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# RHEOLOGICAL PROPERTIES OF RAPESEED OIL AND HYDRAULIC OIL

## - Research Note -

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*Acestă lucrare prezintă comportarea reologică a uleiului brut de rapiță, uleiului degumat de rapiță, uleiului uscat de rapiță, uleiului albit de rapiță, uleiul rafinat de rapiță şi a uleiului hidraulic. Vâscozitatea aparentă a tuturor acestor uleiuri a fost determinată la temperaturile şi vitezele de forfecare, de la 400C la 900C şi, respectiv, 3.3 - 120 s-1. Scopul acestui studiu a fost, să găsească o dependență polinomială între temperatură şi vâscozitatea uleiului, folosind o modificare ecuație Andrade. Constantele Andrade ale ecuației A, B, C, au fost determinate pentru uleiuri studiate.*

*In this paper the rheological behavior of crude rapeseed oil, degummed rape oil, rapeseed oil dry, bleached rapeseed oil, refined rapeseed oil and hydraulic oil is presented. Apparent viscosity of all these oils was determined at temperatures and shear rates ranging from 400C to 900C and respectively, from 3.3 to 120 s-1. The aim of this study was to find a polynomial dependence between temperature and oil viscosity, using a modified Andrade equation. Andrade equation constants A, B, C were determined for the studied oils.*

**Keywords**: rheological behavior, rapeseed oil, hydraulic oil

### 1. Introduction

Viscosity is one of the important properties of oils. Rheological properties of different oils are very useful in their processing, handling, storage and for the design of hydraulic systems [1, 2]. Because temperature has a significant influence on oil viscosity, this influence is a very interesting subject for the researchers and manufacturers in this field. Although the issue seems to be simple, in practice the viscosities values for different oils are not found. In industrial applications, empirical formulas are generally used for accurate prediction of oil viscosities.

However, the lack of a precise model valid for all liquids makes difficult to predict the effect of temperature on viscosity. Some of the most known mathematical models were developed by Vogel-Fulcher, Arrhenius and Andrade

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[3, 4]. These models are using empirical data to predict the temperature influence on viscosity for a wide range of temperatures.

Vogel-Fulcher's model is one of the first attempts to predict liquid viscosities and has no theoretical basis. Later, based on the principles of statistical mechanics, the accuracy of predictions Fulcher-Vogel viscosity liquid was improved. The relationship of Vogel-Fulcher viscosity-temperature law is [5-7]:

$$\eta = \eta_0 \exp [K/(T-T_\infty)] \tag{1}$$

Equation (1) requires at least three points to determine the model constants.
For most liquids at temperatures below the normal boiling point, the plot of ln η versus 1/T or ln η versus ln T is approximately linear [8]. Hence, most regressions equations are presented in the form as mentioned. A simplified form of equation (1) can be written according to Arrhenius type relation [9]. Using the natural logarithmic format and higher-order polynomial in 1/T, to give better accuracy, the modified Andrade's equation can be written as [10-13]:

$$\ln \eta = A + B/T + C/T^2 + D/T^3 + E/T^4 \tag{2}$$

## 2. Experimental details

Vegetable oils used in this work are provided by a company from Bucharest, Romania. In this paper were studied, from rheological point of view, crude rapeseed oil, degummed rape oil, rapeseed oil dry, rapeseed oil bleached, refined rapeseed oil and hydraulic oil containing no additives.

Vegetable oils 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 $90^0$C and the measurements were made from 10 to 10 degrees. The accuracy of the temperature was $\pm$ $0.1^0$C.

## 3. Results and discussion

The program Origin 6.0 was used to determine Andrade constants for all the studied oils. Andrade equation was used in the form in which higher order terms were eliminated. The new equation form is given by:

$$\ln \eta = A + B/T + C/T^2 \tag{3}$$

Oil viscosities are influenced by temperature. Oil viscosities are influenced by temperature In addition, the parameters A, B and C are changing with shear rate. Therefore, by imposing a constant shear rate, the parameters of Andrade equation can be determined for a temperature range. In order to determine the equation constants Origin 6.0 software was used. Tables 1-6 contain the rheological constants of Andrade's equation and the correlation coefficient for the studied oils. As one can observe from tables 1-6 a good agreement between experimental data and Andrade equation was obtain for all the studied oils. From the results presented in tables 1-6 the lowest correlation coefficient was 0.9990 and the highest one was 1.

*Table 1*

**The shear rate, Andrade's equation constants, correlation coefficient and temperature range for crude rapeseed oil**

| Shear rate, $s^{-1}$ | Constants Andrade's equation | | | $R^2$ | Temp. Range ($^0C$) |
|---|---|---|---|---|---|
| | A | B | C | | |
| 3.30 | 4.0085 | -0.2703 | 0.0093 | 0.9995 | 40-90 |
| 6.00 | 4.0298 | -0.3273 | 0.0124 | 0.9992 | 40-90 |
| 10.60 | 3.9777 | -0.3583 | 0.0182 | 0.9991 | 40-90 |
| 17.87 | 3.8673 | -0.3213 | 0.0131 | 0.9995 | 40-90 |
| 30.00 | 3.8744 | -0.3559 | 0.0172 | 0.9999 | 40-90 |
| 52.95 | 3.8374 | -0.3439 | 0.0137 | 0.9994 | 40-90 |
| 80.00 | 3.8586 | -0.3639 | 0.0156 | 0.9998 | 40-90 |
| 120.0 | 3.8023 | -0.3327 | 0.0113 | 0.9998 | 40-90 |

*Table 2*

**The shear rate, Andrade's equation constants, correlation coefficient and temperature range for degummed rape oil**

| Shear rate, $s^{-1}$ | Constants Andrade's equation | | | $R^2$ | Temp. Range ($^0C$) |
|---|---|---|---|---|---|
| | A | B | C | | |
| 3.3 | 3.8391 | -0.1747 | -0.0031 | 0.9996 | 40-90 |
| 6.0 | 3.9215 | -0.3078 | 0.0145 | 0.9990 | 40-90 |
| 10.6 | 4.0013 | -0.4177 | 0.0276 | 0.9986 | 40-90 |
| 17.87 | 3.8605 | -0.3118 | 0.0075 | 0.9993 | 40-90 |
| 30.0 | 3.8504 | -0.3497 | 0.0167 | 0.9992 | 40-90 |
| 52.95 | 3.8199 | -0.3362 | 0.0124 | 0.9994 | 40-90 |
| 80.0 | 3.8504 | -0.3645 | 0.0159 | 0.9999 | 40-90 |
| 120.0 | 3.8222 | -0.3487 | 0.0134 | 0.9999 | 40-90 |

*Table 3*

**The shear rate, Andrade's equation constants, correlation coefficient and temperature range for dry rapeseed oil**

| Shear rate, $s^{-1}$ | Constants Andrade's equation | | | $R^2$ | Temp. Range ($^0C$) |
|---|---|---|---|---|---|
| | A | B | C | | |
| 3.30 | 4.0821 | -0.3472 | 0.0222 | 0.9994 | 40-90 |
| 6.00 | 3.9835 | -0.3497 | 0.0215 | 0.9971 | 40-90 |
| 10.60 | 4.1092 | -0.4758 | 0.0343 | 0.9994 | 40-90 |
| 17.87 | 3.8365 | -0.3127 | 0.0096 | 0.9994 | 40-90 |
| 30.00 | 3.8360 | -0.3373 | 0.0138 | 0.9997 | 40-90 |
| 52.95 | 3.8057 | -0.3338 | 0.0126 | 0.9996 | 40-90 |
| 80.00 | 3.8125 | -0.3462 | 0.0140 | 0.9995 | 40-90 |
| 120.0 | 3.7058 | -0.2917 | 0.0071 | 0.9999 | 40-90 |

*Table 4*

**The shear rate, Andrade's equation constants, correlation coefficient and temperature range for rapeseed oil bleached**

| Shear rate, $s^{-1}$ | Constants Andrade's equation | | | $R^2$ | Temp. Range ($^0C$) |
|---|---|---|---|---|---|
| | A | B | C | | |
| 3.3 | 4.0079 | -0.3468 | 0.0152 | 0.9982 | 40-90 |
| 6.0 | 4.0067 | -0.3543 | 0.0179 | 0.9995 | 40-90 |
| 10.6 | 3.9208 | -0.3363 | 0.0139 | 0.9976 | 40-90 |
| 17.87 | 3.9113 | -0.3551 | 0.0165 | 0.9971 | 40-90 |
| 30.0 | 3.8281 | -0.3231 | 0.0132 | 0.9988 | 40-90 |
| 52.95 | 3.8255 | -0.3346 | 0.0130 | 0.9996 | 40-90 |
| 80.0 | 3.8399 | -0.3515 | 0.0149 | 0.9998 | 40-90 |
| 120.0 | 3.7288 | -0.2944 | 0.0076 | 0.9999 | 40-90 |

*Table 5*

**The shear rate, Andrade's equation constants, correlation coefficient and temperature range for refined rapeseed oil**

| Shear rate, $s^{-1}$ | Constants Andrade's equation | | | $R^2$ | Temp. Range ($^0C$) |
|---|---|---|---|---|---|
| | A | B | C | | |
| 3.30 | 4.0967 | -0.3033 | 0.0165 | 0.9494 | 40-90 |
| 6.00 | 3.9954 | -0.3369 | 0.0196 | 0.9916 | 40-90 |
| 10.60 | 3.8805 | -0.2853 | 0.0093 | 0.9971 | 40-90 |
| 17.87 | 3.8556 | -0.3047 | 0.0099 | 0.9988 | 40-90 |
| 30.00 | 3.8693 | -0.3400 | 0.0153 | 0.9995 | 40-90 |
| 52.95 | 3.8596 | -0.3552 | 0.0160 | 0.9998 | 40-90 |
| 80.00 | 3.8572 | -0.3547 | 0.0152 | 0.9999 | 40-90 |
| 120.0 | 3.8004 | -0.3242 | 0.0181 | 0.9999 | 40-90 |

*Table 6*

**The shear rate, Andrade's equation constants, correlation coefficient and temperature range for hydraulic oil**

| Shear rate, $s^{-1}$ | Constants Andrade's equation | | | $R^2$ | Temp. Range ($^0$C) |
|---|---|---|---|---|---|
| | A | B | C | | |
| 3.3 | 4.2806 | -0.5176 | 0.0312 | 0.9849 | 40-90 |
| 6.0 | 3.9418 | -0.3537 | 0.0104 | 0.9953 | 40-90 |
| 10.6 | 3.9147 | -0.3797 | 0.0146 | 0.9969 | 40-90 |
| 17.87 | 3.8607 | -0.3773 | 0.0147 | 0.9993 | 40-90 |
| 30.0 | 3.8523 | -0.4112 | 0.0187 | 0.9993 | 40-90 |
| 52.95 | 3.8775 | -0.4463 | 0.0224 | 0.9999 | 40-90 |
| 80.0 | 3.8796 | -0.4541 | 0.0220 | 0.9997 | 40-90 |
| 120.0 | 3.8502 | -0.4403 | 0.0193 | 1.0000 | 40-90 |

## 4. Conclusion

The viscosity of all oil samples was examined with modified Andrade equation. There is no need to use a higher order polynomial function of 1 / T, because the regression coefficients calculated have higher values (between 0.9990 and 1). A very good agreement between experimental data and Andrade equation was obtained. Therefore, the Andrade equation can be used to determine oil viscosity at different temperatures for different shear rates with better accuracy for applications such as pipeline system design and/or hydraulic applications.

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