties.*

1. Introduction

Over the past decade, recycling technologies have been rapidly developing as an integral part of the technological process of commercial production, particularly in the petrochemical industry. This is primarily due to the optimization of production costs, the shortage of high-quality hydrocarbon feedstock for production and the significant accumulation of production and consumption waste hazardous to the environment. Thus, activities related to the development and production of petroleum products, including greases derived from recycled materials such as various types of waste, have recently gained popularity. And the products of such technologies - greases - can partially satisfy the growing demand for lubricants and are increasingly widely used in various industries.

2. The objective of the research

It is known that among the most important operational indicators of the quality of greases are their lubricating properties, which determine the ability of the grease to resist wear of friction surfaces [1-3]. The lubricating properties of greases are a function of the grease composition [4], the technology of its preparation [5], the degree of filling of the friction unit [6-7], the thickness of the lubricating layer [7-9].

Plastic lubricants, for the most part, consist of two main components that determine their structure and properties. These components include the liquid oil - the dispersion medium - and the thickener - the dispersed phase. The latter forms the structural framework and determines the properties of the grease. At the same time, the structural properties of lubricants are greatly influenced by the dispersion medium, which affects the change in the size of the particles of the dispersed phase and their orientation relative to each other when building the final structure of the lubricant. It is believed that up to 60 % of the oil is firmly bound to the lubricant's structural framework, with the remaining 40 % of the oil retained in the framework cells [10-11].

Quite often, to improve lubricating properties, which is especially important for antifriction and multi-purpose greases, up to 10 % of anti-wear, extreme pressure and antifriction additives are added to their composition [12-13]. Thus, it can be asserted that the lubricating properties of grease depend not only on the content of additives but also on the structure of the grease and the properties of the base oil, which is the dispersion medium of the grease.

Considering this, the main goal of the research presented by us is to investigate the influence of the properties of the base oil and the type of thickener on the lubricating properties of two-component multipurpose plastic lubricants obtained from secondary raw materials - production and consumption waste.

3. Materials and methods of the research

3.1.Materials

Two-component plastic lubricants obtained on the basis of used lubricating oils (Group I – motor oils of viscosity classes SAE15W-40, SAE10W-40; Group II – transmission oils of viscosity class SAE 85W-90; Group III – hydraulic oils of the HLP brand -46; Group IV – industrial oils of the brands BP Energol CS68, Mobil DTE Oil Medium Heavy) and solid polymer thickener (LDPE and HDPE, PP) were subjected to research. The starting materials, the method of their preparation, and the method of obtaining two-component greases are completely similar to those presented in [14]. No additives were added to the tested grease samples, which made it possible to evaluate the actual effect of the base oil and thickener on the lubricating properties of the greases obtained from them.

3.2.Methods of the research

The kinematic viscosity (v^{100}, mm^2/s) and viscosity index (VI, units) of the base oil were determined according to the standard methods ASTM D7152 and ASTM D 2270, respectively. The colloidal stability ($X_{c.s.}$, %) of the obtained greases were determined according to the standard methods ASTM D 1742. The lubricating properties of greases - wear index at a constant load of 196N ($D_{w(196)}$, mm), welding load (P_{We}, N), critical load (P_c, N) and scoring index (I_b, N) - were evaluated using the Four-Ball Wear Test ASTM D 2266, ASTM D2596 and ASTM D 2783.

4. Results and discussion

The results of the laboratory studies (see Fig. 1-2) showed that all groups of base oils, according to the indicator (v^{100}, mm^2/s), are characterised by the highest values of groups I and II.

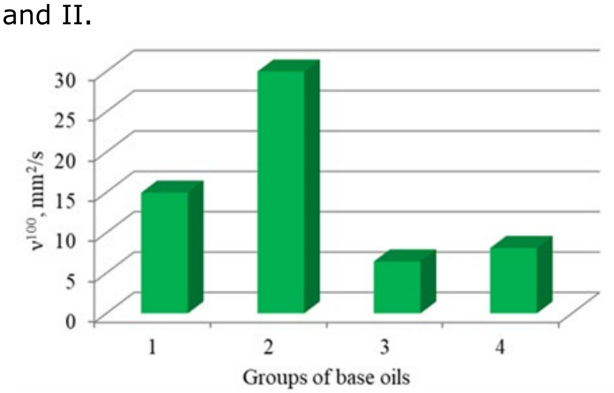

Figure 1. Average v^{100} value for the base oil group:1 - Group I; 2 - Group II; 3 - Group III; 4 - Group IV.

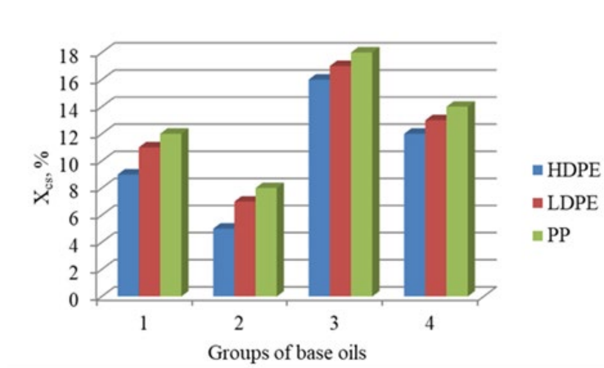

Figure 2. Average $X_{c.s.}$ value for the base oil group:1 - Group I; 2 - Group II; 3 - Group III; 4 - Group IV.

As a result, greases obtained on the basis of these groups of oils have the best values of the indicator ($X_{c.s.}$, %). This is explained by the fact that the higher the indicator (v^{100}, mm^2/s) of the base oil, the stronger it is held in the cells of the frame of the plastic lubricant created by the thickener. The most stable structure ($X_{c.s.}$= 5.0-8.0 %) is characterized by plastic lubricants obtained on the basis of Group II oils (v^{100}=30.0 mm^2/s), the most unstable ($X_{c.s.}$=16.0 -18.0 %) – lubricants based on Group III oils (v^{100}=6.45 mm^2/s). On the other hand, the ability of the polymer itself to retain oil in the grease structure is also of significant importance. For example, the ability to retain base oil in the grease structure decreases in the HDPE→LDPE→PP series due to the structure and properties of the polymer.

When studying the effect of oil group on the viscosity index (see Fig. 3), we note that the value of the index (VI, units) decreases in the order Group I → Group II → Group III → Group IV, and this, in turn, significantly affects the temperature range of grease application. In view of this, greases based on Group I oils (VI=127 units) will have the widest temperature range of application, and greases based on Group IV oils (VI=91 units) will have the narrowest. Greases based on oils of other groups (VI=90-110 units) will have an intermediate value.

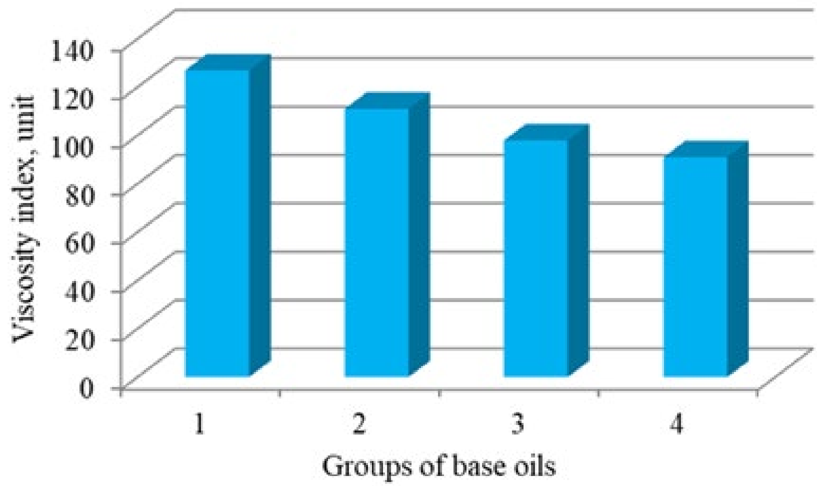

Figure 3. Average value VI for the base oil group:1 - Group I; 2 - Group II; 3 - Group III; 4 - Group IV.

Assessing the effect of the base oil on the lubricating properties of two-component greases (see Figs. 4-7), we note that greases based on Group II oils have the best properties ($D_{w(196)}$ = 0.40-0.49 mm; P_{We} = 3450-3550 N; P_c = 1000-1025 N; I_b = 600-670 N). This is due to both the high viscosity of the base oil and the residual potential of additives (anti-wear, extreme pressure, and antifriction), which is part of the initial potential [15-16] and, given the low temperatures of obtaining greases (up to 200 °C) [14,17], is transferred to the final product and, subsequently, performs its lubricating functions.

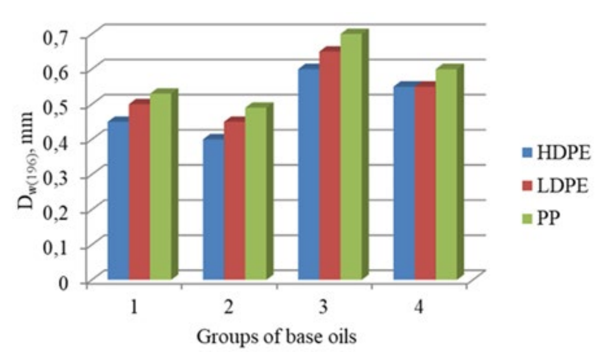

Figure 4. Average $D_{w(196)}$ value for the base oil group:1 - Group I; 2 - Group II; 3 - Group III; 4 - Group IV.

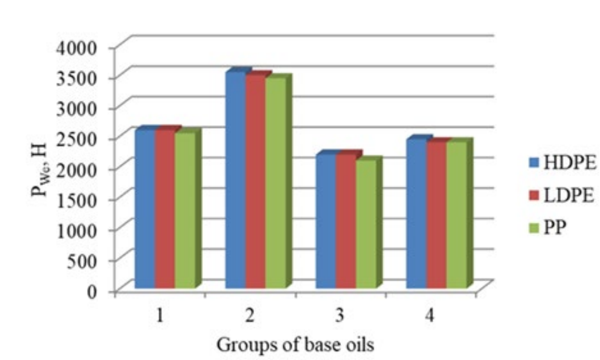

Figure 5. Average P_{We} value for the base oil group:1 - Group I; 2 - Group II; 3 - Group III; 4 - Group IV.

The worst lubricating properties are observed in greases based on Group III oils ($D_{w(196)}$ = 0.60-0.70 mm; P_{We} = 2100-2200 N; P_c = 770-790 N; I_b = 350-380 N) and Group IV ($D_{w(196)}$ = 0.55-0.60 mm; P_{We} = 2400-2450 N; P_c = 840-870 N; I_b = 390-400 N). These oils contain only antiwear additives from the above additives, in an amount much less than in Group I and Group II oils [18]. And this, together with low viscosity (v^{100}=6.45-8.12 mm^2/s), leads to low lubricating properties compared to greases based on Group I and Group II oils. The lubricating properties, as in the case of the indicator ($X_{c.s.}$, %), deteriorate in the HDPE→LDPE→PP series, which indicates their close relationship.

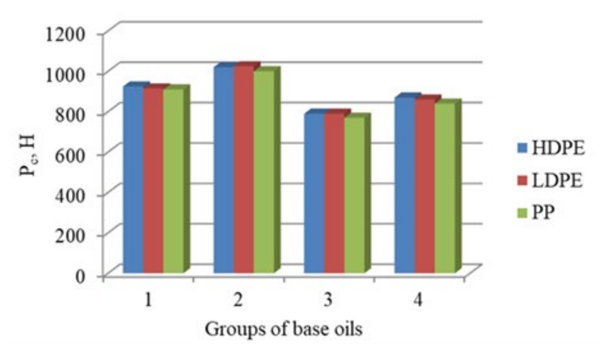

Figure 6. Average P_c value for the base oil group: 1 - Group I; 2 - Group II; 3 - Group III; 4 - Group IV.

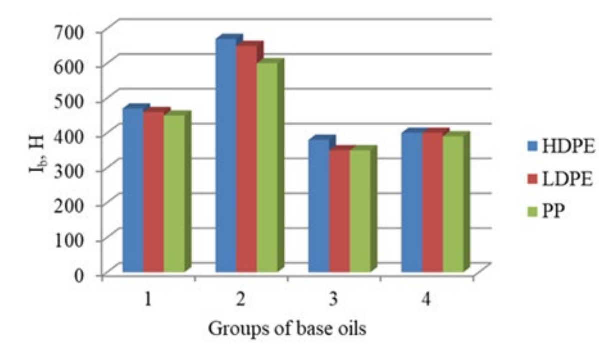

Figure 7. Average I_b value for the base oil group: 1 - Group I; 2 - Group II; 3 - Group III; 4 - Group IV.

Comparing the obtained two-component greases with industrial analogues, it should be noted that the lubricating properties of greases based on Group I and Group II oils significantly exceed those of Agrinol Solidol G0, G1; Agrinol Fiol 1, 2, for which $D_{w(196)}$ (not higher than 0.60-0.65 mm), P_{We} (not less than 1235-1500 N), P_c (not lower than 650 N), I_b (270 N) are established.

$D_{w(196)}$ and P_{We} are at the level of Mobil Grease Special greases ($D_{w(196)}$ = 0.40 mm, P_{We} = 2500 N); NESTE MP Grease ($D_{w(196)}$ = 0.40 mm, P_{We} = 2600 N); Shell RETINAX Grease CMX1.2 ($D_{w(196)}$ = 0.50 mm, P_{We} = 4000 N); Mobilux EP ($D_{w(196)}$ = 0.40-0.50 mm, P_{We} = 2500 N).

5. Conclusions

As a result of the research, it was found that for multi-purpose two-component greases derived from recycled materials, as in the case of greases derived from classical petroleum or synthetic oil and soap thickener, the viscosity of the base oil has a very significant effect on colloidal stability. With an increase in the viscosity of the base oil from 6.45 mm^2/s to 30.0 mm^2/s, the colloidal stability of the grease improves (by an average of 10 %). At the same time, taking into account the residual potential of additives, there is also an improvement in lubricating properties ($D_{w(196)}$ decreases by 0.2 mm; P_{We} increases by 250-1300 N).

The ability to retain base oil in the grease structure decreases in the HDPE→LDPE→PP series due to the peculiarities of the polymer structure and properties, which affects the deterioration of colloidal stability and lubricating properties of the grease.

The viscosity index of the base oil has a significant impact on the temperature range of the grease, i.e. the higher the value of this index, the wider the temperature range of the grease is.

Comparison of the obtained two-component greases with industrial analogues showed that the lubricating properties of greases based on Group I and Group II oils significantly exceed those of Agrinol Solidol G0, G1; Agrinol Fiol 1, 2 and are at the level of Mobil Grease Special ($D_{w(196)}$ = 0.40 mm, P_{We} = 2500 N); NESTE MP Grease ($D_{w(196)}$ = 0.40 mm, P_{We} = 2600 N); Shell RETINAX Grease CMX1.2 ($D_{w(196)}$ = 0.50 mm, P_{We} = 4000 N); Mobilux EP ($D_{w(196)}$ = 0.40-0.50 mm, P_{We} = 2500 N).

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