UDC 621.89(045)
DOI: 10.18372/2306-1472.83.14654

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THE EFFECT OF CONCENTRATION OF A LIQUID CRYSTAL ADDITIVE AND ELECTRIC FIELD ON PHYSICAL AND CHEMICAL PROPERTIES OF INDUSTRIAL OIL

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Abstract

Objective: *The objective of the article is research into the effect of liquid crystal additive concentration and electric field on the viscosity of industrial oil, and study into influence of concentration on low-temperature properties of oil.* ***Methods:*** *The research and calculations were made by the methods presented in State Standards DSTU GOST 33-2003, GOST 25371-201 and GOST 20287-91.* ***Findings:*** *The authors obtained dependencies of change in viscosity and chilling temperature of industrial oil on liquid crystal additive concentration. Besides, they obtained dependencies of change in industrial oil viscosity treated by electric field at various concentrations of a liquid crystal additive. The study deals with the viscosity index for industrial oil with various concentrations of an additive. A range of the concentrations chosen was also substantiated. The results of the research were processed in Statistica software; regression equations which described dependencies of oil viscosity on additive concentration were obtained.*

Keywords: viscosity; viscosity index; industrial oil; liquid crystal additive; chilling temperature

1. Introduction

Nowadays technologies cannot be developed without application of different appliances and mechanisms. Any engineering system consists of friction units which can malfunction; therefore they may require repair or replacement. Thus, their lower wear-out, longer service life and fail-safe operation are of primary importance. And lubricants for them are improving. New syntactic basic oils and compounds of additives are being developing. Their price increases in comparison with additive-free mineral oils. Industrial mechanisms and equipment require a vast amount of oils. Industrial oils are in widespread use. The cost of these oils is relatively low, and they do not contain the functional additives which decrease their lubrication capacity. Thus, a search for reasonably priced alternatives which can improve the properties of industrial oils and maintain their qualitative characteristics is a strategic pathway of research.

2. Analysis of recent research and publications, statement of the problem

There is a lot of research into different additives. All these additives are of different origin, chemical structure, aggregate state, etc. However, the authors studied into liquid crystal substances as additives for lubricating materials [1-5]. There are various types of such substances: neumatics, smectics, cholesterics, lyotropic liquid crystals and others [6-8]; and there exist a lot of tests on them. It is known that liquid crystal additives form an oil film on friction surfaces, and this film is of high supportive capacity and low friction in the layers [9, 10], which makes them promising for application in the field. Additives can also affect qualitative characteristics (viscosity, chilling temperature) of basic oils [11,12].

Analysis of the results presented in [13, 14] shows high efficiency of cholesterics as additives. They considerably improve the lubricating capacity of basic oils. In their previous research the authors chose and tested a liquid crystal substance of phenanthrene structure, which was added in various concentrations to the И-30A industrial oil. The results of tribological research demonstrated the maximum decrease in the average wear scar diameter at the 0.4% additive concentration by about 35…50% relative to the wear scar diameter of an additive-free oil obtained in research. Besides, the load wear index also increased by 48…49% in the testing range, the same as the critical loading. Thus, a liquid crystal additive of phenanthrene structure positively influenced the anti-wear extreme pressure properties of industrial oil. The results of tribological research will be presented in more detail in an individual publication.

Though such an additive considerably improved the tribological properties of industrial oil, there was a need to be convinced that it did not worsen the qualitative properties regulated by GOSTs. Thus, for И-30A oil by GOST 20788 the kinematic viscosity at 40ºC is 41-51 mm²/sec, the chilling temperature does not exceed -15ºC.

Moreover, the effect of an external electric field on properties of oils with above-mentioned additives is not studied, thought it is known, that liquid-crystal substances strongly respond to electric fields [8,10,15].

3. Objective and tasks of the research

1. Research into the effect of concentration of a liquid-crystal additive and electric fields on viscosity of industrial oil.
2. Research into concentration of a liquid-crystal additive on low-temperature properties of industrial oil.

4. Materials and research methods

The effect of a liquid-crystal additive of phenanthreme structure on kinematic viscosity of the industrial oil И-30A GOST 20799-88 was studied with a Viscosimeter VPJ-4 according to DSTU GOST 33-2003. The study was based on measuring a flow time for the oil in the viscosimeter placed in a temperature control bath (thermostat Gradient-2) at a given temperature. The measurements were taken at temperatures of 40ºC and 100ºC. Besides, the viscosity index (VI) was also determined by GOST 25371-2018.

The effect on the chilling temperature was determined by GOST 20287-91. The test example was heated, then placed in a chilling bath (in a test-tube) and cooled at a given speed. When the oil under study reached a needed temperature, the test-tub was leaned at 45° and kept in this position for a minute. A displacement of the meniscus was observed. The temperature at which the test oil thickened (its level was motionless when the tub leaned at 45° for one minute) was established as the chilling temperature.

On the basis of the studies considered, the following samples were manufactured:

1. additive-free И-30A industrial oil;
2. И-30A + 0.1% liquid crystal additive;
3. И-30A + 0.3% liquid crystal additive;
4. И-30A + 0.5% liquid crystal additive;

For better dissolvability of an additive in oil, the samples were treated with ultrasound in an ultrasound bath at a frequency of 40 kHz and capacity of 50 W. The additive-free sample was also treated similarly. The samples were treated by electric field according to the recommendations presented in study [15].

5. Results of the research

The results of the research are given in Table.

Table

Viscosity and low-temperature properties of the test samples

№	Concentration C, %	Ultrasound treatment	Electric field treatment	Viscosity at 40ºC, ν, mm/sec^2	Viscosity at 100ºC, ν, mm/sec^2	Viscosity index, VI	Chilling temperature, T, ºC
1	0	-	-	44.649	6.477	93	-18
2	0	+	-	44.625	6.473	93	-18
3	0.1	+	-	44.962	6.537	94	-17
4	0.3	+	-	45.176	6.534	93	-17
5	0.5	+	-	45.859	6.567	92	-15
6	0.5	+	+	45.873	6.613	94	-14

The results of the research were processed in Statistica software; the regression equations which described dependencies of oil viscosity on concentrations of the liquid-crystal additives were obtained.

- at 40ºC:

$$\nu = 27.0583 \cdot C^3 - 18.49 \cdot C^2 + 4.9484 \cdot C + 44.625; \quad (1)$$

- at 100ºC:

$$\nu = 5.267 \cdot C^3 - 4.29 \cdot C^2 + 1.016 \cdot C + 6.473. \quad (2)$$

The equations were adequate. The adequacy was checked by Fisher's ratio test [16].

The dependencies determined by the results of the research are graphically presented in Figs. 1-4.

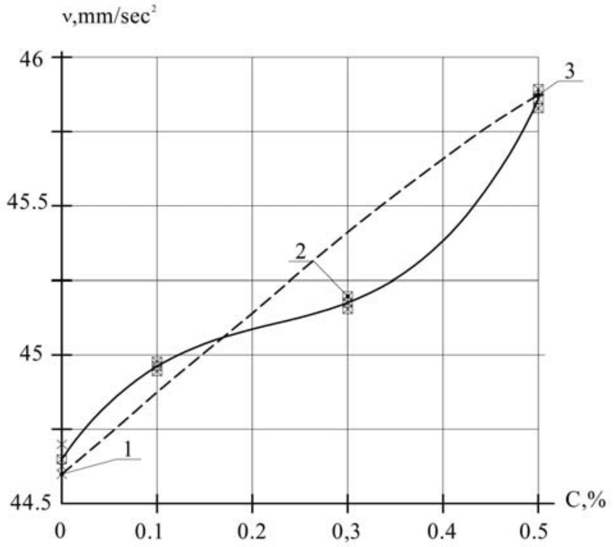

Fig. 1. Change in viscosity of И-30A oil according to additive concentration; temperature 40ºC
1 – substances not treated with ultrasound;
2 – substances treated with ultrasound;
3 – substance treated with ultrasound and electric field

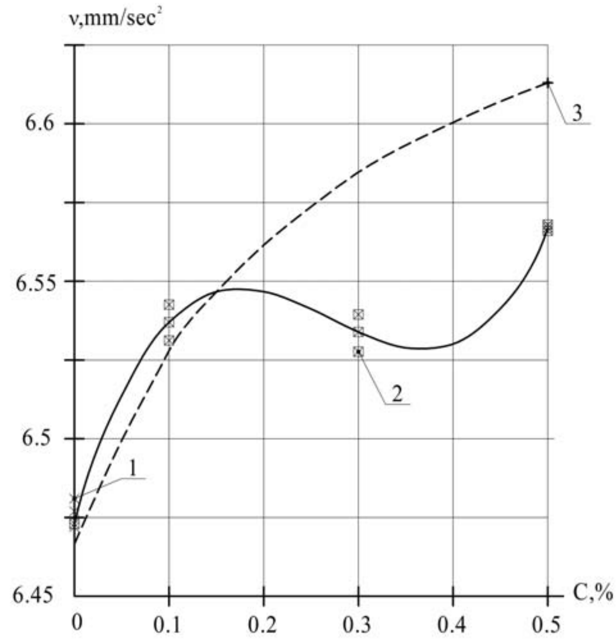

Fig. 2. Change in viscosity of И-30A oil according to additive concentration; temperature 100ºC
1 – substances not treated with ultrasound;
2 – substances treated with ultrasound;
3 – substances treated with ultrasound and electric field

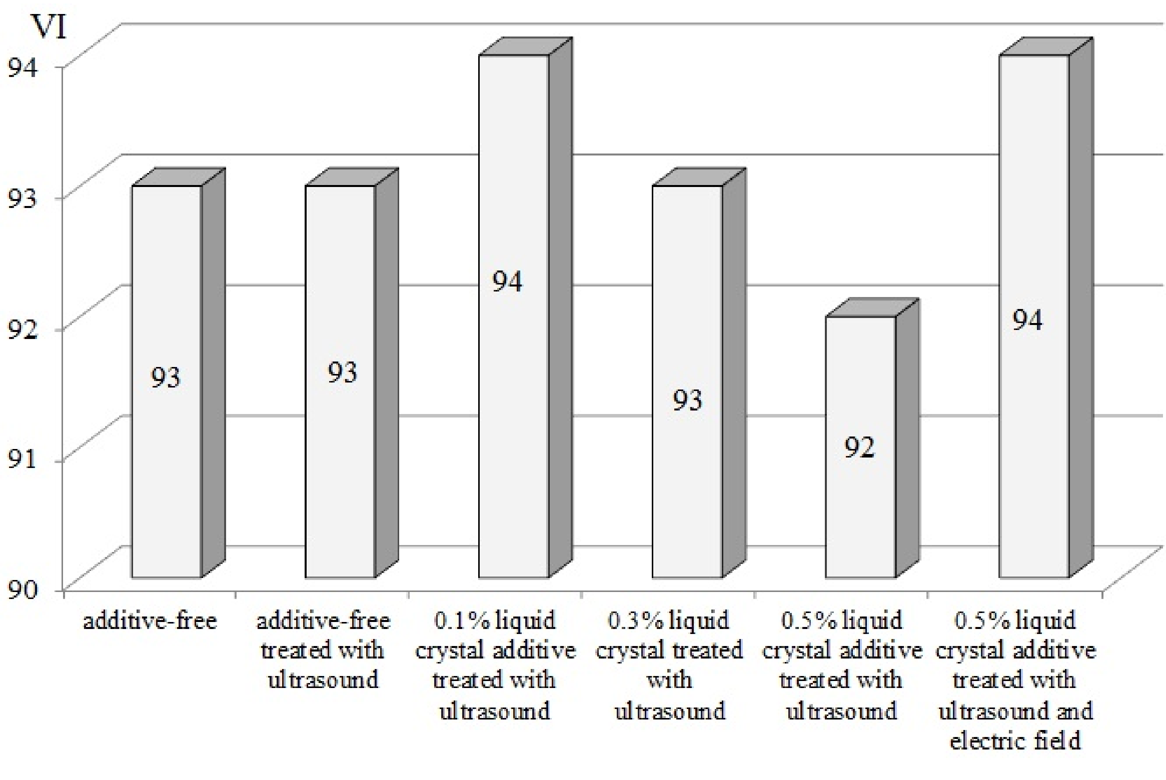

Fig. 3. Change in viscosity of И-30A oil according to additive concentration

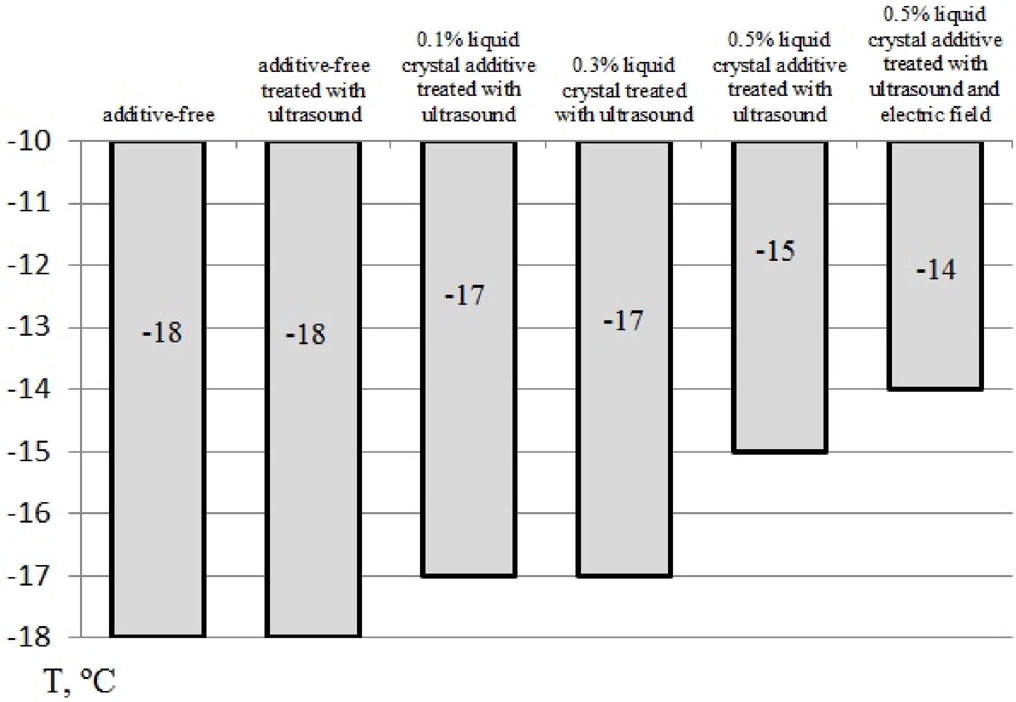

Fig. 4. Change in viscosity of И-30А oil according to additive concentration

7. Conclusions

1. Research into viscosity change of И-30А oil at various concentrations of a liquid-crystal additive of phenanthreme structure demonstrated higher viscosities at higher concentrations from 44.625 mm/sec^2 (additive-free oil treated with ultrasound) to 45.859 mm/sec^2 (0.5 % additive treated with ultrasound) at 40ºC, and from 6.473 mm/sec^2 (additive-free oil treated with ultrasound) to 6.567 mm/sec^2 (0.5% additive treated with ultrasound) at 100ºC. In the chosen range of concentrations the viscosity was within the values regulated by the normative documentation for industrial oil, i.e. by GOST 20788-88 the kinematic viscosity of industrial oil И-30А at 40ºC has to be within a range of 41-51 mm²/sec. For additive-free oil treated by electrical field kinematic viscosity decreases, and at concentrations higher than 0.2% it increases in comparison with that of non-treated samples.

2. The viscosity index demonstrated such results: 93 for additive-free oil И-30А with and without treatment with ultrasound; 94 and 93 – for 0.1 and 0.3 % additives, respectively; 92 – for 0.5% additive; and 94 for 0.5% additive treated by electric field.

3. Research into low-temperature properties of oil showed an increase in the chilling temperature from -18ºC (additive-free oil) to -15ºC (0.5% additive). The chilling temperature in the chosen range of concentrations did not exceed the range regulated by normative documents for industrial oils, e.g. by GOST 20799-88 the chilling temperature of industrial oil И-30А at 40ºC should not exceed -15ºC. On the basis of the results obtained the authors can conclude that additive concentration should not exceed 0.5%, as the chilling temperature at this concentration reaches the boundary possible temperature regulated by the normative documentation. Electrically treated oil with 0.5% additive worsens the low-temperature properties at -14ºC which goes beyond the admissible values. At lower concentrations the chilling temperature is satisfactory and similar to oils without electric treatment.

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Дослідження впливу концентрації рідкокристалічної присадки та електричного поля на фізико-хімічні властивості індустріальної оливи

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Мета: Метою статті є вивчення впливу концентрації рідкокристалічної присадки та електричного поля на в'язкість індустріальної оливи, а також дослідження впливу концентрації на низькотемпературні властивості оливи. **Методи:** Дослідження і розрахунки проводилися за методами описаними в державних стандартах ДСТУ ГОСТ 33-2003, ГОСТ 25371-2018 та ГОСТ 20287-91. **Результати:** Отримано залежність зміни в'язкості та температури застигання індустріальної оливи від концентрації рідкокристалічної присадки. Отримано залежність зміни в'язкості індустріальної оливи при обробці електричним полем, за різних концентрацій рідкокристалічної присадки. Розраховано індекс в'язкості для індустріальної оливи з різними концентраціями присадки. Обґрунтовано обраний нами діапазон концентрацій. Результати досліджень оброблені в програмі Statistica, отримано рівняння регресії, які описують залежність в'язкості оливи від концентрації присадки.

Ключові слова: в'язкість, індекс в'язкості, індустріальна олива, рідкокристалічна присадка, температура застигання

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Исследование влияния концентрации жидкокристаллической присадки и электрического поля на физико-химические свойства индустриального масла

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Цель: Целью статьи является изучение влияния концентрации жидкокристаллической присадки и электрического поля на вязкость индустриального масла, а также исследование влияния концентрации на низкотемпературные свойства масла. **Методы**: Исследование и расчеты проводились по методам, описанным в государственных стандартах ГОСТ 33-2003, ГОСТ 25371-2018 и ГОСТ 20287-91. **Результаты**: Получены зависимости изменения вязкости и температуры застывания индустриального масла от концентрации жидкокристаллической присадки. Получена зависимость изменения вязкости индустриального масла при обработке электрическим полем, при разных концентрациях жидкокристаллической присадки. Рассчитан индекс вязкости для индустриального масла с различными концентрациями присадки. Обоснованно выбранный нами диапазон концентраций. Результаты исследований обработаны в программе Statistica, получено уравнение регрессии, описывающие зависимость вязкости масла от концентрации присадки.

Ключевые слова: вязкость, индекс вязкости, индустриальное масло, жидкокристаллическая присадка, температура застывания

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