Mathematical Equations That Describe The Rheological Behavior Of Sunflower Oil

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Abstract: In this paper proposes have found two mathematical equations that describe the rheological behavior of refined sunflower oil. Mathematical equations were found by plotting the logarithm of dynamic viscosity depending on the shear rate logarithm of refined sunflower oil. Refined sunflower oil was studied by Haake VT 550 viscometer for shear rates between 3 and 1312 s^{-1} and temperatures between 40 and 100^0C. Log parameters η_0, a, b and c were obtained by linear and polynomial fitting of the lines obtained.

Keywords: equations; sunflower oil; rheological; models

1. Introduction

In engineering lubricating oils biodegradable is a solution for equipment working under high risk of environmental pollution [1-4, 6]. This equipment is used in agriculture, construction, shipping, forestry, printing, railways, automotive. Environmental pollution caused by such equipment is worrying because of the loss of lubricants in soil and water. These biodegradable lubricants are applied in different areas. Vegetable oils are non-polluting compared with those minerals [5-10, 15]. These mechanisms are generally used for open, closed systems are rare these biodegradable oils on the market.

Biodegradable oils (rapeseed, sunflower, castor oil) are considered to be liquid lubricants are compounds containing fatty acids with glycerol. Fatty acids contained in bio oils are oleic acid, linoleic acid, palmitic acid, stearic acid, erucic acid, but the most important being oleic acid [11-13, 14]. The biodegradable lubricant base oils can be used: polyglycols, synthetic ester oils and vegetable oils.

Biodegradable oils based on vegetable oils have low performance while synthetic esters have high performance, but moderate biodegradability [14-17].

The most important parameters that describe the rheological behavior of oil are dynamic viscosity, shear rate, and temperature was studied in this paper. The rheological properties of the fluid depend on many factors, such as temperature, concentration of the compound, shear rate, pressure, time, chemical properties, additives used.

To express the dynamic viscosity dependence on shear rate according refined sunflower oil we started from these mathematical equations proposed by Abramovic [18-20]:

$$Log\,\eta = A/T - B \quad (1)$$

$$\eta = A - B\,Log\,t \quad (2)$$

This article equation (1) and (2) and propose two new equations addiction logarithm of dynamic viscosity depending on the shear rate logarithm refined sunflower oil can be used as a biodegradable lubricant.

2. Materials

The refined sunflower oil was purchased from the Ulerom SA Romania from a specialized distribution chain. To study the rheological behaviour of the oil it was used viscometer Haake VT 550 viscometer equipped with HV_1 sensor. For the rheological study the was tested refined sunflower oil. The value of dynamic viscosity was determined for shear rates, ranging between 3.3 to 120s^{-1} and the testing temperatures between 40^{o}C, 50^{o}C, 60^{o}C, 70^{o}C, 80^{o}C, 90^{o}C and 100^{o}C.

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3. Results and discussion

The Figure 1 shows the dependence of the log dynamic viscosity versus log shear rate for studied refined sunflower oil at temperatures 40°C, 50°C , 60°C, 70°C, 80°C, 90°C and 100°C.

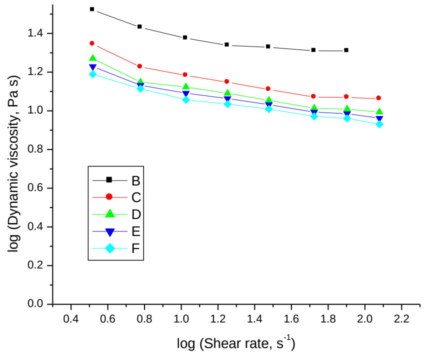

Fig. 1 Dependence log dynamic vicosity versus log shear rate for refined sunflower oil at temperatures: B – 40°C, C –50°C , D – 60°C, E – 70°C, F – 80°C, G – 90°C and H – 100°C

As shown in chart logarithm of dynamic viscosity decreases with increasing log shear rate with increasing temperature.

This article proposes two (3) and (4) dependency relations of log dynamic viscosity according to the log shear rate for refined sunflower oil. The values of constants log η_0, a, b, c and correlation coefficients, R were determined by fitting linear or polynomial curves obtained for refined sunflower oil.

$$\log \eta = \log \eta_0 + a \log \dot{\gamma} \quad (3)$$

and

$$\log \eta = \log \eta_0 + b \log \dot{\gamma} + c \log (\dot{\gamma})^2 \quad (4)$$

The dependence of log dynamic viscosity on the log shear rate for refined sunflower oil at temperatures 40°C , 60°C and 70°C (the black curves from Fig. 2, 3 and 4) was fitting linear as shown in figures 2, 3 and 4. The linear dependence of log dynamic viscosity on the log shear rate for refined sunflower oil at 40°C is described for equation (3):

$$\log \eta = 1.5519 - 0.1441 \log \dot{\gamma}$$

where log η_0 = 1.5519 and a = -0.1441. The correlation coefficient is R^2 = -0.9267.

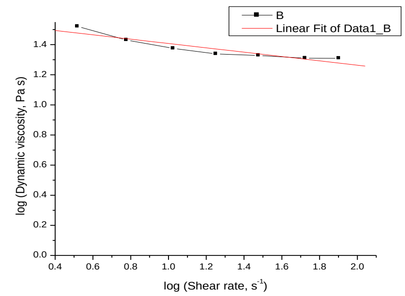

Fig. 2. The dependence log dynamic viscosity on the log shear rate at 40°C for right to B and 1B represents the linear fitting to B

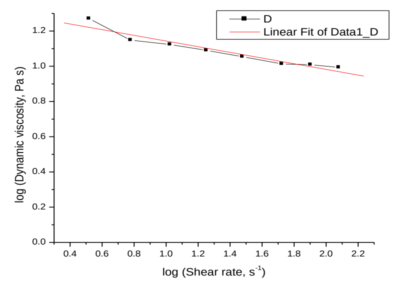

Fig. 3. The dependence log dynamic viscosity on the log shear rate at 60°C for right to D and 1D represents the linear fitting to D

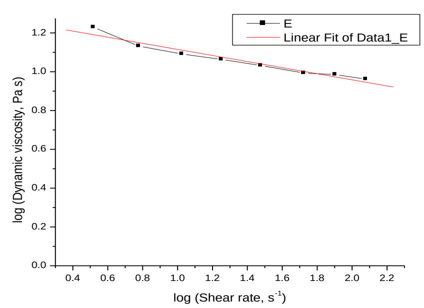

Fig. 4. The dependence log dynamic viscosity on the log shear rate at 70°C for right to E and 1E represents the linear fitting to E

Table 1 shows the value of parameters of the described by equation (3) refined sunflower oil and correlation coefficient, R. As shown in table

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1 the software found it linear equation applied shear rate right of refined sunflower oil. The root mean square error means that experimental data is spread equation. Remains the same temperature range, where the equation was fitted other experimental data.

As seen in Table 1, log η_0 decreases with increasing temperature for refined sunflower oil. The highest temperature is 40^{o}C and the lowest temperature of 100^{o}C. Parameter representing the slope has similar values for all temperatures studied. Correlation coefficients have values close to unity which demonstrates that math equation describes very well found rheological behavior of refined sunflower oil.

The dependence of log dynamic viscosity on the log shear rate for refined sunflower oil at temperature 40^{o}C, 60^{o}C and 70^{o}C (the black curves from **Fig. 5, 6** and **7**) was fitting polynomial as shown in figures 5, 6 and 7. The polynomial dependence of log dynamic viscosity versus log shear rate for refined sunflower oil at 40^{o}C is described for equation (4):

$$log\eta=1.7336-0.4931log\,\dot{\gamma} + 0.1433\ log\ (\dot{\gamma})^2$$

where log η_0 = 1.7336, b = -0.4931 and c = 0.1433. The correlation coefficient is R^2 = 0.9943.

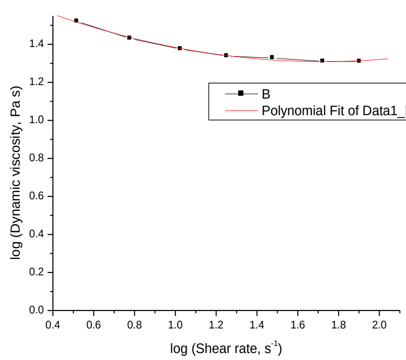

Fig. 5. The dependence log dynamic viscosity on the log shear rate at 40^{o}C for right to B and 1B represents the polynomial fitting to B

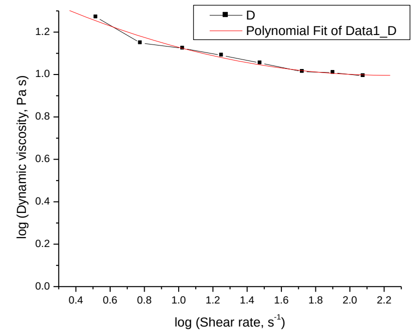

Fig. 6. The dependence log dynamic viscosity on the log shear rate at 60^{o}C for right to D and 1D represents the polynomial fitting to D

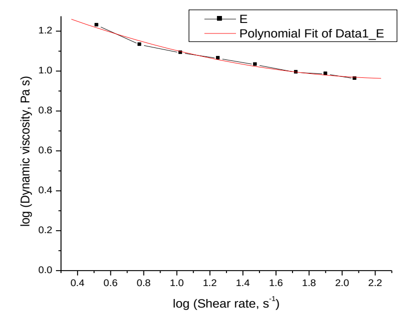

Fig. 7. The dependence log dynamic viscosity on the log shear rate at 70^{o}C for right to E and 1E represents the polynomial fitting to E

Table 2 shows the value of parameters of the described by equation (4) refined sunflower oil and correlation coefficient, R. As shown in table 2 the software found it polynomial equation applied temperature right of refined sunflower oil. As seen in table 2, log η_0 decreases with increasing temperature and the logarithm of the shear rate. Parameter b that the polynomial equation is slope has a value nearly the same for all temperatures, except for the temperature of 70^{o}C, for which the value of b is close to zero. The parameter c decreases with increasing temperature; the highest value is for 40^{o}C temperature and lowest temperature of 100^{o}C. The correlation coefficients have values close to unity for all temperatures at which the determinations are made.

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Table 1. The temperature, value of parameters of described by equation (3) and coefficient correlation for refined sunflower oil

Temperature, ^0C	Value of parameters of the described by equation (3)		Correlation coefficient, R^2
	$\log \eta_0$	a	
40	1.5519	-0.1441	-0.9267
50	1.3791	-0.1689	-0.9529
60	1.3046	-0.1613	-0.9593
70	1.2719	-0.1569	-0.9735
80	1.2386	-0.1526	-0.9805
90	1.2289	-0.1646	-0.9843
100	1.2215	-0.1707	-0.9681

Table 2. The temperature, value of parameters of described by equation (4) and coefficient correlation for refined sunflower oil

Temperature, ^0C	Value of parameters of the described by equation (4)			Correlation coefficient, R^2
	$\log \eta_0$	b	c	
40	1.7336	-0.4931	0.1433	0.9943
50	1.5426	-0.4649	0.1130	0.9869
60	1.4323	-0.3924	0.0883	0.9737
70	1.2826	-0.0737	0.0043	0.9816
80	1.3233	-0.3059	0.0586	0.9889
90	1.3070	-0.3060	0.0540	0.9891
100	1.3578	-0.4174	0.0942	0.9926

6. Conclusion

The refined sunflower oil was studied by Haake VT 550 viscometer at shear rates between 3 and 1312 s^{-1} and temperatures between 40 and 100°C. This article shows the dependence of the logarithm of dynamic viscosity depending on the shear rate logarithm of refined sunflower oil. To mathematically express this dependence we found two equations obtained by linear and polynomial fitting of the lines obtained. Log parameters η_0, a, b and c varies with increasing temperature and shear stress refined sunflower oil.

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