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Rheological behavior of SAE 85W-140 oil

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Abstract
In this article, we determined the rheological behavior of SAE 85W140 oil using the Anton Paar MCR302 rheometer. By fitting the experimental data, we obtained four rheological models that describe the behavior of this oil at increasing shear rates and elevated temperatures. These models faithfully describe the rheological behavior of the studied oil because they have correlation coefficients close to unity.

Keywords: Rheology, oil behavior, viscosity

Introduction

Rheology is the science that studies the interdependence between mechanical stresses, the response of bodies and their properties. This science establishes mathematical models that describe the behavior of bodies subjected to stresses. This behavior is determined by the dependence between forces (stresses) and response (deformation, for example).

A force or a system of forces applied to a body leads to its movement. The movement of the body can consist of displacements (translation and/or rotation) or/and deformations (changes in shape and/or volume). In general, displacement does not change the relative position of the elements that form the body, but it does change its position, in relation to an external reference system. Deformation determines the change in the relative position of the constituent elements [1-5].

Deformation, in the case of solids, occurs until equilibrium is reached between internal and external forces. The degree of deformation changes continuously over time for fluids that do not reach an equilibrium deformation. Flow is the phenomenon in which the deformation increases continuously and does not recover after the removal of the force. Flow plays an important role in most operations specific to polymer synthesis and processing technologies.

The rheological models found in the literature are:

Andrade:

$$\eta = A \cdot 10^{B/T} \quad (1)$$

Bingham:

$$\sigma = \sigma_o + \eta \dot{\gamma} \quad (2)$$

Casson:

$$\sigma^{1/2} = \sigma_o^{1/2} + \eta^{1/2} \dot{\gamma}^{1/2} \quad (3)$$

Ostwald-de Waele:

$$\sigma = k \dot{\gamma}^n \quad (4)$$

and Herschel-Bulkley:

$$\sigma = \sigma_o + k\eta \dot{\gamma}^n \quad (5)$$

where σ is the shear stress, τ_o – yield stress, η - viscosity, $\dot{\gamma}$ - shear rate, n – flow index and k – index of consistency.

This paper analyzes the rheological behavior of SAE 85W-140 oil, a high-viscosity lubricant mainly used in transmissions, differentials and other components of the drive system subjected to high loads. SAE 85W-140 oil is characterized by a high viscosity at operating temperatures, which ensures a stable and resistant lubricating film, even under high pressure and elevated temperatures. The study highlights its pseudoplastic behavior, typical of non-Newtonian fluids, in which the viscosity decreases with increasing speed or shear force. Tests performed at different temperatures show good thermal stability and excellent protection against wear and friction. However, due to its high viscosity at low temperatures, SAE 85W-140 oil is not recommended for use in very cold environmental conditions. The rheological properties obtained confirm its optimal applicability in heavy mechanical systems, where reliability and long-term protection are essential [6-12].

Material and methods

The viscosity of SAE 85W140 oil was measured with the Rheometer MCR302 viscometer in the temperature range of 20-100^{0}C at shear rate of 10s^{-1} for 2 minutes. Figure 1 shows the Rheometer.

Fig 1: Anton Paar MCR302

Results & Discussion

Figure 2 represents the dependence of dynamic viscosity on temperature for SAE 85W140 oil. As can be seen in the figure, the dynamic viscosity of the oil decreases with increasing temperature.

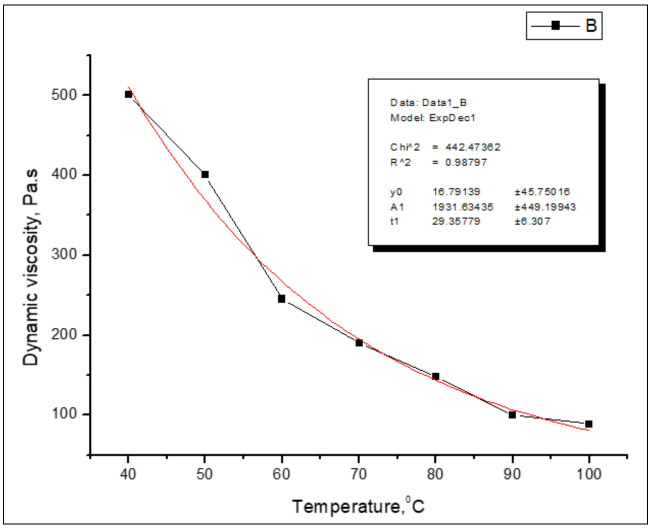

Fig 2: Dynamic viscosity versus temperature for SAE 85W140 oil

Figure 3 shows the temperature dependence of the shear stress for the oil studied. The shear stress decreases exponentially with increasing temperature.

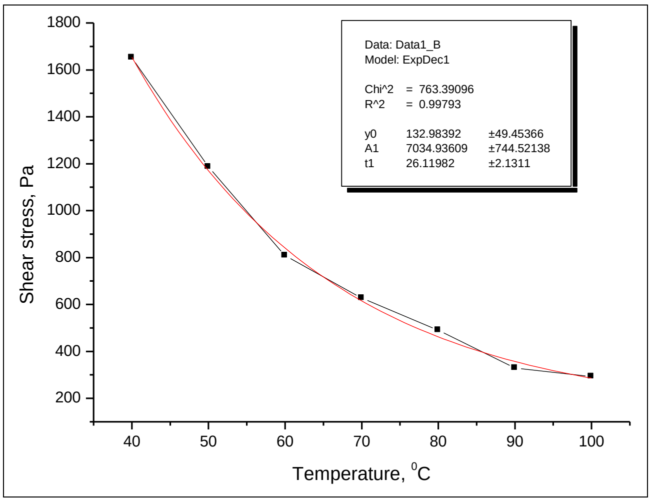

Fig 3: Shear Stress vs Temperature for SAE 85W140 Oil

Figure 4 shows the dynamic viscosity vs shear rate for SAE 85W140 oil. The dynamic viscosity of the oil decreases exponentially with increasing shear rate.

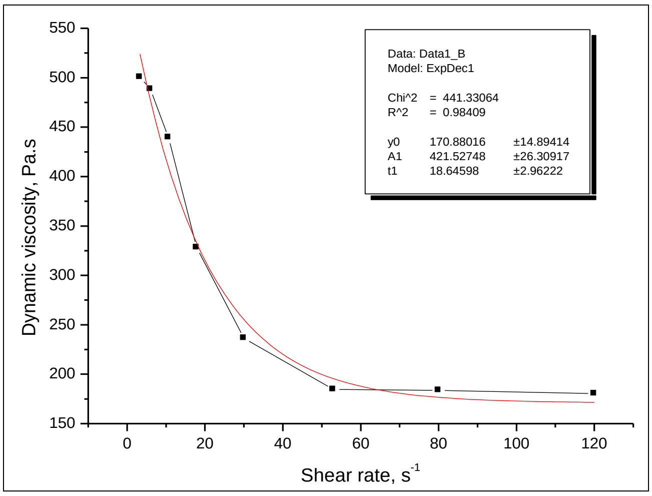

Fig 4: Dependence of dynamic viscosity on shear rate for SAE 85W140 oil

Figure 5 shows the dependence of shear rate on shear stress. Shear stress decreases exponentially with increasing shear rate.

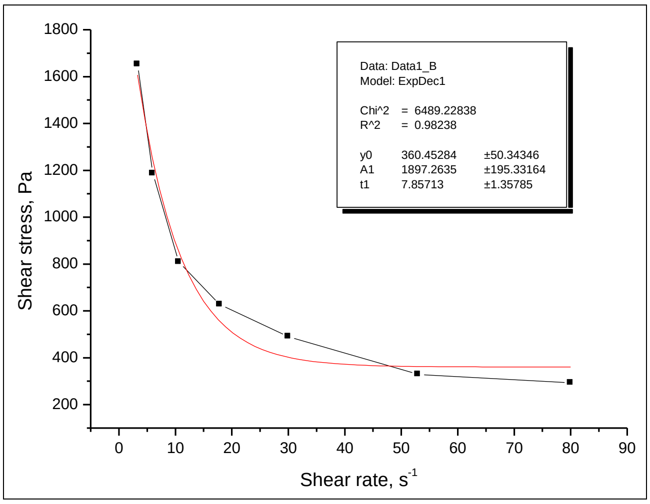

Fig 5: Shear stress dependence on shear rate for SAE 85W140 oil

In table 1 we have included the rheological models that describe the behavior of SAE 85W140 oil. For the found models the correlation coefficients have values close to unity.

Table 1: Rheological models for SAE 85W140 oil

Model	Parameters model	Coeficienti de corelatie
$\eta = \eta_0 + A_1 \exp(-t/t_1)$	η_0 =16,79139 A_1=1931,63435 t_1=29,35779	0,98797
$\tau = \tau_0 + A_1 \exp(-t/t_1)$	τ_0 =132,98392 A_1=7034,93609 t_1=26,11982	0,99793
$\eta = \eta_0 + A_1 \exp(-\dot{\gamma}/t_1)$	η_0 =170,88016 A_1=421,52748 t_1=18,64598	0,98409
$\tau = \tau_0 + A_1 \exp(-\dot{\gamma}/t_1)$	τ_0 =360,45284 A_1=1897,2635 t_1=7,85713	0,98238

Conclusions

The rheological models found by exponential fitting of the experimental data faithfully describe the behavior of the oil in the temperature range at which it was studied. The oil was studied with the MCR302 rheometer. SAE 85W-140 oil exhibits a typical non-Newtonian, pseudoplastic behavior, characterized by a decrease in viscosity with increasing shear rate. This behavior is advantageous in transmission and differential applications, where mechanical stresses are variable. The oil maintains a high and stable viscosity at high temperatures, providing a consistent lubricating film that effectively protects components subjected to intense mechanical loads and high friction. Due to the high viscosity at cold (85W class), this oil has limited fluidity in low temperature conditions, which can affect the initial lubrication and efficiency of mechanisms in cold environments. The rheological properties highlight that SAE 85W-140 is suitable for use in heavy-duty transmission systems (trucks, industrial machinery, agricultural equipment), where high protection and increased oil film durability are required. For areas with low temperatures or frequent cold starts, it is recommended to use oils with a lower winter class or synthetic variants with a better viscosity index [13-19].

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