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Evaluation of Oil Viscosity Performance Using Several Empirical Correlations for Some Libyan Crude Oils

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Abstract: Evaluation of oil viscosity is an important deal in the design of various operations in oil fields and refineries. Therefore, the variety in viscosity of crude oil, depends on pressure and temperature [1]. In this work, different oil samples from Libyan reservoirs were selected and supplementary data were collected from published literature. Chew-Connally [2], Beggs-Robinson [3], Labedi [4] and modified kartoatmodjo [5] correlations are applied to the acquired data set and a comprehensive error analysis is performed based on a comparison of the predicted value with the experimental value. Results concluded that Beggs-Robinson model gives the lowest value of absolute average deviation (AAD %) 21.19 % compared with the other models promoting this correlation for more applications.

Keywords: Viscosity, Saturated Oil, Correlation, Pressure, Temperature, Value

1. Introduction

Since petroleum and reservoir fluids, such as crude oils and natural gases, are of significant importance, accurate and reliable fluid properties (ex., fluid density, solution gas-oil ratio, bubble point pressure) are required. One of these properties is the viscosity, which required in many engineering disciplines ranging from the design of transport equipments, such as pipelines or compressors, to the simulation of production profiles of oil and gas reservoirs, enhance oil recovery, or /and the storage of natural gas.

Viscosity is a very important physical property that plays a great role in controlling oil f low through porous media and pipes, and it defined as the internal resistance of the fluid to flow. Oil viscosity is a strong function of many thermodynamic and physical properties such as pressure, temperature, solution gas-oil ratio, saturated (bubble point) pressure, gas gravity and oil gravity.

Viscosity testing of crude can be measured at laboratory at reservoir temperature, and/or it can be obtained by estimating a proper model of empirical correlations. Generally viscosity reported in standard PVT analyses, where increasing pressure always causes increase in viscosity above the bubble point. However below the bubble point, increasing pressure causes an increase in solution gas, which in turn decreases the oil viscosity. Thus, oil viscosity correlations all belong to three categories: The dead oil viscosity (oil with no free gas in the solution), the saturated (bubble point), and under-saturated oil viscosity.

Evaluation of viscosity is an important step to plan thermal methods of enhanced oil recovery, and to design production equipment and pipelines[6].Correlations proposed to calculate oil viscosity are categorized into two types: 1- black oil type correlations, that predict viscosities from available field-measured variables include reservoir temperature, oil API gravity, solution gas-oil ratio, saturation pressure, 2-compositional type correlations derive mostly from the principle of corresponding states and its extensions [7].

An assessment of the available correlations has been performed to identify an approach to estimate saturated oil viscosity. Viscosity data has been provided through the Libyan Petroleum Institute (LPI) oils from six reservoirs identified as Oil 1, Oil 2, Oil 3, Oil 4, Oil 5 and Oil 6. Empirical correlations, in many instance, is the only available resort. The purpose of this investigation is to evaluate the saturated (μ_{ob}) oil viscosity using some common published oil viscosity empirical correlations, and then compared with the experimental viscosities data collected from labs. Statistical analysis is the criteria adopted for the evaluation in this study.

2. Review of Experimental Data and Empirical Correlations

The viscosity is usually reported in the standard pressure-temperature- volume (PVT) analyses. If the laboratory data are not available, engineers may refer to the published empirical correlations, which usually vary in the complexity and accuracy depending upon the available data of the crude oils.

In this study, experimental data of six oil samples named as: Oil 1, Oil 2, Oil 3, Oil 4, Oil 5 and Oil 6 derived from Libyan oil reservoirs. Data used includes API gravity at reservoir temperature, solution oil gas ratio, oil reservoir temperature, bubble point pressure, specific gravity of gas, and viscosities have been measured at various pressures, table 1.

Table 1. *Data for oil viscosity correlations.*

Sample	°API	R_s	T (°F)	P_b(psi)	SG_{gas}	μ_{ob}.(cp)	μ_{od} (cp)
Oil 1	36.51	1382	184	3302	0.9808	0.2888	6554
Oil 2	47.8	800	174.4	1560	1.0202	0.4342	0.8617
Oil 3	38.94	521	161	1400	1.085	0.696	1.94
Oil 4	43.26	119	200	287	1.5863	0.7615	1.001
Oil 5	42.18	138	167	340	1.3836	0.734	1.62
Oil 6	46.62	1762	176	2445	1.0209	0.29	0.81

Saturated oil viscosity correlations usually depend on the dead oil viscosity and solution gas–oil ratio R_s at bubble point pressure. The most common correlations which have been used in the literature to evaluate the saturated oil viscosities are Chew-Connally, 1959; Beggs-Robinson, 1975; modified kartoatmodjo (medium oils), and Labedi 1992.

Statistical analysis in terms of percent absolute deviation (% AD) and the percent absolute average deviations (% AAD) are used to subject the evaluation of the viscosity correlations. It can be defined as:

$$\%AD = \frac{|\mu^{exp} - \mu^{cal}|}{\mu^{exp}} \times 100 \quad (1)$$

$$\%AAD = \frac{1}{n} \sum_{i=1}^{n} \frac{|\mu^{exp} - \mu^{cal}|}{\mu^{exp}} \times 100 \quad (2)$$

Where n is the number of experimental points, μ^{exp} the experimental viscosity and μ^{cal} the calculated viscosity. The % AAD indicates how close the calculated values are to experimental values.

3. Results and Discussions

Saturated oil viscosities are predicted using Chew-Connally, Beggs-Robinson, Labedi and modified kartoatmodjo (medium oils) correlations. Statistical analysis in terms of percent absolute deviation (% AD) and the percent absolute average deviations (% AAD) are used to subject the evaluation of the viscosity correlations. The accuracy and ability of each mentioned correlation for calculation of saturated oil viscosity was checked with experimental data.

Beggs & Robison correlation has tested with the experimental viscosity of saturated oils from six reservoirs, and the comparison result is presented in the Figure 1. The overall AAD% for this model is 21.19%

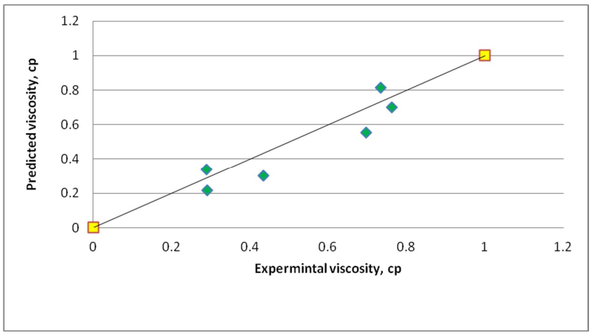

Figure 1. *Experimental viscosities vs predicted (Beggs & Robinson correlation).*

Chew-Connally correlation has been tested with the experimental viscosity of the saturated oils from selected Libyan oil reservoirs. Figure 2 shows graphically results, and the overall of AAD% is 26.19%.

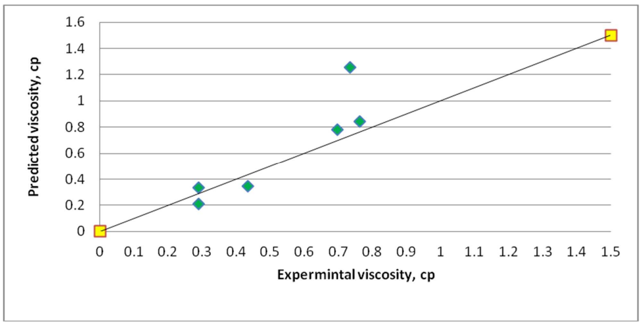

Figure 2. *Estimated vs. measured viscosities (Chew & Connally correlation).*

Labide correlation was applied to estimate the saturated oil viscosities of investigated Libyan oil samples. Compression of predicted values the measured one are shown in Figure 3. The overall of AAD% is 36.14 %.

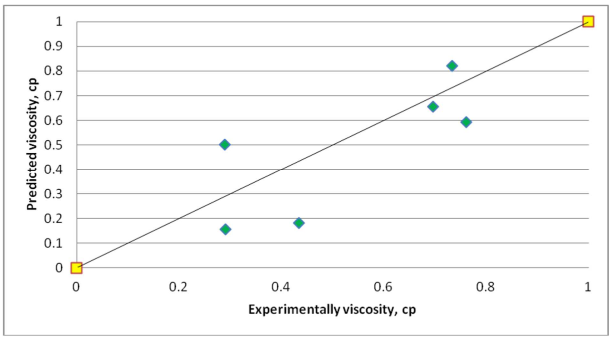

Figure 3. *Estimated viscosities vs. Measured (Labide correlation).*

Modified Kartoatmodjo (medium oils) correlation has been tested using data obtained from the LPI for six Libyan crude oils, and the obtained results are shown graphically in Figure

4. The overall of AAD% is 38.56 %.

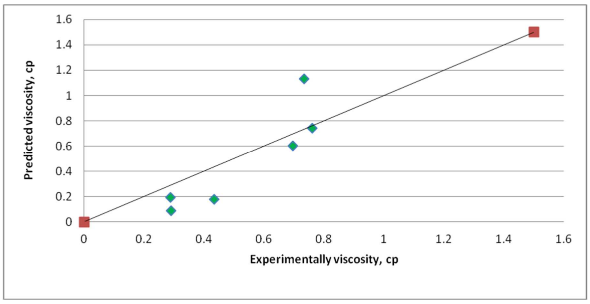

Figure 4. *Estimated viscosities vs. Measured (modified kartoatmodjo correlation).*

Over-all percentage (%AAD) of predictive capabilities of investigated models is summarized in Figure 5. Values of the overall %AAD resulted from Beggs & Robinson model, Chew & Connally model, Labide model and modified Karto-atmodjo model are 21.19, 26.19, 36.14 and 38.55% respectively. More-over the Beggs & Robinson model gave the lowest values of % AAD compared with the other models.

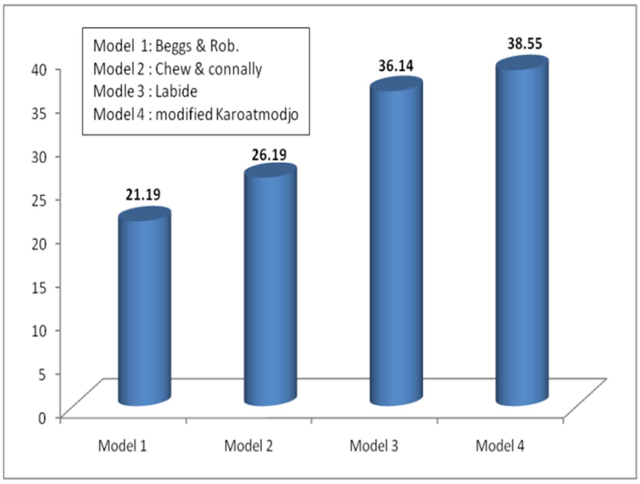

Figure 5. *Overall % AAD of the different predictive models.*

4. Conclusion and Recommendation

Several empirical models for estimating the viscosity of crude oils have been applied using data selected from Libyan oil reservoirs. Good agreements between the predicted and experimental values have been observed. The saturated oil viscosity (μ_{ob}), has been estimated based on dead oil viscosity (μ_{od}), that calculated by Beggs & Robinson correlation, which found to be the most successful, with (AAD %) 21.19%. It is recommended to apply more common empirical proposed correlations for estimating and predicting the viscosities of Libyan crude oils, to save money and time.

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Nomenclature

API = Oil API gravity.
Rs = Solution gas-oil ratio (SCF/STB).
μ_{od} = Dead oil viscosity as measured at 14.7 psia and reservoir temperature, cp.
μ_{ob} = Saturated oil viscosity at bubble point pressure, (cp).
SG_{gas} = Specific gravity of gas
μ^{exp} = Experimental viscosity
μ^{cal} = Calculated viscosity
AAD= Absolute average deviation
AD = Average deviation

Appendix

The Chew-Connally Correlation

$$\mu_{ob} = (10)^a (\mu_{od})^b$$

Where

$$a = R_s[2.2(10^{-7})R_s - 7.4$$

$$b = \frac{0.68}{10^c} + \frac{0.25}{10^d} + \frac{0.062}{10^e}$$

$$c = 8.62(10^{-5})R_s$$

$$d = 1.1(10^{-3})R_s$$

$$e = 3.47(10^{-3})R_s$$

Where
μ_{ob} = viscosity of the oil at the bubble-point pressure, cp
μ_{od} = viscosity of the dead oil at 14.7 psia and reservoir temperature, cp,
Rs= solution GOR, scf/STB
The Beggs-Robinson Correlation

$$\mu_{ob} = a(\mu_{od})^b$$

Where

$$a = 10.715(R_s + 100)^{-0.515}$$

$$b = 5.44(R_s + 150)^{-0.338}$$

μ_{ob} = viscosity of the oil at the bubble-point pressure, cp
μ_{od} = viscosity of the dead oil at 14.7 psia & reservoir temperature, cp
Rs= solution GOR, scf/STB
The Labedi Correlation

$$\mu_{ob} = (10^{2.344-0.03542\times API}) \times \frac{\mu_{od}^{0.6447}}{p_b^{0.426}}$$

Where
μob = viscosity of the oil at the bubble-point pressure, cp
μod = viscosity of the dead oil at 14.7 psia & reservoir

temperature, cp

Rs= solution GOR, scf/STB

The modified kartoatmodjo (medium oils) Correlation

$$\mu_{ob} = 0.0132 + 0.9821 * F - 0.005215 * F^2$$

Where

$$F = \left(0.2038 + 0.8591 * 10^{(-0.000845 * R_s)}\right) * \mu_{od}\left(0.385 + 0.5664 * 10^{(-0.00081 * R_s)}\right)$$

Where

μ_{ob} = viscosity of the oil at the bubble-point pressure, cp

μ_{od} = viscosity of the dead oil at 14.7 psia and reservoir temperature, cp

Rs= solution GOR, scf/STB

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