ORIGINAL PAPER

RHEOLOGICAL BEHAVIOR STUDY OF HIDRAULIC OIL

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Manuscript received: 15.12.2012; Accepted paper: 11.02.2012;

Published online: 10.03.2012.

Abstract. *Rheological behavior of this article presents hydraulic oil. Dynamic viscosity of hydraulic oil was determined at temperatures between 40^0C -90^0C and shear rates ranging from 3.3-120s^{-1}. Temperature of hydraulic oil at 313K has a Bingham fluid behavior with correlation coefficient value close to one. Between 323 and 333K temperature behavior of oil has a Casson fluid and the temperature range 343 to363K oil and behaves like an Ostwald-de Waele fluid.*

Keywords: *rheological behaviour, hydraulic oil.*

1. INTRODUCTION

Interest to researchers and manufacturers of oil on the effect of temperature on viscosity increased in recent years [1, 2]. Although the issue seems simple, the contribution is very signifier. This is because the viscosity is an important physical property for the design of hydraulic systems. However, the lack of a precise model which is valid for all liquids is difficult to predict the effect of temperature on viscosity. Known some commonly used mathematical models developed and expanded Vogel-Fulcher, Arrhenius and Andrade [3, 4]. Models are developed using empirical data to predict the dependence of viscosity for a wide range of temperatures. The object of this paper is to determine the rheological behaviour of hydraulic oil at shear rates ranging between 3 and 120 s^{-1} and temperatures between 40 and 90°C.

2. MATERIALS AND METHODS

Rheological behaviour of hydraulic oil was determined using a Haake VT 550 Viscotester developing shear rates ranging between 3 and 1312 s^{-1} and measuring viscosities from 10^4 to 10^6 mPa·s when the HV_1 viscosity sensor is used. The temperature ranged between 40 and 90°C and the measurements were made from 10 to 10°C. The accuracy of the temperature was ± 0.1°C.

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3. RESULTS AND DISCUSSION

Viscosity is a measure of the "shear strength" of a thin layer of oil or, in other words, of the property the oil has to develop and maintain a certain amount of shearing stress dependent on flow, and than to offer continued resistance to flow. Its viscosity still decreases logarithmically with temperature, but the slope representing the change is lessened. This slope is dependent on the nature and amount of additive to the base oil. The rheograms obtained of hydraulic oil for shear rates ranging between 3 and 120 s^{-1} were analysed according to the models that describe the deviations from the Newtonian behaviour [5, 6]:

Bingham:

$$\tau = \tau_o + \eta \dot{\gamma} \tag{1}$$

Casson:

$$\tau^{1/2} = \tau_o^{1/2} + \eta^{1/2} \dot{\gamma}^{1/2} \tag{2}$$

Ostwald-de Waele:

$$\tau = k \dot{\gamma} \tag{3}$$

and Herschel-Bulkley:

$$\tau = \tau_o + k \dot{\gamma}^n \tag{4}$$

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

The rheograms of hydraulic oil at the specified temperatures and shear rates are shown in Fig. 1.

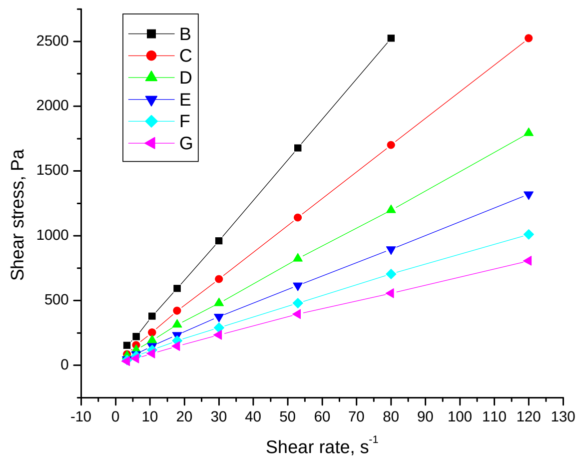

Fig. 1. Rheograms of hydraulic oil at: ■ 313K; ♦ – 323K; ▲ – 333K; ▼ – 343K; ♦ - 353K; ◄ – 363K.

The Fig. 1 presented rheograms of hydraulic oil. Temperature of hydraulic oil at 313K has a Bingham fluid behavior with correlation coefficient value close to one. Between 323 and 333K temperature behavior of oil has a Casson fluid and the temperature range 343K to 363K oil and behaves like an Ostwald-de Waele fluid. Coefficients correlation a models Bingham, Casson, Ostwald-de Waele and Herschel-Bulkley listed in Table 1.

Table1. Coefficients of correlation in models (1)-(4) for hydraulic oil at temperature 313-363K.

Coefficients of correlation, R^2				
Temperature [K]	**Model Bingham**	**Model Casson**	**Model Ostwald-de Waele**	**Model Herschel-Bulkley**
313	0.9996	0.9982	0.9981	0.9981
323	0.9994	0.9999	0.9998	0.9998
333	0.9998	0.9999	0.9997	0.9997
343	0.9996	0.9998	0.9999	0.9998
353	0.9994	0.9998	0.9999	0.9998
363	0.999	0.9998	0.9999	0.9998

The dynamic viscosity decreases with temperature in accordance to Andrade equation [7-9]:

$$\eta = A. \tag{5}$$

where A and B are constants and T is the absolute temperature.

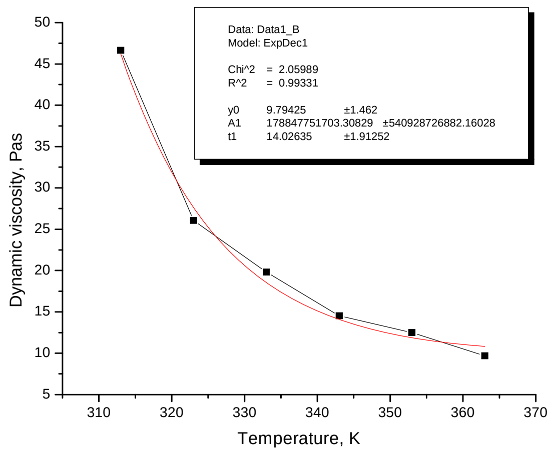

Fig. 2. Dependence of dynamic viscosity by temperature for hydraulic oil at shear rate 3.3 s^{-1}.

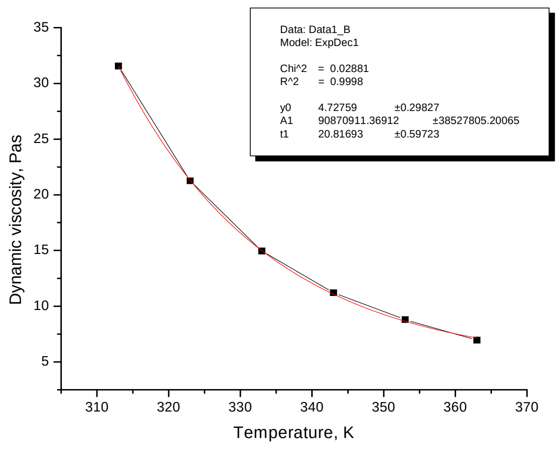

Fig. 3. Dependence of dynamic viscosity by temperature for hydraulic oil at shear rate 80 s^{-1}.

The dependence of dynamic viscosity by temperature for hydraulic oil at shear rate 3.3 s^{-1} and 80 s^{-1} was first order exponential decay shown in Figs 2 and 3. The dynamic viscosity of hydraulic oil decreases exponential which the increasing temperature.

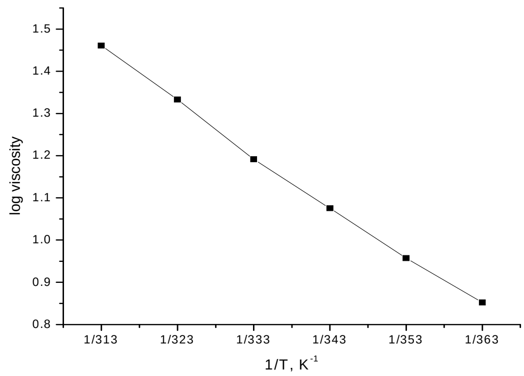

Fig. 4. Plot of log viscosity as a function of 1/T for hydraulic oil.

Plots of log viscosity versus 1/T for all the hydraulic oil is given in figure 4. The constants A and B were also determined for hydraulic oil was: logA.= -0.12404 and B = 1.55448.

4. CONCLUSIONS

The dynamic viscosity of hydraulic oil was determined at temperatures between 40^0C - 90^0C and shear rates ranging from 3.3-120 s^{-1}.

The dynamic viscosity of hydraulic oil decreases exponential which increasing temperature. Temperature of hydraulic oil at 313K has a Bingham fluid behavior with correlation coefficient value close to one.

Between 323 and 333K temperature behavior of oil has a Casson fluid and the temperature range 343 to 363K oil and behaves like an Ostwald-de Waele fluid.

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