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# Study of HTHS Viscosity of Modern Motor Oils

E. Zadorozhnaya[a], I. Levanov[a,*], O. Oskina[a]

[a] *South Ural State University, 76, Lenin Avenue, Chelyabinsk, 454080, The Russian Federation*

**Abstract**

The article presents the results of experimental studies of HTHS viscosity of modern motor oils belonging to different viscosity classes. Changes in viscosity due to shear rate increase from $10^6$ $s^{-1}$ to $1{,}8 \cdot 10^6$ $s^{-1}$ are presented for oils of classes SAE 5W-30, 5W-40, 5W-50. The results can be used in designing the friction units of internal combustion engines, in particular, the bearings of the crankshaft.

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*Keywords:* Properties of non-Newtonian multigrade oils; viscosity; shear rate; rheology; journal bearing.

## 1. Introduction

Currently, the multigrade motor oils, condensed by viscous polymer additives, are widely used in the operation of internal combustion engines (ICE). Such additives usually add to obtain a flatter viscosity-temperature characteristic and improve the viscosity index of multigrade oils. That is, at low temperatures, the viscosity should be not too high to ensure pumpability in the lubrication system, access nodes, and minimal frictional resistance during cranking. At the same time, at high temperatures, the viscosity must be sufficient to provide a lubricating layer in the friction unit, which can carry the load.

The rheological behaviour of multigrade oils has features that are called in the literature as non-Newtonian properties. The dependence of viscosity on shear rate (pseudo-plasticity, temporary decrease or anomaly in the viscosity), viscoelasticity (relaxation of shear stresses, the appearance of normal stresses in the shear) is among the most well-known properties of non-Newtonian multigrade oils. Due to the dependence of viscosity on shear rate,

* Corresponding author. Tel.: +7-908-050-3053; fax: +7-351-267-9214.
*E-mail address:* levanovig@susu.ru


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these oils are also called "energy efficient" because they reduce the power loss to friction in the engine, and therefore a fuel consumption.

**Nomenclature**

| | |
|---|---|
| $K_c$ | A parameter shear stability oil, Pa |
| $\mu_1$ | First Newtonian (low-shear-rate) viscosity, Pa·s |
| $\mu_2$ | Second Newtonian viscosity, Pa·s |
| $\dot{\gamma}$ | Shear rate, $s^{-1}$ |
| $\mu^*$ | Apparent viscosity, Pa·s |
| $C_1, C_2, C_3$ | Temperature constants, which are characteristics of the lubricant |
| $\beta(T)$ | Piezocoefficient viscosity, $Pa^{-1}$ |
| $T_p$ | Estimated temperature of the lubricant film, °C |
| $p$ | Film pressure, Pa |

Various rheological models are used to describe the rheological behaviour of multigrade engine oils. The power law of Ostwald-Weil [1], the dependencies proposed by Gecim [2], Coy [3] are the most known models for describing the rheological behaviour of multigrade oils. The dependence of the viscosity proposed by Gecim is the best for describing the behaviour of multigrade oils

$$\mu^*(\dot{\gamma}) = \mu_1 \frac{K_c + \mu_2 \cdot \dot{\gamma}}{K_c + \mu_1 \cdot \dot{\gamma}}. \tag{1}$$

The typical dependence of the multigrade oils viscosity on shear rate is presented in Fig. 1.

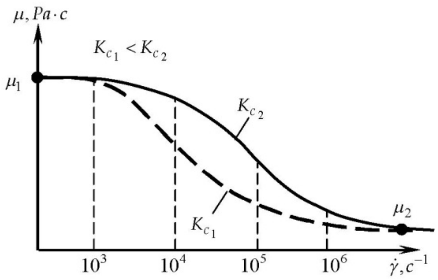


Fig. 1. Fundamental character of the non-Newtonian oils viscosity

Recently researchers have begun to develop various modifications of the models, taking into account not only the shear rate but also the temperature, the pressure in the tribo-unit, etc. [3, 7].

$$\mu^*(T,p,\dot{\gamma}) = \begin{cases} \mu_1 \cdot C_1 e^{\left(C_2/\left(T_p+C_3\right)\right)+\beta\left(T_p\right)\cdot p}, 1 \le \dot{\gamma} \le \dot{\gamma}_1; \\ \left(I_2\right)^{\left(n\left(T_p\right)-1\right)/2} \cdot C_1 e^{\left(C_2/\left(T_p+C_3\right)\right)+\beta\left(T_p\right)\cdot p}, \dot{\gamma}_1 \le \dot{\gamma} \le \dot{\gamma}_2; \quad \dot{\gamma} = \sqrt{I_2}. \\ \mu_2 \cdot C_1 e^{\left(C_2/\left(T_p+C_3\right)\right)+\beta\left(T_p\right)\cdot p}, \dot{\gamma} > \dot{\gamma}_2, \end{cases} \tag{2}$$