New Models Polynomial Experimental of Variation Dynamic Viscosity –Temperature For Soybean Oil

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Abstract: This article proposes new rheological models for soybean oil. The purpose of this study was to find an polynomial dependence between temperature and dynamic viscosity of soybean oil, using one equation. Equation constants A, B_1 and B_2 were determined by fitting polynomial. The soybean oil have investigated using a Haake VT 550 Viscotester developing shear rates ranging between 3 and 120 s^{-1} and measuring viscosities from 10^4 to 10^6 mPa·s when the HV_1 viscosity sensor is used. Soybean oil dynamic viscosity decreases with increasing temperature at constant shear rate. Plotting the dynamic viscosity depending on temperature shows an polynomial decline.

Keywords: soybean oil, polynomial, rheology.

1. Introduction

Viscosity is a very important fluid property within the oil industry, but less frequently studied compared to thermodynamic and equilibrium properties. The viscosity is required in many engineering disciplines ranging from the design of transport equipment to simulations of petroleum reservoirs and chemical processes [1-4] For the oil industry reliable and accurate viscosity models applicable over wide range of temperature, pressure, solid wax content, composition, thermal and shear history in Newtonian and non-Newtonian conditions are required. An accurate estimation of the viscosity will result in more efficient explorations of new oil fields and production techniques. Despite the importance petroleum fluids have had for many years and the tremendous number of works already completed in oil industry, there is still a lack of studies concerning the viscosity versus temperature and pressure of some components of petroleum fluids. Precipitated wax, shear and thermal history have pronounced effects on viscosity and rheological behaviour of waxy crudes [5-16].

There are several viscosity-temperature equations. Some of them are purely empirical whereas others are derived from theoretical models. The most commonly used equations are given in Table 1 [4].

Among them the most accurate is the Vogel equation. Three viscosity measurements at different temperatures for specific oil are needed in order to determine the three constants in this equation.

Table.1 Viscosity-temperature equations

Name	Equation	Comments
Reynolds	$\mu_0 = be^{-aTA}$	Early equation; accurate only for a very limited temperature range
Slotte	$\mu_0 = a/(b+T_A)^c$	Reasonable; useful in numerical analysis
Walther	$\nu_0 + a = bd^{1/T_A^c}$	Forms the basis of the ASTM viscosity-temperature chart
Vogel	$\mu_0 = ae^{b/(T_A - c)}$	Most accurate; very useful in engineering calculations

where:

a, *b*, *c*, *d* – are constants;

ν_0 – is the kinematic viscosity at the atmospheric pressure [m^2/s];
μ_0 – is the dynamic viscosity at the atmospheric pressure [Pas];
T_A – is the absolute temperature [K].

2. Materials

Types of soybean oil used in this paper are produced from soybean crop produced in Romania. The soybean oil have investigated using a Haake VT 550 Viscotester developing shear rates ranging between 3 and 120 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.

3. Results and discussion

Figure 1 shows dependency of the dynamic viscosity on the $1/T^2$ for studied soybean oil at shear rate $3.3s^{-1}$, $6s^{-1}$, $10.6s^{-1}$, $17.87s^{-1}$, $30s^{-1}$, $52.95s^{-1}$, $80s^{-1}$ and $120s^{-1}$.
This article proposes one correlations (Eq.1) dynamic viscosity according to the$1/T^2$ for soybean oil.

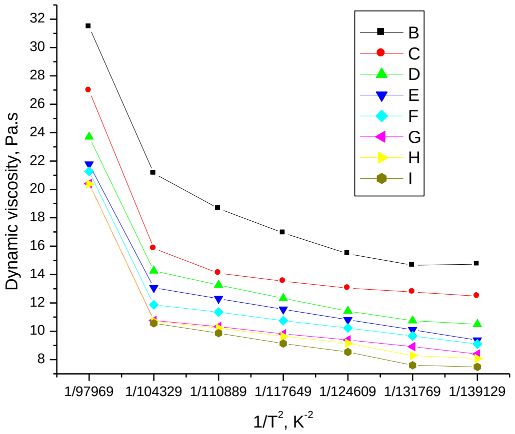

Fig.1. The correlation dynamic viscosity on the $1/T^2$ at: B – $3.3s^{-1}$, C – $6s^{-1}$, D – $10.6s^{-1}$, E – $17.87s^{-1}$, F – $30s^{-1}$, G – $52.95s^{-1}$, H – $80s^{-1}$ and I – $120s^{-1}$

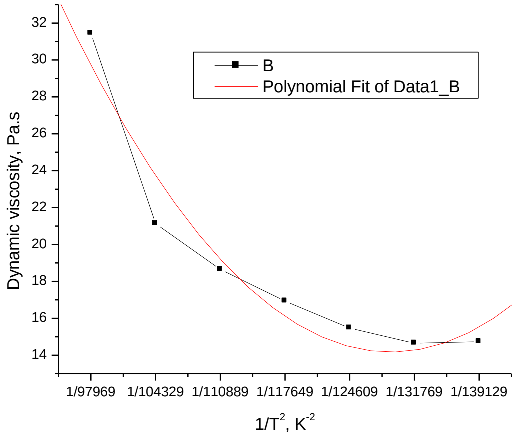

Fig. 2 . The correlation dynamic viscosity on the $1/T^2$ at $3.3s^{-1}$

The dependency of dynamic viscosity on the $1/T^2$ for soybean oil at shear rate $3.3s^{-1}$, $6s^{-1}$, $10.6s^{-1}$, $17.87s^{-1}$, $30s^{-1}$, $52.95s^{-1}$ and $80s^{-1}$ (the black curves from Fig. 2, 3, 4, 5, 6, 7 and 8) was fitting polynomial as shown in figures 2, 3, 4, 5, 6, 7 and 8. The polynomial dependence of dynamic viscosity on the $1/T^2$ for soybean oil at $3.3s^{-1}$ is described for equation (1):

$$\eta = 37.1614 -8.1602\cdot(1/T^2) + 0.7240\cdot(1/T^2)^2 \qquad (1)$$

where A =37.1614, B_1 =-8.1602 and B_2 =0.7240. The correlation coefficient is R^2 = 0.9413.

In table 2 we see that the empirical relations who give the best results in this study the temperature dependence of oil dynamic viscosity is described by equations (1), where the correlation coefficient values are close by 1.00. Equation (1) is not suitable to describe the temperature dependence of oil viscosity, because the values of correlation coefficients are less than 1.

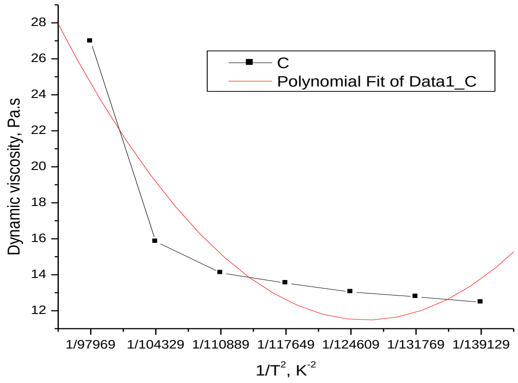

Fig. 3. The correlation dynamic viscosity on the $1/T^2$ at $6s^{-1}$

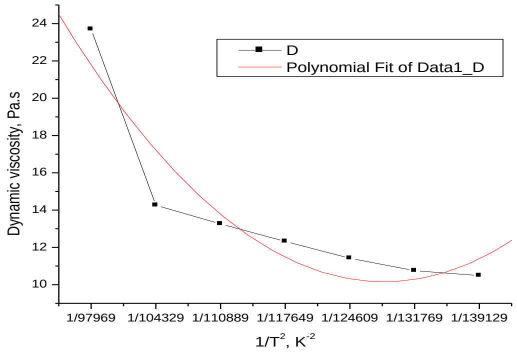

Fig. 4. The correlation dynamic viscosity on the $1/T^2$ at $10.6s^{-1}$

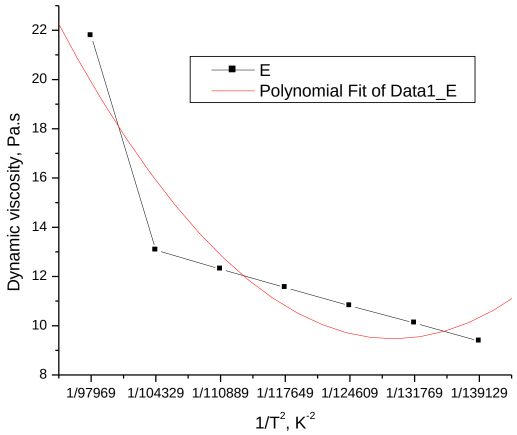

Fig. 5. The correlation dynamic viscosity on the $1/T^2$ at $17.87s^{-1}$

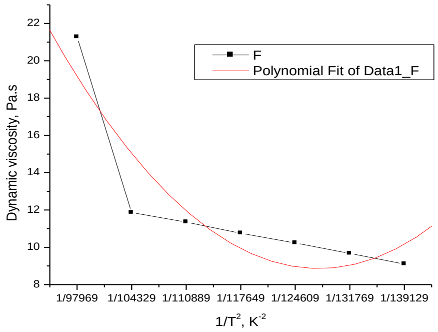

Fig. 6. The correlation dynamic viscosity on the $1/T^2$ at $30s^{-1}$

The parameter A value decreases as the shear rate increases, the B_1 parameter increases with the shear rate increase approaching the value one, and B_2 decreases as the shear speed increases. Correlation coefficients have values close to one at shear rates of 3.3 and $120s^{-1}$.

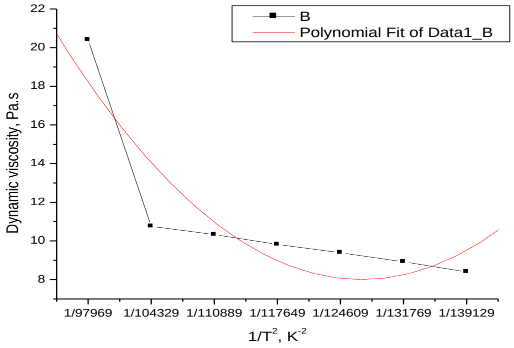

Fig. 7. The correlation dynamic viscosity on the $1/T^2$ at $52.95s^{-1}$

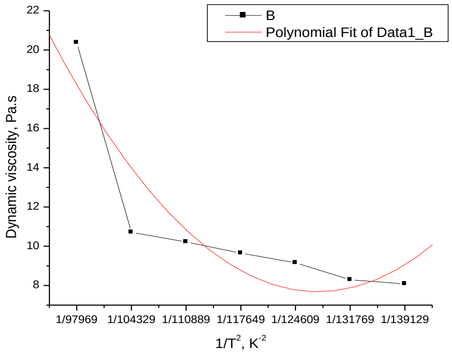

Fig. 8. The correlation dynamic viscosity on the $1/T^2$ at $80s^{-1}$

Table 2. The shear rate, value of parameters of described by equation (1) and coefficient correlation for soybean oil

Shear rate, s^{-1}	Value of parameters			Correlation coefficient, R^2
	A	B_1	B_2	
3.3	37.1614	-8.1602	0.7240	0.9413
6	31.5829	-7.6831	0.7340	0.8556
10.6	27.4743	-6.2679	0.5670	0.8766
17.87	24.8357	-5.4247	0.4788	0.8577
30	24.3357	-5.7013	0.5251	0.8216
52.95	23.4700	-5.7956	0.5429	0.8058
80	23.5500	-5.8676	0.5424	0.8215
120	12.4306	-0.9814	0.0368	0.9862

4. Conclusions

The equations that best describe the temperature dependent dynamic viscosity of soybean oil studied are (1) for which correlation coefficients have values close to one. Soybean oil dynamic viscosity decreases with increasing temperature at constant shear rate. Plotting the dynamic viscosity depending on temperature shows a polynomial decline.

5. Reference

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