ORIGINAL PAPER

RHEOLOGICAL PROPERTIES OF MINERAL OIL

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Abstract. *In this article presents us rheological behavior of mineral oil. Apparent viscosity of mineral oil was determined at temperatures between 400C-900C and shear rates ranging from 3.3-120s-1. This study is to find a polynomial dependence on temperature and oil viscosity shear rate. Value of parameters of the theoretical models described by equations and correlation coefficient were determined by correlating a characteristic polynomial equation of each curve.*

Keywords: *mineral oil, equation, temperature.*

1. INTRODUCTION

The effect of temperature on viscosity has been the interest of researchers in universities and manufactures of lubricant oils until recent years [1, 2]. The subject seems simple but the contribution is very significant. This is because viscosity is an important energy transfer property and it is also one of the most basic physical properties in the design of hydraulic systems or hydromachines. However, lack of an accurate model that is valid for all liquid makes it difficult to predict the effect of temperature on viscosity.

The mineral oil has been proposed several empirical relationships describing the temperature dependent dynamic viscosity. The more important of these is the Andrade equation (1). Andrade [3, 4] equations are modified versions of equations (2) and (3) [5-10]:

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

$$\ln \eta = A + B/T + C/T^2 \quad (2)$$

$$\ln \eta = A + B/T + CT \quad (3)$$

To elucidate the effect of temperature on the absolute viscosity the following equations (4) and (5) have also been used:

$$\log \eta = A/T - B \quad (4)$$

$$\eta = A - B \log T \quad (5)$$

where T is the temperature absolute and A, B and C in the equations (1) to (5) are correlation constants. The results of regression analyses to these relations are presented in Tables 1, 2, 3, 4 and 5. In this study we determined the viscosity of mineral oil in the temperature range from 40 ^{0}C to 90 ^{0}C. 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.

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2. MATERIALS AND METHODS

The mineral oil no additive used in this work is provided by a company in Bucharest, Romania. The mineral oil no additive have investigated using a Haake VT 550 Viscotester developing shear rates ranging between 3 and 120s^{-1} and measuring viscosities from 10^4 to 10^6 mPa·s when the HV1 viscosity sensor is used. The temperature ranged between 40 and 90 ^{0}C and the measurements were made from 10 to 10 ^{0}C. The accuracy of the temperature was ± 0.1 ^{0}C.

3. RESULTS AND DISCUSSION

Fig. 1 shows the dynamic viscosity temperature dependence for studied mineral oil no additive. The behavior of oil mineral no additive is that the viscosity decreases with increasing temperature.

The Fig. 2 shows the log viscosity depending on the inverse absolute temperature for mineral oil.

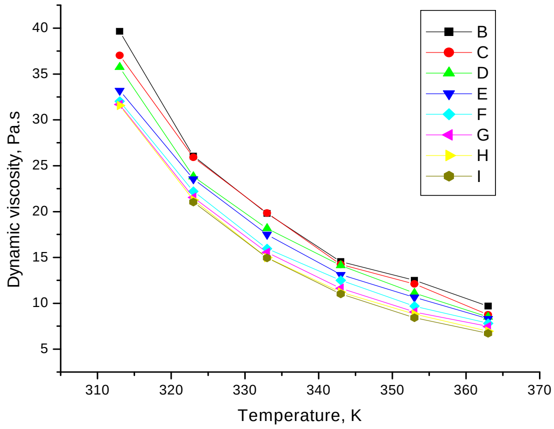

Fig. 1. The viscosities of investigated oils as a function of temperature of mineral oil for different shear rate: B - 3.3s^{-1} ; C – 6s^{-1}, D –10.6s^{-1}, E - 17.87s^{-1}, F - 30s^{-1}, G-52.85s^{-1}, H – 80s^{-1}, I – 12s^{-1}.

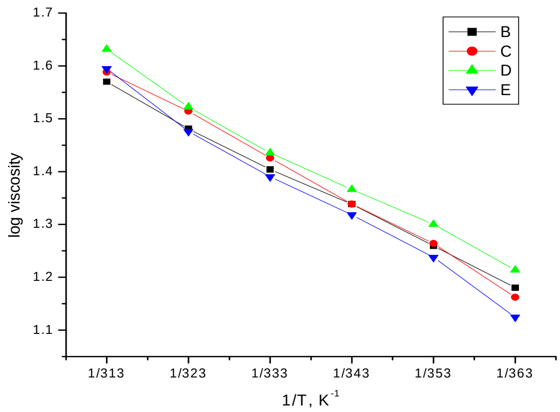

Fig. 2. Dependence log viscosity on the 1/T for mineral oil of different shear rate: B - 3.3s^{-1} ; C – 6s^{-1}, D –10.6s^{-1}, E - 17.87s^{-1}.

Oil mineral viscosity is a function of temperature. The program Origin 6.0 was used to determine constants equation for mineral oil. In addition, the parameters A, B and C change with shear rate. Therefore, by imposing constant shear rate, the parameters can be determined. In order to determine the equation constants, the following steps were performed using the Origin 6.0 software: load the non-linear regression package, input experimental data, title x-label, y-label and set the required equation, perform non-linear regression and plot experimental data and best fitted curve, calculate the mean square error and coefficient of determination and show the best fitted equation constant, mean square error and coefficient of determination.

Tables 1 – 5 show the rheological constants mineral oil. As shown in Tables 1 – 5, the software found it polynomial equations applied shear rate curves of mineral oil. The root mean square error means that experimental data is spread equation. Remains the same temperature range, where the Andrade equation was fitted other experimental data.

From the results of the regression tabulated in tables 1 – 5, the lowest coefficient of determination and the highest mean square error were 0.9490 and 1.0000, respectively.

Table 1. The shear rate, value of parameters of the theoretical model described by equation (4), coefficient correlation and range temperatures for mineral oil

Shear rate [s^{-1}]	Value of parameters of the theoretical model described by equation (4)		R^2	Temp. Range [^{0}C]
	A	B		
3.30	0.1185	1.6742	0.9900	40-90
6.00	0.1219	1.6696	0.9962	40-90
10.60	0.1206	1.6411	0.9956	40-90
17.87	0.1191	1.6170	0.9966	40-90
30.00	0.1215	1.5969	0.9949	40-90
52.95	0.1256	1.5930	0.9936	40-90
80.00	0.1303	1.5956	0.9942	40-90
120.0	0.1240	1.5545	0.9968	40-90

Table 2. The shear rate, value of parameters of the theoretical model described by equation (5), coefficient correlation and range temperatures for mineral oil

Shear rate [s^{-1}]	Value of parameters of the theoretical model described by equation (5)		R^2	Temp. Range [^{0}C]
	A	B		
3.3	1117.3925	433.8558	0.9490	40-90
6.0	1082.6130	420.4191	0.9688	40-90
10.6	1025.5587	398.2772	0.9599	40-90
17.87	963.7169	374.1542	0.9675	40-90
30.0	932.2974	362.1328	0.9609	40-90
52.95	933.9722	363.0114	0.9575	40-90
80.0	943.4917	366.9182	0.9557	40-90
120.0	718.4253	278.5090	0.9749	40-90

Table 3. The shear rate, value of parameters of the theoretical model described by equation (2), coefficient correlation and range temperatures for mineral oil

Shear rate [s^{-1}]	Value of parameters of the theoretical model described by equation (2)			R^2	Temp. Range [^{0}C]
	A	B	C		
3.30	1.7698	-0.1902	0.0102	0.9959	40-90
6.00	1.7119	-0.1536	0.0045	0.9953	40-90
10.60	1.7001	-0.1649	0.0063	0.9970	40-90
17.87	1.6766	-0.1638	0.0064	0.9993	40-90
30.00	1.6730	-0.1786	0.0082	0.9994	40-90
52.95	1.6839	-0.1938	0.0097	0.9999	40-90
80.00	1.6849	-0.1972	0.0095	0.9997	40-90
120.0	1.6721	-0.1912	0.0084	1.0000	40-90

Table 4. The shear rate, value of parameters of the theoretical model described by equation (3), coefficient correlation and range temperatures for mineral oil

Shear rate [s^{-1}]	Value of parameters of the theoretical model described by equation (3)			R^2	Temp. Range [^{0}C]
	A	B	C		
3.3	14.6715	4.4378	0.0352	0.9998	40-90
6.0	12.3891	3.8578	0.0291	0.9973	40-90
10.6	11.9164	3.7787	0.0277	0.9956	40-90
17.87	11.7601	3.7233	0.0274	0.9966	40-90
30.0	11.8745	3.6771	0.0279	0.9949	40-90
52.95	12.1431	3.6681	0.0289	0.9936	40-90
80.0	12.4657	3.6741	0.0300	0.9942	40-90
120.0	11.9478	3.5795	0.2856	0.9968	40-90

Table 5. The shear rate, value of parameters of the theoretical model described by equation (1), coefficient correlation and range temperatures for mineral oil

Shear rate [s^{-1}]	Value of parameters of the theoretical model described by equation (1)		R^2	Temp. Range [^{0}C]
	A	B		
3.3	28.3557	10.6970	0.9993	40-90
6.0	25.3749	9.5438	0.9993	40-90
10.6	24.3718	9.1586	0.9986	40-90
17.87	24.6350	9.2688	0.9980	40-90
30.0	25.0850	9.4580	0.9968	40-90
52.95	25.8847	9.7815	0.9958	40-90
80.0	26.7882	10.1444	0.9963	40-90
120.0	25.8946	9.7976	0.9980	40-90

4. CONCLUSIONS

Mineral oil tested was examined with modified Andrade equation. There was no need to use a higher order polynomial function of 1/T, because most coefficients were determined higher values of 0.9999. Viscosity curve model showed a good fitting for mineral oil. Representation of temperature dependence of viscosity to determine a mean square error approaches 1 at almost all shear rates. In the present study was possible to obtain the correct value of viscosity at different temperatures by placing the constant changing Andrade equation at different shear rates. Therefore, the model temperature dependence of viscosity can be used to determine oil viscosity at different temperatures for different shear rates with better accuracy for applications such as pipeline system design, hydraulic applications.

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