ORIGINAL PAPER

A NEW VISCOSITY-SHEAR RATE RELATIONSHIP FOR RAPESEED OIL

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Abstract: *This article proposes four relationships of dynamic viscosity – shear rate dependence for vegetable oils. The purpose of this study was to find a exponential dependence between temperature and dynamic viscosity of vegetable oil, using the equations. Equation constants A, B and C were determined by fitting exponential.*

Keywords**:** *viscosity –shear rate, vegetable oil, relationship*

1. INTRODUCTION

Viscosity study has been widely studied by scientist and engineers on various purposes. These include polymer science, heat transfer phenomena, petroleum reservoir development, coatings, scale modeling of magnetic intrusion, oil degradation, lubrication, etc.[1-6] Viscosity is influenced by different factors, such as, additive, catalyst, temperature, shear rate, time, molecular weight, moisture, pressure, concentration, etc. Among these, temperature and shear rate are the most studied parameters.

In general, viscosity is defined as the ratio of shear stress (force over cross section area) to the rate of deformation (the difference of velocity over a sheared distance), and it is presented by:

$$\eta = \tau / \dot{\gamma} \tag{1}$$

where, η, dynamic viscosity (Pa.s); τ , shear stress (N/m^2); and , $\dot{\gamma}$ rate of deformation or velocity gradient or better known as shear rate (1/s). This relation will gives constant viscosity, if shear stress is proportionally changed with velocity gradient. Fluid that follows this behavior is termed as Newtonian fluid [7]. However, in the measurement of viscosity, an increase in shear stress leads to a greater portion increase in shear rate, and therefore, reducing viscosity value as indicated by viscometer. This phenomenon is known as shear-thinning behavior.

For inverse observation, it exhibits shear-thickening. In this study, the authors limit the following literature reviews to shear-thinning, which is the topic of the current study.

Thus, in nature, Equation (1) has failed to provide a good representation of real phenomena for all fluids. It indicates the presence of scientific gap for which new equation is needed. There were numerous researchers responded to propose alternative equation. Among those equations are power-law, Cross, Carreau, Bingham, Herschel-Bulkley, Casson, Sisko, etc. These equations are presented in sequence as followings [8-11]:

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Bingham:

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

Casson:

$$\tau^{1/2} = \tau_o^{1/2} + \eta^{1/2} \dot{\gamma}^{1/2} \tag{3}$$

Ostwald-de Waele:

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

and Herschel-Bulkley:

$$\tau = \tau_o + k \dot{\gamma}^{n} \tag{5}$$

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

This article proposes four new relationships of dependence of dynamic viscosity of vegetable oils shear rate.

Dynamic viscosity of oils was determined at two temperatures, 40^0C and 100^0C and for shear rate in the range 3.3-120 s^{-1}. The purpose of this study was to find a exponential dependence between shear rate and dynamic viscosity of vegetable oil no additive using differed equations. Equation constants A, B and C were determined by fitting exponential.

2. MATERIALS AND METHODS

The dynamic viscosity of the refined rapeseed mineral oil was measured with Haake VT 550 viscotester. When using HV_1 viscosity sensor, the characteristics of this equipment are: shear rates between 3 and 120s^{-1} and measuring viscosities from 10^4 to 10^6 mPa.s.

3. RESULTS AND DISCUSSION

Figures 1 and 2 show the dynamic viscosity - shear rate dependence for vegetable oil at differed absolute temperatures. The behavior of oil vegetable is that the dynamic viscosity decreases with increasing shear rate at absolute temperatures.

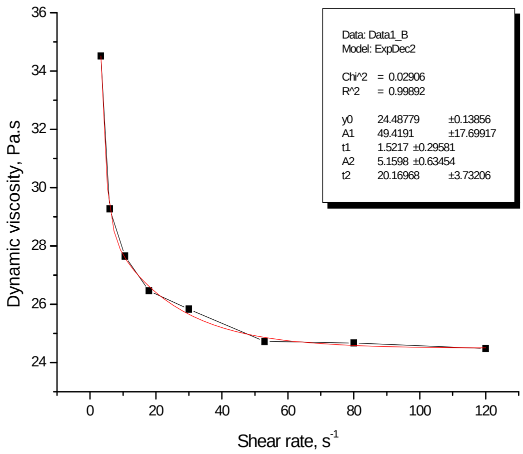

Fig. 1 Dynamic viscosity versus shear rate of for vegetable oil at temperature 323K

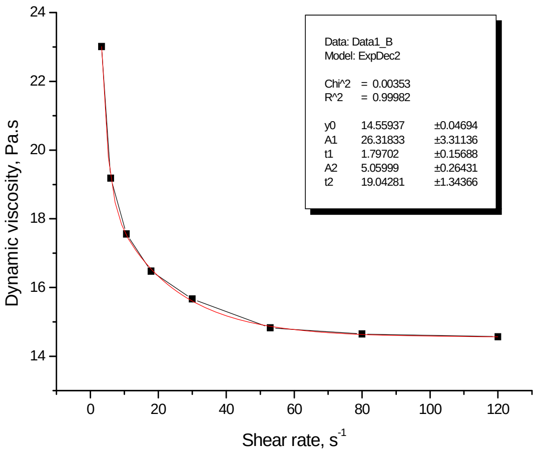

Fig. 2 Dynamic viscosity versus shear rate of for vegetable oil at temperature 343K

This article proposes four equations (6) - (8) shear rate dependence of dynamic viscosity checked only for vegetable oils. The software Origin 6.0 was used to determine constants equation for vegetable oil. In addition, the parameters A, B, C, η_0, t_1, t_2 and t_3 change with temperature. Therefore, by imposing constant temperature, the parameters can be determined. In order to determine the equation constants, the following steps were performed using the Origin 6.0 software: load the non-linear regression package, input experimental data, title x-label, y-label and set the required equation, perform non-linear regression and plot experimental data and best fitted curve, calculate the mean square error and coefficient of determination and show the best fitted equation constant, mean square error and coefficient of determination.

Tables 1, 2 and 3 show the constants vegetable oil. As shown in Tables 1, 2 and 3 the software found it exponential equations applied temperature curves of vegetable oil. The root mean square error means that experimental data is spread equation. Remains the same shear rate range, where the equation was fitted other experimental data.

From the results of the regression tabulated in tables 1, 2 and 3, the lowest coefficient of determination and the highest mean square error were 0.9567 and 0.9998, respectively.

$$\eta = \eta_0 + A\exp(-\dot{\gamma}/B) \qquad (6)$$

$$\eta = \eta_0 + A\exp(-\dot{\gamma}/t_1) + B\exp(-\dot{\gamma}/t_2) \qquad (7)$$

$$\eta = \eta_0 + A\exp(-\dot{\gamma}/t_1) + B\exp(-\dot{\gamma}/t_2) + C\exp(-\dot{\gamma}/t_3) \qquad (8)$$

were A, B, C, η_0, t_1, t_2 and t_3 was constants vegetable oil and variation with temperature.

Table 1. The temperature, correlation parameters (eq. 6), coefficient correlation from 313 to 363K for vegetable oil

Temperature, K	Correlation parameters (eq. 6)			Correlation coefficient, R^2
	η_0	A	B	
313	34.2664	24.9706	4.5696	0.9896
323	25.1133	17.5729	4.9130	0.9567
333	18.6740	8.6479	13.5552	0.9695
343	14.9827	12.4931	6.6002	0.9669
353	12.0943	17.0838	5.6201	0.9839
363	9.9177	9.7490	7.5121	0.9801

Table 2. The temperature, correlation parameters (eq. 7), coefficient correlation from 313 to 363K for vegetable oil

Temperature, K	Correlation parameters (eq. 7)					Correlation coefficient, R^2
	η_0	A	B	t_1	t_2	
313	33.7575	29.9958	5.3958	2.6206	15.2199	0.9989
323	24.4878	49.4191	5.1598	1.5217	20.1697	0.9989
333	18.5124	136.6210	6.8744	0.7479	18.8091	0.9896
343	14.5594	26.3183	5.0599	1.7970	19.0429	0.9998
353	11.1092	17.1018	0.9864	5.6109	-3.7478E83	0.9839
363	8.9699	10.2463	2.4552	4.6847	68.6231	0.9990

Table 3. The temperature, correlation parameters (eq. 8), coefficient correlation from 313 to 363K for vegetable oil

T, K	Correlation parameters (eq. 8)							Correlation coefficient, R^2
	η_0	A	B	C	t_1	t_2	t_3	
313	31.4586	30.0117	5.4112	2.2999	2.6169	15.1788	-1.0915E86	0.9989
323	24.8628	17.6105	0.2978	-0.0451	4.8993	-2.7539E17	-1.3645E83	0.9567
333	17.5114	6.8745	137.8739	1.0010	18.8089	0.7465	-1,7836E150	0.9896
343	13.7901	26.1709	5.0619	0.7389	1.8066	19.3112	2.4460E18	0.9998
353	11.4832	18.5167	1.1346	1.5020	3.8566	36.2699	37.8139	0.9950
363	8.5498	10.2479	2.4812	0.3938	4.6839	69.2907	7.5291E141	0.9990

4. CONCLUSIONS

This article proposes four new relationships dynamic viscosity dependence of the shear rate vegetable oil no additive. Check the only vegetable oils. Equation constants were determined by exponential beast curves obtained at different temperatures using the program Origin 6.0. The correlation coefficients thus obtained were 0.9567 and 0.9998 values between.

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