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A new viscosity-temperature relationship for mineral oil SAE 10W

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Abstract This article proposes four relationships of dynamic viscosity temperature dependence for a non-addtivated mineral oil. The purpose of this study was to find a polynomial or exponential dependence between temperature and dynamic viscosity of mineral oil, using the Andrade equation changes. Equation constants A, B, C and D were determined by fitting polynomial or exponential.

Keywords: viscosity, temperature, mineral oil.

1. Introduction

Viscosity is one of the most important physical properties of a fluid system. [1–5] Oil viscosity changes with shear rate, temperature, pressure, moisture, and concentration; all these dependencies can be modeled using different types of equations.

The effect of temperature on viscosity is normally fitted with the Arrhenius-type relationship:

$$\eta = A exp(E_a/RT) \quad (1)$$

where η is dynamic viscosity (Pa.s); A is the pre-exponential factor (Pa.s); E_a is the exponential constant that is known as activation energy (J/mol); R is the gas constant ($Jmol^{-1}K^{-1}$) and T is the absolute temperature (K).

Modeling the temperature effect on the dynamic viscosity of mineral oils s important and has been investigated by various researchers [9−12].

Two parameters equations were proposed by .[6]

Equation (2)

$$ln\eta = A + BlnT \quad (2)$$

and - [7].

Equation (3)

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

$$ln\eta = A + B/(T+C) \quad (4)$$

$$ln\eta = A + B/T+C/T^2 \quad (5)$$

$$ln\eta = A + B/T+CT \quad (6)$$

$$ln\eta = A + BT+CT^2 \quad (7)$$

and tree parameters equations were proposed by [8], where A, B and C are constants, and T is absolute temperature (K).

This article proposes four new relationships to describe the dependence of dynamic viscosity of mineral oil on temperature. Dynamic viscosity of oils was determined at two temperatures, 40^0C and 100^0C and for shear rate in the range 3.3 - 120 s^{-1}. The purpose of this study was to find a polynomial or exponential dependence between temperature and dynamic viscosity for a mineral oil with no additive using Andrade equation changes.

2. Experimental

The mineral oil with no additive used in this work was provided by a company from Bucharest, Romania. The properties of mineral oil were: density 0.8727g/cm^3, kinetic viscosity at 40^0C is 8.83cSt and 100^0C is 89.41cSt. The mineral oil has the following main components: hydrocarbons – 75,01%, aromatic – 20,55% and small amount of resins – 4,43%.

The dynamic viscosity of the mineral oil was measured with Haake VT 550 viscotester. When using HV_1 viscosity sensor, the characteristics of this equipment are: shear rates between 3 and 120s $^{-1}$ and measuring viscosities from 10^4 to 10^6 mPa.s.

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3. Results and Discussions

Figures 1, 2, 3, 4, 5, 6, 7 and 8 show the dependence of dynamic viscosity on temperature of the studied mineral oil at shear rates $3.3s^{-1}$, $6s^{-1}$, $10.6s^{-1}$, $17.87s^{-1}$, $30s^{-1}$, $52.95s^{-1}$, $80s^{-1}$ and $120s^{-1}$. From these figures it can be observed that the dynamic viscosity of the mineral oil decreases with temperature increasing.

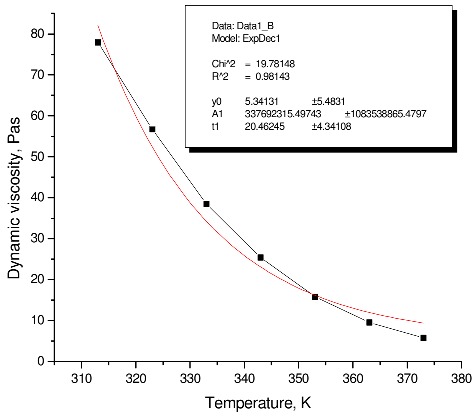

Fig. 1. . Dynamic viscosity versus temperature for the mineral oil at a shear rate 3.3 s^{-1}

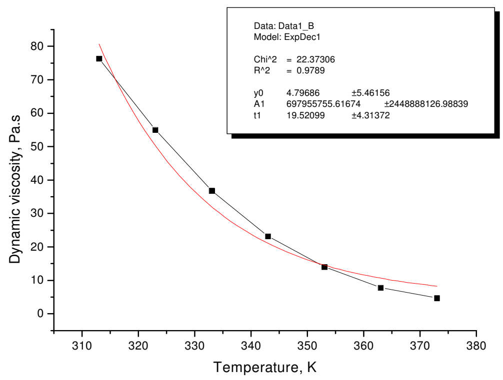

Fig. 2. Dynamic viscosity versus temperature for the mineral oil at a shear rate $6s^{-1}$

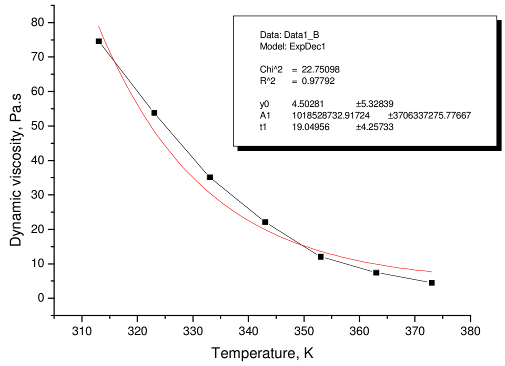

Fig. 3 . Dynamic viscosity versus temperature for the mineral oil at a shear rate 10. $6s^{-1}$

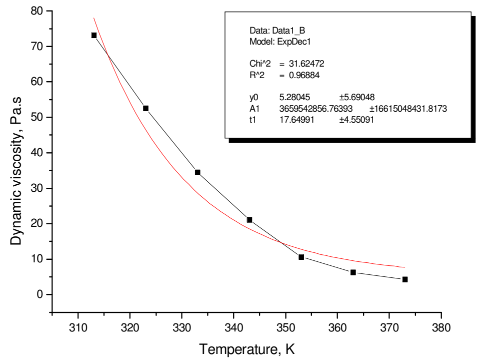

Fig. 4. . Dynamic viscosity versus temperature for the mineral oil at a shear rate $17.87s^{-1}$

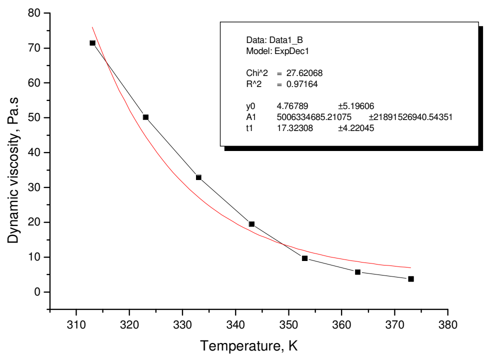

Fig. 5 . Dynamic viscosity versus temperature for the mineral oil at a shear rate $30s^{-1}$

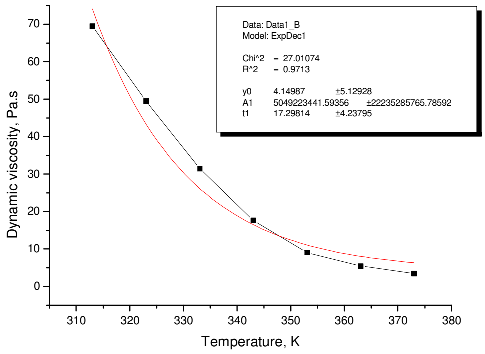

Fig. 6 . Dynamic viscosity versus temperature for the mineral oil at a shear rate 52.95s^{-1}

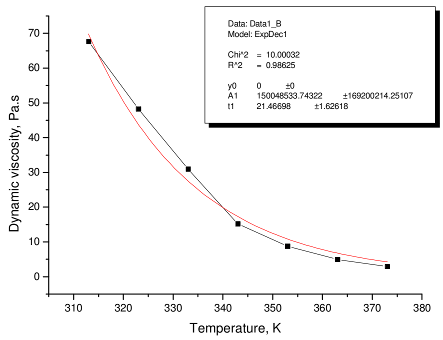

Fig. 7 . Dynamic viscosity versus temperature for the mineral oil at a shear rate 80s^{-1}

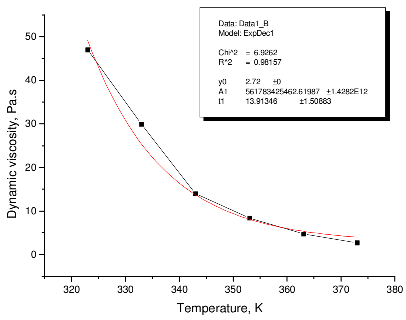

Fig. 8 . Dynamic viscosity versus temperature for the mineral oil at a shear rate 120s^{-1}

In this paper there are proposed four equations (eq. 8-11) to predict the dependence of the dynamic viscosity of mineral oils on the temperature.

The software Origin 6.0 was used to determine equation constants from the measured for the mineral oil. In addition, the parameters A, B, C, η_0, and D 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 constant of determination and show the best fitted equation constants mean square error and coefficient of determination.

The values of the constants from eq. (8) - (11) for the studied mineral oil are presented in Table 1-4

From the results of the regression tabulated in tables 1, 2, 3 and 4, it can be observed that the correlation coefficients varied between 0.9528 and 0.9999.

$$\eta = A + BT + CT^2 \quad (8)$$

$$\eta = B + (A - B)/(1 + exp((T-T_0)/dT)) \quad (9)$$

$$\eta = A + BT + CT^2 + DT^3 \quad (10)$$

$$\eta = \eta_0 + Aexp(-T/B) \quad (11)$$

were T is absolute temperature A, B, C and D are constants corresponding to a dynamic viscosity of 50 Pa·s and width dT.

Table 1. Correlation constants for viscosity calculation (eq.8) for different share rates and temperature ranging from 313 K to 363K

Shear rate, s^{-1}	Correlation parameters (eq. 8)			Correlation coefficient, R^2
	A	B	C	
3.30	2592.2737	-13.7749	0.0183	0.9997
6.00	2669.9158	-14.2450	0.0190	0.9998
10.60	2737.3219	-14.6618	0.0197	0.9998
17.87	2763.7588	-14.8332	0.0199	0.9997
30.00	2798.3249	-15.0709	0.0203	0.9999
52.95	2815.4822	-15.2002	0.0206	0.9996
80.00	2698.3829	-14.5415	0.0196	0.9996
120.0	2772.1080	-14.9789	0.0203	0.9999

Table 2. Correlation constants for viscosity calculation (eq.9) for different share rates and temperature ranging from 313 K to 363K

Shear rate, s^{-1}	Correlation parameters (eq. 9)				Correlation coefficient, R^2
	A	B	T_0	dT	
3.30	174.0800	-0.3303	309.0800	19.2660	0.9999
6.00	154.2800	-0.2795	312.7100	17.6150	0.9999
10.60	129.6100	0.5349	317.5800	15.4830	0.9998
17.87	117.9500	0.5237	319.9100	14.4530	0.9993
30.00	121.4700	0.1568	318.1300	14.6460	0.9993
52.95	104.6400	1.0327	321.5400	12.8730	0.9998
80.00	102.6500	0.3666	321.5300	13.1750	0.9997
120.0	81.7490	0.8117	326.3500	11.7860	0.9996

Table 3. Correlation constants for viscosity calculation (eq.10) for different share rates and temperature ranging from 313 K to 363K

Shear rate, s^{-1}	Correlation parameters (eq.10)				R^2
	A	B	C	D	
3.30	7382.9159	-55.9845	0.1420	-1.2056E-4	0.9997
6.00	4586.4500	-31.0746	0.0682	-4.7778E-5	0.9999
10.60	3537.2849	-21.6996	0.0403	-2.0000E-5	0.9997
17.87	1390.9069	-2.7901	-0.0152	3.4167E-5	0.9998
30.00	2874.0163	-15.7487	0.0223	-1.9444E-6	0.9998
52.95	2256.0430	-10.3008	0.0063	1.3889E-5	0.9993
80.00	1916.0446	-7.3599	-0.0023	2.2222E-5	0.9978
120.0	11824.2658	-92.5856	0.2417	-2.1019E-4	0.9962

Table 4. Correlation constants for viscosity calculation (eq.11) for different share rates and temperature ranging from 313 K to 363K

Shear rate, s^{-1}	Correlation parameters (eq.11)			R^2
	η_0	A	B	
3.30	5.3413	3.3769E8	20.4625	0.9814
6.00	4.7969	6.9796E8	19.5209	0.9789
10.60	5.5659	2.8927E9	17.9031	0.9702
17.87	7.0979	2.6954E10	15.8497	0.9528
30.00	6.4941	3.8084E10	15.5615	0.9562
52.95	5.8112	3.7358E10	15.5631	0.9563
80.00	0.0000	1.2511E8	21.7378	0.9866
120.0	4.9330	1.9415E13	12.0548	0.9563

4. Conclusions

This article proposes the relationship to describe the dependence of the dynamic viscosity of a mineral oil with no additive, on the temperature. Experimental data for one type of mineral oil were used to calculate the accuracy the proposed models. Equation constants were determined by exponential or polynomial beast curves obtained at different shear rates using the program Origin 6.0. The correlation coefficients thus obtained varied between 0.9528 and 0.9999.

5. References

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