ORIGINAL PAPER

RHEOLOGICAL STUDY BEHAVIOR OF SOYBEAN OIL

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Abstract. *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. This article proposes four relationships of dynamic viscosity – temperature dependence for soybean oil. The purpose of this study was to find an exponential dependence between temperature and dynamic viscosity of soybean oil, using the equations. Equation constants* η_0*,* A_1 *and* t_1 *were determined by fitting exponential. The correlation coefficients thus obtained varied between 0.7864 and 0.9999.*

Keywords: *soybean oil, rheological, behavior.*

1. INTRODUCTION

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 [1].

The viscosity of liquid fuel is an important characteristic because it determines the flowthrough pipelines, injector nozzles and formation of fuel in cylinder. The viscosity of soybean oil was found to be extremely high compared to petroleum oils.

The high viscosity of soybean oil is due to presence of unsaturation in molecules and its structure. It was observed that viscosity get regularly decreases as increasing temperature because with increasing temperature breaking of double bonds in molecule will take place due to this intermolecular force of attraction decreases [2].

The influence of either temperature or shear rate on viscosity is only the two of the many parameters involved. In the literature, there are numerous equations addressing either or a combination of parameters on viscosity, such as, shear-time, composition, moisture, pressure, oil degradation, molecular weight, density etc. [3-12].

The soybean oil has been proposed several empirical relationships describing the temperature dependent dynamic viscosity. The more important of these is the Andrade [13] equation (1).

$$\eta = A\cdot 10^{B/T} \tag{1}$$

$$\eta = A/v - B \tag{2}$$

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where v means the specific volume of the oil, T is the temperature absolute and A and B in the equations (1) and (2) are correlation constants.

This article proposes four new rheological models for soybean oil. Dynamic viscosity of oils was determined at temperatures and shear rates, the 373 K and the 313 K, respectively, 3.3 - 120 s^{-1}. The purpose of this study was to find an exponential dependence between shear rate and shear stress of soybean oil using differed equations. Equation constants η_0, A_1 and t_1 were determined by fitting exponential.

2. MATERIALS AND METHODS

Soybean oils used in this work are provided by a company from Bucharest, Romania. Soybean oil is liquid at room temperature and has the following characteristics: specific gravity = 0.8475, density 0.9175 g/ml (25 °C), flash point 310 °C. The compostions soybean oil: 14.3% saturated, 28% monounsaturated and 57.1% polyunsaturated.

Soybean 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 ºC and the measurements were made from 10 to 10 degrees. The accuracy of the temperature was ± 0.1 ºC.

3. RESULTS AND DISCUSSION

Fig. 1 shows dependency of the dynamic viscosity on the T 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.3) dynamic viscosity according to the temperature absolute for soybean oil. We used the computer program Origin 6.0 to determine the constants η_0 , A_1 and t_1 and the correlation coefficients, R^2. The values of constants η_0, A_1 and t_1 were determined by fitting exponential curves obtained for soybean oil.

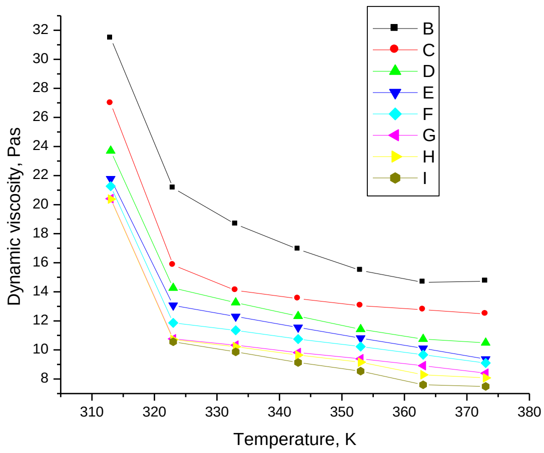

Figure 1. The correlation dynamic viscosity on the absolute temperature at: B – 3.3s^{-1}, C – 6s^{-1}, D – 10.6s^{-1}, E – 17.87s^{-1}, F – 30s^{-1}, G – 52.95s^{-1}, H – 80s^{-1} and I – 120s^{-1}.

$$\eta = \eta_0 + A_1 exp(T/t_1) \quad (3)$$

The dependency of dynamic viscosity on the absolute temperature for soybean oil at shear rate $3.3s^{-1}$, $6s^{-1}$, $52.95s^{-1}$ and $80s^{-1}$ (the black curves from Figs. 2-5) was fitting exponential as shown in Figs. 2-5. The exponential dependence of dynamic viscosity on the absolute temperature for soybean oil at $3.3s^{-1}$ is described for equation (4):

$$\eta = 15.41055 + 1.8065E15 exp(T/ 9.67682) \quad (4)$$

where η_0 = 15.41055 , t_1 = 9.67682 and A_1 = 1.8065E15. The correlation coefficient is R^2 = 0.98436.

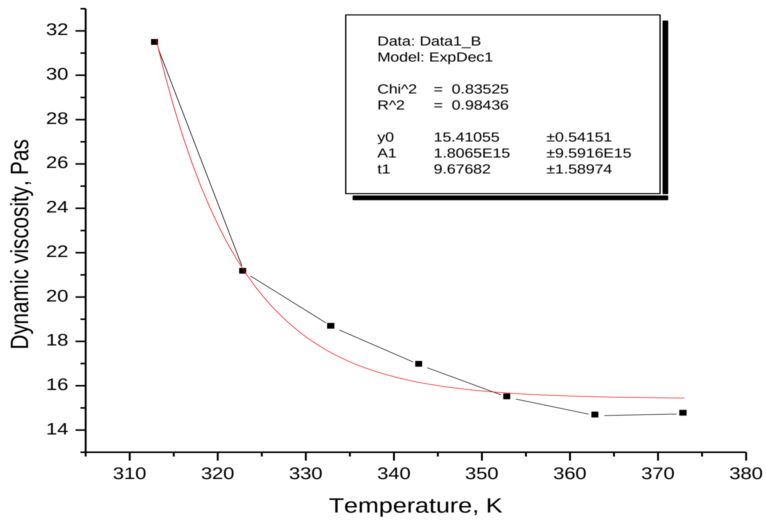

Figure 2. The correlation dynamic viscosity on the absolute temperature at $3.3s^{-1}$ for right to B and 1B represents the exponential fitting to B.

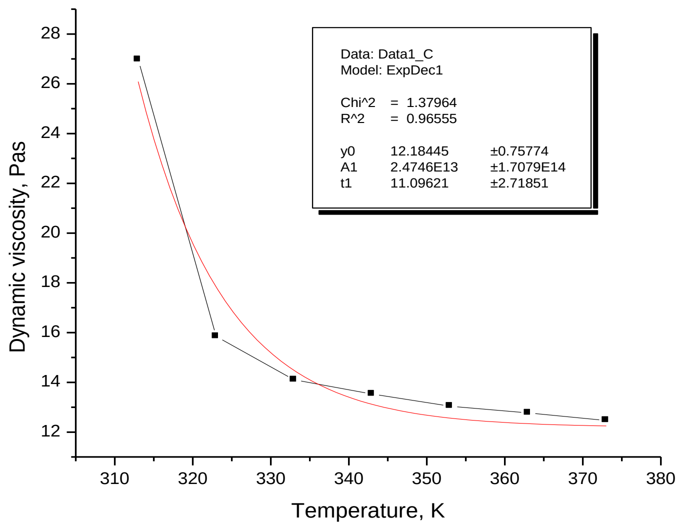

Figure 3. The correlation dynamic viscosity on the absolute temperature at $6s^{-1}$ for right to C and 1C represents the exponential fitting to C.

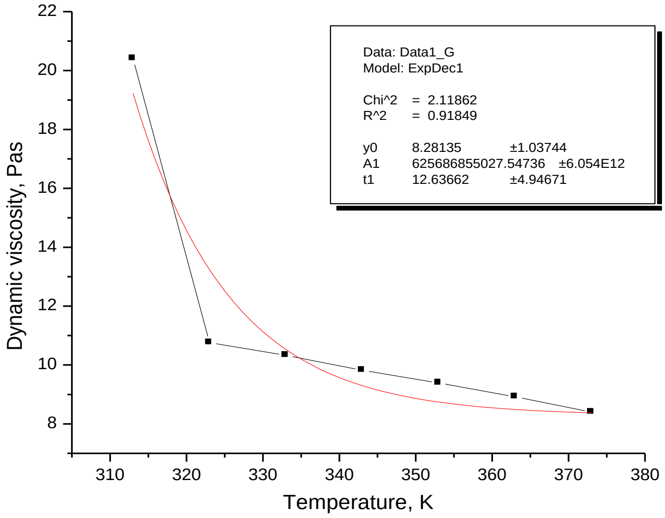

Figure 4. The correlation dynamic viscosity on the absolute temperature at 52.95 s^{-1} for right to G and 1G represents the exponential fitting to G.

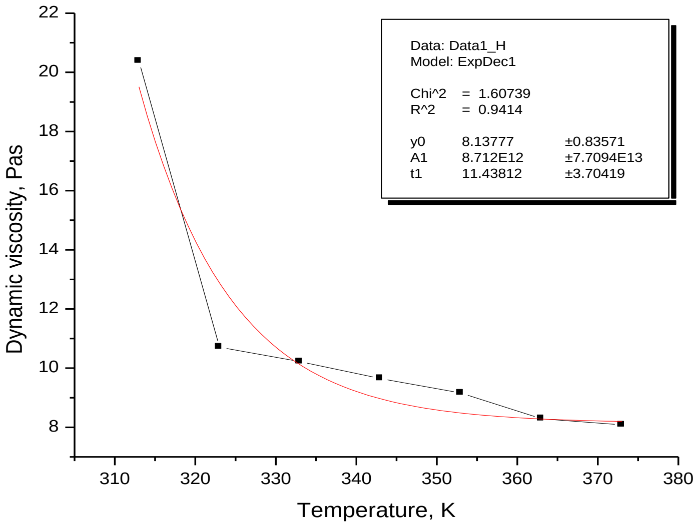

Figure 5. The correlation dynamic viscosity on the absolute temperature at 80s^{-1} for right to H and 1H represents the exponential fitting to H.

Table 1 shows the value of parameters of the described by equation (3) soybean oil and correlation coefficient, R^2. As shown in Table 1 parameter η_0 decreases with increasing shear rate, the parameter A_1 has values close all shear rates and correlation coefficients are close to unity. The root mean square error means that experimental data is spread equation.

Table 1. The shear rate, value of parameters of described by equation (3) and coefficient correlation for soybean oil.

Shear rate [s^{-1}]	Value of parameters			Correlation coefficient, R^2
	η_0	A_1	t_1	
3.3	15.4106	1.8065E15	9.6768	0.9844
6	12.1844	2.4746E13	11.0962	0.9656
10.6	10.6208	3.1663E12	11.9178	0.9669
17.87	9.4743	2.3015E10	14.6027	0.9398
30	9.0642	2.4908E11	13.1313	0.9257
52.95	8.2814	6.2568E11	12.6366	0.9185
80	8.1378	8.7119E12	11.4381	0.9414
120	8.0567	6.8522E12	11.3243	0.7864

4. CONCLUSIONS

This article proposes the rheological models to describe the dependence of the dynamic viscosity of soybean oil with on the temperature. Experimental data for one type of soybean oil were used to calculate the accuracy the proposed models. Equation constants were determined by exponential beast curves obtained at different shear rates using the program Origin 6.0. The correlation coefficients thus obtained varied between 0.7864 and 0.9999.

REFERENCES

[1] Giap, S.G.E., Nik, W.M.N.W., Ahmad, M.F., Amran, A., *Engineering e-Transaction*, **4**(2), 81, 2009.
[2] Kailas, M.T, Mahajan, D.T, *International Journal of Mechanical Engineering and Technology (IJMET)*, **3**(2), 511, 2012.
[3] Al-Zahrani, S.M., Al-Fariss, T.F., *Chemical Engineering and Processing: Process Intensification*, **37**(5), 433, 1998.
[4] Ryu, H.C., Bae, Y.C, Lee, S.H., Yi, S., Park, Y.H., *Polymer*, **39**(25), 6293, 1998.
[5] Akdogan, H., McHugh, T.H., *Journal of Food Processing and Preservation*, **23**(4), 285, 1999.
[6] Akinoso, R., Igbeka, J.C., *Journal of Food Science and Technology*, **43**(6), 612, 2006.
[7] Armelin, E., Marti, M., Rude, E., Labanda, J., Llorens Aleman, J.C., *Progress in organic coatings*, **57**, 229, 2006.
[8] Stanciu, I., *Journal of Science and Arts*, **2**(43), 443, 2018.
[9] Novak, L.T., *Industrial and Engineering Chemistry Research*, **45**(21), 7329, 2006.

[10] Benedito, J., Garcia-Perez, J.V., Dobarganes, M.C., Mulet, A., *Food Research International*, **40**(3), 406, 2007.
[11] Ceriani, R., Goncalves, C.B., Rabelo, J., Caruso, M., Cunha, A.C.C., Cavaleri, F.W., Batista, E.A.C., Meirelles, A.J.A. *Journal of Chemical and Engineering Data*, **52**(3), 965, 2007.
[12] Ceriani, R., Paiva F.R., Gonçalves C.B., Batista E.A.C., Meirelles A.J.A., *Journal of Chemical and Engineering Data*, **53**(8), 1846, 2008.
[13] Beun, S., Bailly, C., Dabin, A., Vreven, J., Devaux, J., Leloup, G., *Dental Materials*, **25**(2), 198, 2009.
[14] Stanciu, I., *Journal of Science and Arts*, **1**(42), 197, 2018.
[15] Andrade E.N., Da. C., *Nature*, **125,** 309, 1930.