Research Paper Chemistry

The Effect Temperature and Shear Rate on the Rheological Behavior for Sunflower Oil

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KEYWORDS sunflower oil, dynamic viscosity, Andrade's equation, temperature

ABSTRACT

The sunflower oil was carefully studied in recent years because they may constitute a raw material for biodegradable lubricants getting organic. These oils are an alternative to synthetic mineral oils. The biodegradable oils represent now an ingenious solution in lubrication engineering for equipment which works preponderantly in conditions that have high risk of environmental pollution. In this article we determined the dynamic viscosity sunflower oil at temperatures between 313 and 373 K and shear rates between 3.3 and 120 s-1. The some empirical relations that describe the temperature dependence of dynamic viscosity were fitted to the experimental data and the correlation constants for the best fit are presented.

INTRODUCTION

The biodegradable represent now a solution in lubrication engineering for equipments which work preponderantly in conditions that have high risk of environmental pollution. This refers to machines and equipments that work in agriculture, building industry, shipping industry, forestry, printing industry, railways industry, car industry, where the environment pollution problem is of high concern, because of loss of lubricants in soil or/and water. The refined sunflower oil is considered liquid lubricants and from chemical point of view they are compounds of glycerin with fatty acids [1-3]. The fatty acids contained in sunflower oil are oleic acid, linoleic acid, palmitic acid, stearic acid, erucic acid etc., and the most important of them being the oleic acid. Generally, as base oils for biodegradable lubricants there may be used: polyglycols, synthetic ester oils and vegetal oils. The rheological properties of a fluid depend on several factors, such as temperature, compounds' concentration, shear rate, pressure, time, chemical properties, additives used [4]. In this study we determined the viscosity of refined sunflower oil in the temperature range from 313 K to 373 K. The empirical relations describing the dynamic viscosity variation with temperature were fitted to experimental data and correlation constants for the best fit are presented in this paper.

MATERIALS AND METHOD

The refined sunflower oil used in this work is provided by a company from Bucharest, Romania. The sunflower 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 10^6mPa.s when the HV_1 viscosity sensor is used. The temperature ranging was from 40 to 100°C and the measurements were made from 10 to 10 degrees. The accuracy of the temperatures was ± 0.1°C.

RESULTS AND DISCUSSION

Figure 1 shows the temperature dependence of dynamic viscosity of refined sunflower oil at different shear rates. From the graph decreases the dynamic viscosity of refined sunflower oil with increasing temperature and shear rate. The dependence dynamic viscosity versus inverse absolute temperature is described of the Andrade [4-6] equation (1):

$$\eta = A \cdot 10^{B/T} \qquad (1)$$

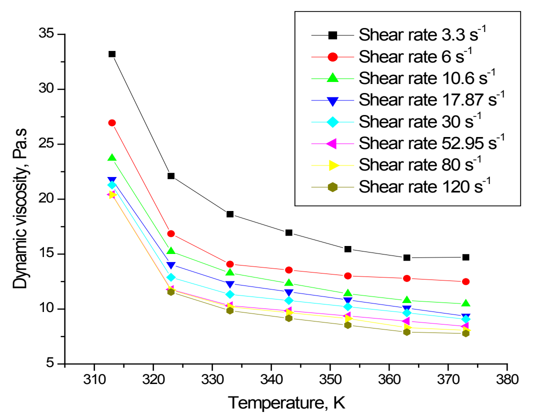


Figure 1: The dynamic viscosity versus absolute temperature at shear rate s-1

In Tables 1 present the values of the constants A and B as well as correlation coefficients, R^2 empirical relations (1).

TABLE – 1

VALUES OF PARAMETERS OF THE THEORETICAL MODELS DESCRIBED BY EQUATION (1) AND THE STANDARD ERROR OF REGRESSION ANALYSIS, R^2

Shear rate, s^{-1}	A	B	R^2
3.3	4597.3757	0.1614	0.9992
6	2347.8481	0.1402	0.9903
10.6	1695.4696	0.1352	0.9839
17.87	1445.0072	0.1411	0.9888
30	1485.2515	0.1449	0.9958
52.95	1476.4543	0.1513	0.9992
80	1306.4115	0.1512	0.9977
120	297.2829	0.0615	0.9987

Value of parameter A for refined sunflower oil obtained with equation (1) is 4597.3757 at shear rate 3.3 s^{-1}. To shear rate 6 s^{-1} the values of parameter A is 2249.5276 times lower with that obtained at shear rate 3.3 s^{-1}. The shear rate 10.6 s^{-1} the values of parameter A is 2901.9061 times lower with that obtained at shear rate 3.3 s^{-1}. A shear rate 17.87 s^{-1} the values of parameter A is 3152.3585 times lower with that obtained at shear rate 3.3 s^{-1}. The shear rate 30 s^{-1} the values of parameter A is 3112.1242 times lower with that obtained at shear rate 3.3 s^{-1}. The shear rate 52.95 s^{-1} the values of parameter A is 3120.9214 times lower with that obtained at shear rate 3.3 s^{-1}. The shear rate 80 s^{-1} the values of parameter A is 3290.9642 times lower with that obtained at shear rate 3.3 s^{-1}. The shear rate 120 s^{-1} the values of parameter A is 4002.8099 times lower with that obtained at shear rate 3.3 s^{-1}.

Value of parameter B for refined sunflower oil obtained with equation (1) is 0.1614 at shear rate 3.3 s^{-1}. To shear rate 6 s^{-1} the values of parameter B is 0.0212 times lower with that obtained at shear rate 3.3 s^{-1}. The shear rate 10.6 s^{-1} the values of parameter B is 0.0262 times lower with that obtained at shear rate 3.3 s^{-1}. A shear rate 17.87 s^{-1} the values of parameter B is 0.0203 times lower with that obtained at shear rate 3.3 s^{-1}. The shear rate 30 s^{-1} the values of parameter B is 0.0165 times lower with that obtained at shear rate 3.3 s^{-1}. The shear rate 52.95 s^{-1} the values of parameter B is 0.0101 times lower with that obtained at shear rate 3.3 s^{-1}. The shear rate 80 s^{-1} the values of parameter B is 0.0102 times lower with that obtained at shear rate 3.3 s^{-1}. The shear rate 120 s^{-1} the values of parameter B is 0.0999 times lower with that obtained at shear rate 3.3 s^{-1}.

Figure 2 shows the log dynamic viscosity versus inverse absolute temperature for refined sunflower oil at different shear rates.

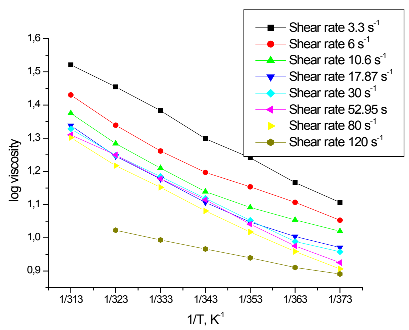


Figure 2: The dependence log dynamic viscosity versus 1/T at shear rate s^{-1}

To elucidate the effect inverse absolute temperature on the log dynamic viscosity the following equations (2) [7-11]:

$$\log \eta = A/T - B \qquad (2)$$

In Tables 2 present the values of the constants A and B as well as correlation coefficients, R^2 empirical relations (2).

TABLE – 2
VALUES OF PARAMETERS OF THE THEORETICAL MODELS DESCRIBED BY EQUATION (2) AND THE STANDARD ERROR OF REGRESSION ANALYSIS, R^2

Shear rate, s^{-1}	A	B	R^2
3.3	0.1614	3.6625	0.9992
6	0.1402	3.3707	0.9903
10.6	0.1352	3.2293	0.9839
17.87	0.1411	3.1599	0.9888
30	0.1449	3.1718	0.9958
52.95	0.1513	3.1692	0.9992
80	0.1512	3.1161	0.9977
120	0.0615	2.4732	0.9987

Value of parameter A for refined sunflower oil obtained with equation (2) is 0.1614 at shear rate 3.3 s^{-1}. To shear rate 6 s^{-1} the values of parameter A is 0.0212 times lower with that obtained at shear rate 3.3s^{-1}. The shear rate 10.6 s^{-1} the values of parameter A is 0.0262 times lower with that obtained at shear rate 3.3 s^{-1}. A shear rate 17.87 s^{-1} the values of parameter A is 0.0203 times lower with that obtained at shear rate 3.3 s^{-1}. The shear rate 30 s^{-1} the values of parameter A is 0.0165 times lower with that obtained at shear rate 3.3 s^{-1}. The shear rate 52.95 s^{-1} the values of parameter A is 0.0101 times lower with that obtained at shear rate 3.3 s^{-1}. The shear rate 80 s^{-1} the values of parameter A is 0.0102 times lower with that obtained at shear rate 3.3 s^{-1}. The shear rate 120 s^{-1} the values of parameter A is 0.0999 times lower with that obtained at shear rate 3.3 s^{-1}.

Value of parameter B for refined sunflower oil obtained with equation (2) is 3.6625 at shear rate 3.3 s^{-1}. To shear rate 6 s^{-1} the values of parameter B is 0.2918 times lower with that obtained at shear rate 3.3 s^{-1}. The shear rate 10.6 s^{-1} the values of parameter B is 0.4332 times lower with that obtained at shear rate 3.3 s^{-1}. A shear rate 17.87 s^{-1} the values of parameter B is 0.5026 times lower with that obtained at shear rate 3.3 s^{-1}. The shear rate 30s^{-1} the values of parameter B is 0.4907 times lower with that obtained at shear rate 3.3 s^{-1}.

The refined sunflower oil has been empirical relationships describing the log absolute temperature dependent dynamic viscosity the following equations (3):

$$\eta = A - B \log T \qquad (3)$$

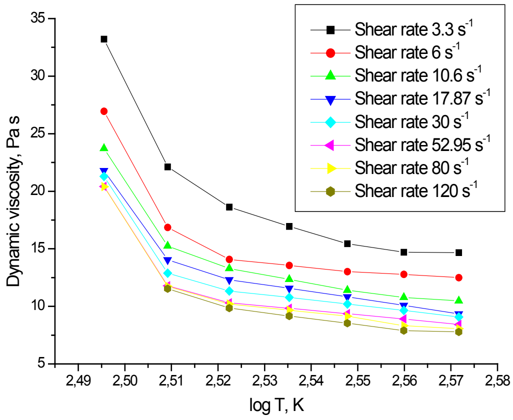
where T is the temperature absolute, A and B in the equations (1), (2) to (3) are correlation constants. The results of regression analyses to these relations are presented in Tables 1, 2 and 3.

TABLE – 3
VALUES OF PARAMETERS OF THE THEORETICAL MODELS DESCRIBED BY EQUATION (3) AND THE STANDARD ERROR OF REGRESSION ANALYSIS, R^2

Shear rate, s^{-1}	A	B	R^2
3.3	551.2847	209.8578	0.8663
6	397.1656	150.5153	0.7963
10.6	379.5386	144.2663	0.8534
17.87	350.2655	133.1242	0.8632
30	332.2721	126.2938	0.8233
52.95	320.6555	122.0588	0.8026
80	336.2426	128.2949	0.8192
120	156.8450	58.13280	0.9601

Value of parameter A for refined sunflower oil obtained with equation (3) is 551.2847 at shear rate 3.3 s^{-1}. To shear rate 6 s^{-1} the values of parameter A is 154.1191 times lower with that obtained at shear rate 3.3 s^{-1}. The shear rate 10.6 s^{-1} the values of parameter A is 171.7461 times lower with that obtained at shear rate 3.3 s^{-1}. A shear rate 17.87 s^{-1} the values of parameter A is 201.0192 times lower with that obtained at shear rate 3.3 s^{-1}. The shear rate 30s^{-1} the values of parameter A is 219.0126 times lower with that obtained at shear rate 3.3 s^{-1}. The shear rate 52.95 s^{-1} the values of parameter A is 230.6292 times lower with that obtained at shear rate 3.3 s^{-1}. The shear rate 80 s^{-1} the values of parameter A is 215.0421 times lower with that obtained at shear rate 3.3 s^{-1}. The shear rate 120 s^{-1} the values of parameter A is 237.5947 times lower with that obtained at shear rate 3.3 s^{-1}.

Figure 3 shows the dynamic viscosity versus log absolute temperature for refined sunflower oil at different shear rates.



EFigure 3: The dependence dynamic viscosity versus log T at shear rate s^{-1}

In Tables 1, 2 and 3 present the values of the constants A and B as well as correlation coefficients, R^2 empirical relations (1), (2) and (3). Equation (3) is adequate to describe the temperature dependence of the viscosity of sunflower oil, because the values of correlation coefficients are much smaller than 1. Equations (1) and (2) are suitable for describing the temperature dependence of dynamic viscosity of sunflower oil as correlation coefficients are close to the value 1.

CONCLUSIONS

The equations that best describe the temperature dependence of dynamic viscosity of sunflower oil (1) and (2) because the correlation coefficients are close to one. The dynamic viscosity sunflower oil decreases exponentially with increasing temperature and shear rate. Plotting the log of the inverse dynamic viscosity depending on temperature shows a linear decline.

REFERENCES

[1] Abdel-Motagally, F. M. F., and Osman E. A. (2010), "Effect of nitrogen and potassium fertilization combination of productivity of two sunflower cultivars under east of El-ewinate conditions. American-Eurasian Journal of Agricultural & Environmental Science, 8(4), 397-401. | [2] Andrade, E., N., Da. C., Nature, 125, 309, 1930. | [3] Baydar, H., and Erbas S. (2005), "Influence of seed development and seed position on oil, fatty acids and total tocopherol contents in sunflower (Helianthus annuus L.). Turkish Journal of Agriculture and Forestry, 9, 179-186. | [4] Buckley, C., P., Jones, D., C., Polymer, 36, 3301, 1995. | [5] Cameron, A., Basic Lubrication Theory, Ellis Horwood Ltd. Chichester, 3rd ed., 1981. | [6] Gaikwad, R., D., Swamy, P., Acta. Chim. Slov, 55, 683, 2008. | [7] Goh Eng Giap, S., Journal of Physical Science, 21(1), 29, 2010. | [8] Gupta, A., Sharma, S., K., Toor, A., P., Indian Journal of Chemical Technology, 14, 642, 2007. | [9] Hasan Yalcin, Omer Said Toker, Mahmut Dogan (2012). Journal of Oleo science 61(4), 181-187. | [10] Noureddini, H., Teoh, B., C., Davis Clements, L., JAOCTS, 69(12), 1189, 1992. | [11] Perry, R., H., Perry's Chemical Engineering' Handbook, 6th ed., McGraw-Hill, New York, 278, 1984. |