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New Rheological Models for Vegetable Oil

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***Abstract* — This article proposes new rheological models for vegetable oil. The purpose of this study was to find an exponential and linear dependence between temperature and dynamic viscosity of vegetable oil, using the equations. Equation constants a, b c and τ_o were determined by fitting exponential.**

***Keywords* — Rheologic Models, Rapeseed Oil.**

I. INTRODUCTION

Viscosity study has been widely studied by scientists and engineers on various purposes. These include polymer science, heat transfer phenomena, petroleum reservoir development, coatings, scale modelling of magmatic intrusion, oil degradation, lubrication, etc. [1]-[6] This relation will gives constant viscosity, if shear stress is proportionally changed with velocity gradient. Fluid that follows this behaviour is termed as Newtonian fluid.

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 behaviour. 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. 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 [7]-[9]:

Bingham:

$$\tau = \tau_o + \eta\dot{\gamma} \qquad (1)$$

Casson:

$$\tau^{1/2} = \tau_o^{1/2} + \eta^{1/2}\,\dot{\gamma}^{\,1/2} \qquad (2)$$

Ostwald-de Waele:

$$\tau = k\dot{\gamma}^{\,n} \qquad (3)$$

and Herschel-Bulkley:

$$\tau = \tau_o + k\dot{\gamma}^{\,n} \qquad (4)$$

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

This article proposes four new rheological models for vegetable oil. Dynamic viscosity of oils was determined at temperatures and shear rates, the 90^0C and the 40^0C, respectively, 3.3 - 120 s^{-1}. The purpose of this study was to find an exponential dependence between shear rate and shear stress of vegetable oil no additive using differed equations. Equation constants a, b c and τ_o were determined by fitting exponential and linear.

II. MATERIALS AND METHOD

Vegetable oil no additives used in this work are provided by a company from Bucharest, Romania. Vegetable oil were 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 ranging was from 40 to 90^0C and the measurements were made from 10 to 10 degrees. The accuracy of the temperature was $\pm$ 0.1^0C.

III. RESULTS AND DISCUSSION

The rheograms for vegetable oil no additive at the specified temperatures and shear rates are shown in Fig.1.

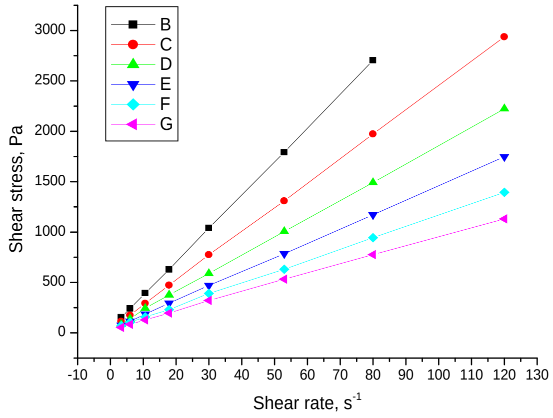

Fig.1. Rheograms for vegetable oils no additive at:
■ - 313; • – 323; ▲ – 333; ▼ – 343; ♦ - 353
and ◄ – 363K

This article proposes four equations (5) - (7) shear rate dependence shear stresses checked only for vegetable oil no additive. The software Origin 6.0 was used to determine constants equation for vegetable oil. In addition, the parameters a, b, c and τ_0 change with temperature. Tables 1, 2 and 3 show the constants vegetable oil no additive. 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 0.9465 and 0.9999, respectively.

$$\tau = a + b\dot{\gamma} \qquad (5)$$

$$\tau = a + b\dot{\gamma} + c\dot{\gamma}^{2} \qquad (6)$$

$$\tau = \tau_0 + a\exp(-\dot{\gamma}/b) \qquad (7)$$

Where a, b, c and τ_0 was constants vegetable oil and variation with temperature.

Table 1: Correlation constants for rheological model (eq.5) at different temperature ranging from 313 K to 363K

Temperature, K	Value of parameters of the theoretical rheological model described by equation (5)		R^2
	a	b	
313	41.1299	33.2214	0.9999
323	36.8590	24.1819	0.9999
333	39.6639	18.2056	0.9999
343	33.5881	14.2763	0.9999
353	36.9874	11.3205	0.9999
363	33.0866	9.2276	0.9998

Table 2: Correlation constants for rheological model (eq.6) at different temperature ranging from 313 K to 363K

Temperature, K	Value of parameters of the theoretical rheological model described by equation (6)			R^2
	a	b	c	
313	45.5086	32.7844	0.0054	0.9999
323	35.2489	24.3016	-0.0010	0.9999
333	36.3689	18.4506	-0.0021	0.9998
343	33.2693	14.3000	-2,0229E-4	0.9999
353	35.6926	11.4168	-8.2159E-4	0.9998
363	23.8375	9,9154	-0.00587	0.9999

Table 3: Correlation constants for rheological model (eq.7) at different temperature ranging from 313 K to 363K

Tempe-rature, K	Value of parameters of the theoretical rheological described by equation (7)			R^2
	τ_0	a	b	
313	1.0509E8	-1.0509E8	3.1633E6	0.9999
323	2937.6000	-3113.1922	66.2462	0.9465
333	2223.6000	-2345.4439	66.0980	0.9477
343	1748.4000	-1840.0881	66.3819	0.9466
353	1394.4000	-1457.1974	66.1598	0.9466
363	1130.4000	-1183.5688	64.5162	0.9525

IV. CONCLUSION

This article proposes the rheological models to describe the dependence of the shear stress of vegetable oil with no additive, on the shear rate. Experimental data for one type of vegetable oil were used to calculate the accuracy the proposed models. Equation constants were determined by exponential or polynomial beast curves obtained at different shear rates using the program Origin 6.0. The correlation coefficients thus obtained varied between 0.9465 and 0.9999.

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