Improving power plant equipment work by applying alloyed industrial oil

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Abstract – The polymethacrylate additives with enhanced functionality were obtained in this work. The influence of the concentration of the additives on the viscosity-temperature, depressor and anti-wear properties of industrial oil I-20A were studied. The obtained lubricant can be used for friction reduction and wear protection of equipment elements of power plants.

Keywords – lauryl methacrylate, methyl acrylate, polymethacrylate additive, alloyed industrial lubricant I-20A, operational properties.

Introduction

During the rapid development of science and technology, there is a need for continuous improvement of mechanical equipment. Therefore, optimizing and improving processes are constantly carried out to reduce the wear value of machine parts. Improvement of the process quality of the technical equipment depends on high quality characteristics of lubricants. It is known that engines and parts of the main and auxiliary equipment elements of power plants are exposed to different types of wear and, eventually, breakdown. The wear of parts leads to worsened operation modes, reduced efficiency, energy loss by power units as well as increased noise and vibration that reduce the product quality and lead to premature industrial failure. Replacement of equipment and parts requires significant costs; therefore, research to improve the durability and longevity of the equipment is a very important technical and economic task [1].

Analysis of previous studies and statement of the problem

The multiple classes of organic compounds with different functional groups and elements [1] are used as additives to provide the necessary operational parameters of the oil. Therefore, an additives classification and their division on the basis of their functionality are conditional because the organic compound can influence some operational characteristics of the oil and, to some extent, improve or worsen certain indices. Most manufacturers of oils prefer to use a single multifunctional additive in all spectra of the lubricant oils.

There are additives with various chemical compositions on the market: polyolefins [2], poly(alkyl methacrylates) [3], copolymers of hydrogenated styrene-butadiene [4], terpolymers, etc. Each chemical composition of the polymer provides a balance between cost and performance characteristics that make them more or less suitable for using in certain compounds of lubricating oils. The most effective among additives that possess viscosity and depressor properties are the copolymers based on higher alkyl methacrylates.

To date, despite the large number of studies in the field of oils and lubricants, there are no reliable criteria for selecting a lubricant additive for gear pairs that work in some specific conditions. Therefore, studies aimed at synthesizing new polymers with enhanced functionality and testing them as multifunctional additives are very important from scientific and applied perspectives. Such a study can provide a solution to the problem of producing competitive and high quality lubricants in Ukraine.

The study is aimed at obtaining new polymethacrylate additives by copolymerization of lauryl methacrylate (LMA) with methyl acrylate (MA) in benzene with enhanced functionality and studying the influence of their concentration and composition on the operational properties of the alloyed industrial lubricant I-20A.

The main results and discussion

The optimal conditions for obtaining polymethacrylate additives were determined on the basis of kinetic studies and the following parameters: the temperature of 80 ± 1°C, the concentration of benzoyl peroxide of 0.5 wt.% based on the total monomers' weight, the ratio of lauryl methacrylate:benzene = 1:1, and the reaction time of 3 to 4 hours. The qualitative composition of the additives was confirmed with the infrared spectrometry. The infrared (IR) spectra were recorded with the Specord IR-75 spectrometer. The IR spectra of copolymers determined the presence of characteristic bands – an ester bond of the MA carbonyl group (1,730 and 1,740 cm^{-1}) and a large paraffin residue of the LMA (2,928 and 2,856 cm^{-1}).

The molecular weight of the synthesized copolymers was determined by a cryoscopic method. An increase of the MA content from 10 to 30 mol % in the monomeric mixture increased the molecular weight of the copolymer from 10,200 to 16,000 (± 0.2%). Therefore, the solubility of the synthesized copolymers in lubricants can be worsened with the MA content in the monomer mixture above 30 mol %.

Thermal stability of the samples was studied with using the derivatograph Q-1500D (the Paulik-Paulik-Erdey system) at a dynamic mode of the heating rate of 10°C/min in the air medium. The weight of each sample was 200 mg. According to a thermogravimetric analysis, it has been found that synthesized (co)polymers are thermally stable up to the temperatures of 255-265°C.

The main indicators of the operational properties of the alloyed industrial lubricant, which were determinant in the experiment, were chosen as follows: kinematic viscosity (υ_{50} and υ_{100}), a viscosity index (VI), a freezing point (T_{Fr}), and antiwear properties.

The model lubricant compositions were prepared to determine the functional influence of the synthesized additives. The polymer was weighed on the analytical balance with a precision of 0.0002 g, and the estimated amount of the oil was weighed on a technical balance. Besides, both substances were mixed for 40 to 60 minutes at 60°C to 120°C. The prepared solution was cooled to and left at room temperature for 6 to 12 hours.

The research of viscosity-and-temperature properties of the alloyed industrial lubricants was performed by determining the following:

(1) the dependence of viscosity on the concentration of the additive in the oil and

(2) the dependence of viscosity on the composition of the additive.

The dependence of viscosity-and-temperature properties of the oil I-20A on the content of (co)monomer in the additive and on the concentration of the additive in the oil are shown in Figure 1.

Figure 1 shows that the viscosity of the samples (the oil I-20A with a PMA additive) develops naturally at the temperatures of 50°C and 100°C. The viscosity curves indicate that an increased concentration of additives in the oil results in increased intermolecular interactions between macromolecules and in a combination of their conformational forms.

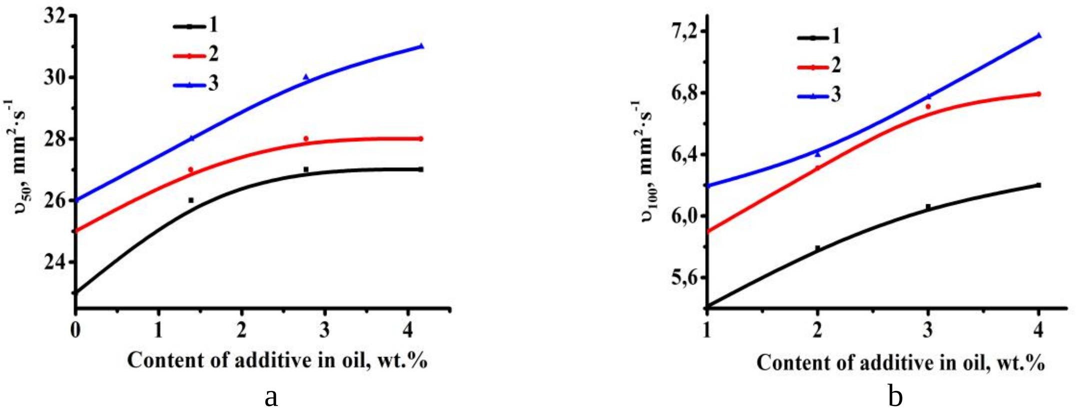

Fig. 1. Dependence of kinematic viscosity on the PMA additive concentration in the oil I-20A: (a) – at 50°C; (b) – at 100°C.
The initial monomer composition of the PMA additives ([LMA] : [MA] mol %):
1 – 90:10; 2 – 80:20; 3 – 70:30

Based on the above listed data and research description, the study of the depressor properties of the lubricant was carried out at the optimum concentration of 2 wt.% of the PMA additive in the oil I-20A. The depressor property of the oil, thickened with additives, was studied by determining the freezing temperature.

The oil I-20A thickened with the PMA20 additive was tested for its antiwear properties. The high viscosity index of the oil with the PMA20 additive (2 wt.%) was found to reduce mechanical friction losses at low temperatures. The antiwear properties of the base oil are significantly improved with the addition of the PMA20 additive, with the wear index (Di) for the base oil I-20A Di = 0.41 mm and for the I-20A with 2 wt.% of the PMA20 Di = 0.32 mm. The lowering of the wear index to 0.32 mm occurs due to formation of a stable boundary film at high contact loadings during the FBM testing.

Conclusion

The influence of polymethacrylate additives in the oil I-20A on the rheological, depressor and antiwear properties was also studied. The viscosity curves for the obtained systems were described. The depressor and antiwear properties of the lubricant were investigated at the optimal concentration of the additive in the amount of 2 wt.% in the oil. It has been found that the PMA20 additive can be used to obtain an alloyed industrial lubricant as a commodity with desirable operational properties (VI = 140 at T_{Fr} = –19°C). The obtained lubricant can be used for friction reduction and wear protection of equipment elements of power plants.

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