Analysis of the mechanism of action and functional properties of viscous additives

M A Kovaleva, V G Shram, N E Soloviev, N N Lysyannikova, A V Lysyannikov and E G Kravtsova

Siberian Federal University, 82/6 Svobodny pr., 660041 Krasnoyarsk, Russia

E-mail: Lera0727@yandex.ru

Abstract. In this paper, the mechanism of action of viscous additives based on polymer components is analyzed. The functional properties of the most common viscosity additives on the domestic market were tested: Kerry, LIQUI MOLY Visco-Stabil and Hi-Gear on oils of various basic bases, namely: Visco2000 15w40 mineral motor oil; semi-synthetic engine oil Genesis Lukoil 10w40; synthetic oil Lukoil Lux 5w40. The effectiveness of the additive Kerry in relation to the semi-synthetic engine oil Genesis Lukoil 10w40 has been revealed.

Motor oils, being the most important structural element of the engine, can perform their functions for a long time and reliably, providing the specified engine life only if its properties correspond to the thermal, mechanical and chemical influences to which the oils are exposed in the engine lubrication system and on the surfaces of lubricated and cooled parts.

The most important and objective characteristic of oils is their viscosity. This characteristic is included in the designation of motor oils. Viscosity determines the possibility and expediency of using oil for specific units and mechanisms, as well as the ability to provide liquid friction, cooling efficiency, compaction of friction units, ease of starting engines [1].

There are such kinds of viscosity as: dynamic, kinematic and conditional.

Dynamic viscosity is the coefficient of internal friction of the layers of liquid lubricant, or more precisely and fully, the resistance force of two layers of liquid lubricant with an area of 1 cm² located at a distance of 1 cm and moving one relative to the other under the influence of an external force at a speed of 1 cm/s.

Kinematic viscosity characterizes the fluid mobility and is equal to the ratio of the dynamic viscosity of the lubricant to its density.

Conventional viscosity (in arbitrary degrees) is the ratio of the kinematic viscosity of the oil to the viscosity of water (when it expires at a temperature of 20 °C).

For lubricating oils, the kinematic viscosity is mainly normalized. For motor, hydraulic and gear oils, kinematic viscosity is normalized at 100 °C, for industrial - at 40 °C.

Oil viscosity depends on the nature and fractional composition [2], [3].

Another important characteristic is the viscosity index (VI). Motor oils must have a viscosity such that they do not liquefy strongly at high temperatures, and, on the contrary, do not lose fluidity at low temperatures. Viscosity index is an empirical dimensionless indicator characterizing the dependence of oil viscosity on temperature. The higher the viscosity index, the lower the viscosity depending on temperature. VI depends on the nature of the oil. Paraffin and isoparaffin hydrocarbons, as well as...
monocyclic naphthenes and aromatic hydrocarbons with long alkyl substituents, have the highest VI. The lowest VI for polycyclic hydrocarbons (naphthenes, aromatic) and resins.

Mixing polymer masses allows you to vary the properties of oils in a fairly narrow range. To expand the working range of lubricating oils, viscous additives are used, which are polymers of various structures and molecular weights.

Viscous or thickening additives are designed to increase the viscosity and viscosity index of oils. Various polymer and copolymer products are used as viscosity additives: polyisobutenes, polymethacrylates, polyvinylalkyl ethers, olefin copolymers, styrene diene copolymers [4], [5].

Oils containing viscous additives are called thickened. Using viscous additives, all-season, northern and arctic oils are obtained. Thickened oils are the most suitable base for universal motor oils. In addition to motor oils, viscosity additives are also used to improve the properties of gear oils and hydraulic fluids.

Thickened oils are solutions of high molecular weight compounds in distillate oils. Additive macromolecules are hundreds of times larger than oil molecules; therefore, the dissolution of the polymer in oil leads to an increase in its viscosity.

At a low temperature, when the oil is viscous, the polymer molecules are in a twisted state and in this form have little effect on viscosity, i.e. at low temperatures, only the naturally low viscosity of the base oil is manifested. With increasing temperature, the solubility of polymer molecules increases, they unwind, increasing the viscosity of the oil. Polymer viscosity modifiers are effective in oils operating under moderate loads, in the absence of high shear deformation.

In the presence of a high load and a high shear rate, long thickener molecules can break into small fragments, as a result of which the thickener's efficiency during operation will decrease [6], [6], [7], [8].

The two most common viscosity additives in the domestic market were selected as objects of study: Kerry and LIQUI MOLY Visco-Stabil; as well as a complex of additives to Hi-Gear engine oil, which incorporates polymers that affect the viscosity of the oil.

All of the above additives were tested on oils of various basic bases, namely:

- visco2000 15w40 mineral engine oil;
- semi-synthetic engine oil Genesis Lukoil 10w40;
- synthetic oil Lukoil Lux 5w40.

To determine the effectiveness of the additives, the kinematic viscosity of each oil was determined and the viscosity index was calculated without and with the addition of additives. Kinematic viscosity was measured with a small viscometer. The operation of the device consists in measuring the time of immersion of the ball under its own weight in oil at a given temperature. Based on the results obtained, the dependences of the kinematic viscosity on temperature were added with the addition of the previously listed additives (figure 1-3).

Figure 1. The dependence of the kinematic viscosity (mm² / s) on the temperature of Visco2000 15w-40 mineral motor oil.
Based on the data obtained, we see that at 400 °C, the Hi-Gear additive has the greatest thickening effect on all types of oils, the LIQUI MOLY Visco-Stabil additive - the smallest, intermediate position is occupied by the Kerry additive. With increasing temperature:

- from 40 to 600°C we observe a decrease in viscosity by 55-60%;
- from 60 to 80°C by 45-50%;
- from 80 to 100°C by 35–40%;
- from 100 to 120°C by 25-30%.

It is worth noting that the addition of additives does not significantly affect the change in viscosity with increasing temperature, the basic nature of the oils is much more important.

Table 1 shows the viscosity index of motor oils when additives are added.

**Table 1. Comparison of viscosity indices for selected samples of motor oils.**

| Name of oil          | Viscosity index, without additives | Viscosity index, with LIQUI MOLY Visco-Stabil additive | Viscosity index, with Kerry additive | Viscosity index, with multi-functional additive |
|----------------------|-----------------------------------|-------------------------------------------------------|-------------------------------------|-----------------------------------------------|
| Mineral oil 15w40    | Visco2000                          | 128                                                   | 129                                 | 116                                           | 118                                           |
| Semi-synthetic oil   | Genesis Lukoil 10w40               | 141                                                   | 139                                 | 153                                           | 135                                           |
| Synthetic oil 5w-40  | Lukoil Lux                          | 133                                                   | 131                                 | 128                                           | 130                                           |
The additives we use are polymeric in nature and are more active for some base oils and less active for others. For example, visco 2000 15w40 mineral oil-thickened sample with additives and additives without additives has a maximum viscosity change of 52 units at 400°C, while Genesis Lukoil 10w40 semi-synthetic engine oil has 30.5 units, and Lukoil Lux 5w40 synthetic engine oil - 25 units. That is, oils with a mineral base thicken more efficiently than oils with a synthetic base. However, when the temperature rises above 1000 °C, the increase in viscosity is insignificant, which, judging by the data in table 1, does not allow one to achieve an increase in the viscosity index of the studied oil samples in all cases except one. In figure 2, you can see that the curve depicting the temperature dependence of viscosity with the addition of Kerry is more gentle than all the others, which indicates an increase in the viscosity index of the test sample and the effectiveness of this additive with respect to the Genesis Lukoil 10w40 semi-synthetic motor oil.

References
[1] Shkolnikov V M 1989 Fuel, lubricants, technical fluids. Assortment and application (Moscow)
[2] Bityukova V R 2017 Ecology and industry of Russia 4 4-11
[3] Lashkhi V L 1988 Chemistry and technology of fuel oils 11 24-9
[4] Kovaleva M A, Kurbatova A D, Lissynnikov A V, Kravtsova E G and A V Tsygankova 2019 IOP Conference Series: Materials Science and Engineering 537
[5] Shram V G, Lissynnikov A V and Kovaleva M A 2016 J Procedia engineering 458-63
[6] Vereshchagin V I, Yanovich V S, Kovalsky B I 2017 Control methods and the results of a study of the state of transmission and motor oils during their oxidation and tribotechnical tests (Krasnoyarsk) p 208
[7] Tagirov T K 2008 Comprehensive study of lubricants based on synthetic, mixed and petroleum oils (Moscow) p 204
[8] Ostrikov V V, Zimin A G, Popov S Yu, Safonov V V and Safonov K V 2012 Agricultural Engineering 6 32-3