ICCPGE 2016, 1, 25 - 30

Measurements and Prediction of Viscosities of Mineral Oil Blends

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Abstract

Five different mineral oils blends were prepared. Experimental viscosities were measured and to develop the reliable mathematical expression at different temperatures using non-linear regression were considered and analysed using standard statistical techniques. The predicted kinematic viscosity results have been validated with the experimental viscosity data gathered in the laboratory. Good results between the predicted and experimental values have been noticed with an overall average absolute deviation of 2.71 %. The developed model was compared with some widely known viscosity models existed in the literature. It can be shown that the performance of the developed model was much better than the investigated models in literature.

Keywords: Chemical; petroleum; gas; conference.

1. Introduction

A Mineral oil is highly refined oil that consists of paraffinic and naphthenic hydrocarbons. In the more conventional oil reservoirs, the need to predict the viscosity of oil blends occurs when reservoir fluids are contaminated with oil-based muds or when production streams from different reservoirs or fields are commingled in a single pipeline. In some heavy oil reservoirs, crude oil can flow in the formation but may not flow through the wellbore because the viscosity becomes very high due to the low temperature around the wellbore as the crude oil flows up to the surface. Injecting light oil is an important recovery method which is being utilized in petroleum industry. In this case, predicting the viscosity of the mixed oil accurately turns to be necessary to decide how much light oil should be added.A program to experimentally determine the physical properties of the fuels and their blends (i.e. mineral oil blends) would be prohibitive in both cost and time; indeed it could probably never be completed. For these reasons accurate correlations of these properties are becoming increasingly important. Basically, most of the formulas (empirical or semi-empirical) are derived from the regression analysis of experimental data instead of the physical mechanisms. Gao Y., Li K. [1] prepared a twenty mixed oil samples with different ratios of light to crude oil from different oil wells but the same oil field. The viscosities of the mixtures were measured at the same shear rate but different temperatures. Five models were examined using the experimental viscosity data to find the most suitable viscosity model for this oil field. Finally, one modified model was proposed to calculate the viscosity of mixed oils with a better accuracy than the existing models. Another model was developed to predict the viscosity of mixed oils at different temperatures and different values of mixing ratio of light to heavy oil. Centeno et al [2] used the experimental data reported in literature to calculate binary interaction parameters. They

observed that a comparison of experimental viscosity data and those calculated with the blending rule showed excellent prediction capability with minimal error. Al Naumi and Vishweshwara [3] studied the effect of temperature on the viscosity of biodiesel and its blends at different temperatures. They showed that the blends which is lower than 30% of biodiesel is matching the viscosity diesel fuels, while higher blends (higher than 30% of biodiesel) need to be heated further higher temperatures, heating for higher temperatures is waste of energy and considered as not economical. In this work, the viscosities of light and heavy mineral oils and their blends were experimentally measured over a temperature range of 20-30 °C. These viscosity data were used to develop a method for predicting the viscosity of mineral oil blends based on known component viscosity. Nonlinear regression technique was used to determine the model parameters.The predicted kinematic viscosity results were validated with the experimental viscosity data gathered in the laboratory. The developed model was compared with some widely known viscosity models existed in the literature.

2. Experimental Work

Two types of mineral oils kindly supplied from Libyan Oil Company were used corresponding to a light (A) and heavy (C) mineral oils. From the base mineral oils, five binary mixtures were prepared with different sample compositions: These are named as follows: Blend 1 (15% A, 85% C), Blend 2 (25% A, 75% C), Blend 3 (32% A, 68% C), Blend 4 (55% A, 45% C) and, Blend 5 (75% A, 25% C). Kinematic viscosities and densities of the blends were measured at atmospheric presume and at temperatures of (20, 25, 30°C). Obtained results are presented in Table 2.1 and Table 2.2 respectively. Details of the followed experimental technique and procedures are found in Allili[4].

3. Theoretical Background

The three frequently-used models (the Amin and Maddox model [5], the Shanshool et al model [6], and the Refutas model [7]) have different characteristics.The expressions of these three models are as follows:
Amin and Maddox model:

Table 2.1: Boiling points and Experimental Kinematic Viscosity of mineral oils Blends at Various temperatures

Kinematic viscosities (cSt)				
Blend	50 % Boiling point (°C)	20 °C	25°C	30 °C
Light (A)	*	26.24	21.18	17.43
Heavy (C)	*	2.39	2.11	1.92
Blend 1	197	2.9172	2.6293	2.3837
Blend 2	201	3.7135	3.3154	2.9765
Blend 3	200	4.4515	3.8765	3.4736
Blend 4	313	7.5482	6.4968	5.6619
Blend 5	345	12.1619	10.4329	8.9455

Table 2.2: Specific gravities and Densities of Blends at various temperatures (°C)

Densities (gm/cc)				
Blend	Specific gravity	20 °C	25°C	30 °C
Blend 1	0.7803	0.7762	0.7743	0.7690
Blend 2	0.7839	0.7798	0.7763	0.7727
Blend 3	0.7917	0.7877	0.7843	0.7808
Blend 4	0.8071	0.8032	0.7998	0.7964
Blend 5	0.8223	0.8185	0.8152	0.8118

$$ln\vartheta = A + \frac{B}{T} \tag{3.1}$$

$$lnB = 4.717 + 0.00526T_b \tag{3.2}$$

$$A = 10^{-6}(91.836T_b^{-0.175} - 29.263)(K/B) \tag{3.3}$$

Where the coefficients A and B are related to 50% boiling point (T_b) and to the Watson characterization factor (K).
Shanshool et al. Model:

$$log(\vartheta + 0.7) = 100(0.01T)^b \tag{3.4}$$

$$\begin{aligned} b = &- 5.745 + 0.616ln(ECN) \\ &- 40.468(ECN)^{-1.5} \end{aligned} \tag{3.5}$$

$$\begin{aligned} ECN(T_b, API) = &- 1799.8195 - 0.0403386T_b \\ &+ 8.19416 * 10^{-5}T_b^2 \\ &- 352.52229 \end{aligned} \tag{3.6}$$

$$(T_b/API)^{0.1} + 2158(T_b/API)^{0.02} \quad (3.7)$$

Refutas (2000) Model:

$$VBN_i = 14.534 \times ln(ln(\vartheta + 0.8)) + 10.975 \quad (3.8)$$

Where VBNi is viscosity blending number, ϑ is the kinematic viscosity in (cSt) of component i. The viscosity blending of the liquid mixture (VBN mixture) is then calculated as follows:

$$VBN_{mixture} = \sum_{i=0}^{N} X_i \times VBN_i \quad (3.9)$$

Where X_i is the mass fraction component i. The kinematic viscosity of the mixture can then be estimated using VBN mixture as follows:

$$\vartheta = exp\left(exp\left(\frac{VB_{mixture} - 10.975}{14.534}\right)\right)^{-0.8} \quad (3.10)$$

3.1. New Developed Model to Predict The Kinematic Viscosity of The Investigated Mineral Oil Blends

The general form of the viscosity model in terms of composition (x) and temperature (T) can be expressed as:

$$\vartheta = a.e^{bx} \quad (3.11)$$

Where (ϑ) is the kinematic viscosity in (cSt), x is mass fraction and the parameters a and b are the coefficients which will be determined by the nonlinear regression technique. Obtained results with R^2 are summarized in Table 3.1.

Table 3.1: Calculated values of parameters at different temperatures

Temperature (°C)	a	b	R^2
20	2.1110	0.0240	0.991
25	1.8950	0.0230	0.992
30	1.7198	0.0224	0.992

The term of parameter (a) is only function of temperature and can be expressed as:

$$a = CT^D \quad (3.12)$$

Where coefficients C and D are constants will be determined.

The values of coefficients C and D were determined by drawing parameter values of a vs temperature and linear relationship was found with values of C = 9.5878 and D = -0.505 (Equation 3.12).
By substituting the value of (a) in the Equation 3.11 it can be expressed the general form of the kinematic viscosity equation as:

$$\vartheta = 9.5878T^{(-0.505)}e^{bx} \quad (3.13)$$

Note: the constant (b) is ranged as: 0.024, 0.023 and 0.0224 for temperatures (20, 25 and 30 °C) receptivity.

4. Results and Discussion

The accuracy of correlations relative to the observed values (experimental values) is determined by using various statistical means. The following criteria are used in this study.
Average deviation (% AD) is defined as:

$$\%AD = \frac{\mid \upsilon^{exp} - \upsilon^{cal} \mid}{\upsilon^{exp}} * 100 \quad (4.1)$$

Where:ν^{exp} and ν^{cal} represented the experimental and calculated kinematic viscosity values respectively. The % AD indicates how close the calculated values are to experimental values. The percentage absolute an average deviation (% AAD) is used to subject the test and can be defined as:

$$\%AAD = \frac{1}{n}\sum_{i=1}^{n} \frac{\mid \upsilon^{exp} - \upsilon^{cal} \mid}{\upsilon^{exp}} * 100 \quad (4.2)$$

Where: n is the total number of data.

4.1. Validation of The Developed Model with Experimental Data

The accuracy and ability of developed model for predicting kinematic viscosity of mineral oil blends was checked with experimental data. Figure 4.1 depicts the comparison of experimental and calculated values of viscosity for different blends at temperature 25°C as an example. It was noticed from the Figure 4.1 that the model provides a good result with experimental data, withan overall average absolute deviation (%AAD) between experimental and predicted data was found 1.80%. The results of % AD and % AAD for each blend of mineral oils at different temperatures are shown

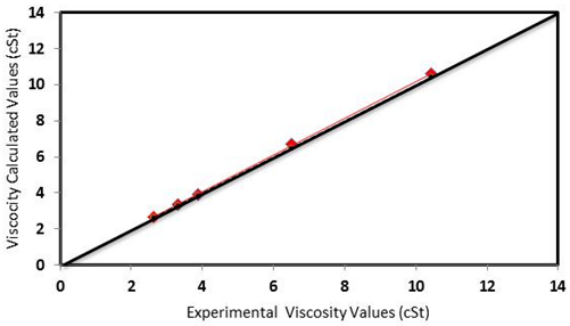

Figure 4.1: Experimental vs calculated viscosities values at 25 °C

in Table 4.1. According to the obtained results from Figure 4.2 it is highly recommended for engineers to prepare and use blends of mineral oils at temperature 25 °C for this work, because it gives the best result when make comparison between the experimental and calculated data.

Table 4.1: %AD and %AAD for each blend at different temperatures

(AD%)					
Temperature (°C)	Blend 1	Blend 2	Blend 3	Blend 4	Blend 5
20	3.8649	3.7247	2.3578	4.8356	5.1521
25	1.4309	1.2423	1.7137	3.0058	1.6089
30	1.1317	1.3246	1.5637	4.3048	3.3299
%AAD	2.14	2.10	1.88	4.05	3.36

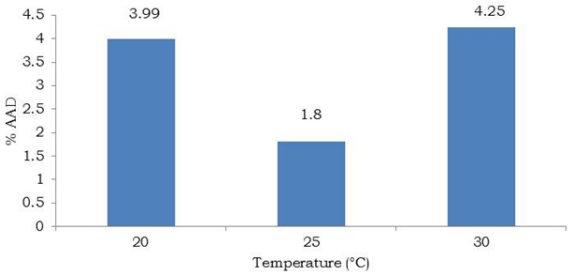

Figure 4.2: %AAD vs. Temperature for all the blends

4.2. Comparison Between The Predictive Capabilities of The Developed Model with Literature Models

The predictive capability of the proposed model was compared with some existing models in the literature. It should be noticed that the same viscosity date base was used to test all the models involved Overall percentage (AAD %) of the predictive capabilities of the models investigated in this study are summarized in Figure 4.3. Results indicated that the performance of this proposed techniques is much better than the literature models.

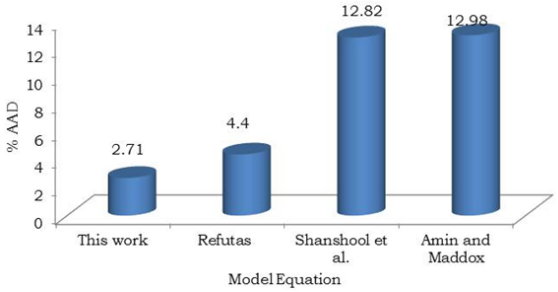

Figure 4.3: Comparison of the predictive capabilities of the different predictive models

5. Conclusion

The kinematic viscosities of light and heavy mineral oils and five blends were measured over a temperature range 20-30 °C. These viscosity data were used to develop a new method for predicting the viscosity of these blends as a function of composition and temperature. The predicting results have been validated with the experimental viscosity data gathered in the laboratory. It was found that the new method gave the best representation of experimental results. The average absolute deviation was found 2.71% compared with investigated models of 4.40% for Refutas [7]; 12.82% for Shanshool et al. [6]; 12.98% for Amin and Maddox [5].

6. Acknowledgment

The authors gratefully acknowledge the technical support given for this work by the Libyan Petroleum Institute.

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