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TESTING THE PERFORMANCE OF SOME DEAD OIL VISCOSITY CORRELATIONS

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Abstract

The knowledge of viscosity plays a very important role in a variety of interesting engineering problems involving fluid flow in porous media and reservoir simulation. The dead oil viscosity is defined as the viscosity of crude oil at atmospheric pressure (no gas in solution) and system temperature. Several correlations have been proposed in the past for predicting the dead oil viscosity. Most of the dead oil viscosity correlations are based on the oil °API gravity and temperature. In this work, evaluating the performance of investigated models. Beal, Beggs-Robinson, Glaso, Labedi and Petrosky and Farshad correlations have been investigated for some Libyan crude oils. Statistical analysis in terms of absolute deviation percent (% AD), and the absolute average deviations percent (% AAD) are used to subject the evaluation of the viscosity correlations. Comparison results indicate that, Beggs-Robinson correlation provide the best prediction for dead oil viscosities in the investigated Libyan oil samples within AAD of 9.58%. Results of this study can be helpful in screening viscosity correlations to suite Libyan crude oils as well as similar crudes.

Key Word: Viscosity; dead oil; correlation; absolute average deviation; temperature.

1. Introduction

Viscosity of dead and live oils is an important property required by specialists in almost all stages of producing oil reservoirs. It becomes more vital in development stages including secondary recovery and EOR. Traditionally, viscosity prediction is a necessity before implementing any recovery techniques. Such data contributes into reservoir simulation to obtain meaningful performance prediction. Therefore, typically, viscosity is measured through laboratory testing, if proper oil samples are available. In many circumstances, laboratory measurement is not possible either because of unavailability of liquid oil samples or budget constraints. Empirical correlations, in many instance, is the only available resort. Nevertheless, it is neither possible nor practical to assume that oil viscosity can be measured at all temperatures, pressures, and composition ranges with desired precisions. Hence, proper correlations to estimate viscosity behavior come to rescue.

Viscosity correlations of crude oils can be categorized to either dead oil or live oil viscosity correlations. Live oil viscosity correlations can be further classified to saturated (at bubble point pressure) or undersaturated (above bubble point pressure). The correlations at, above, and below bubble-point pressure were very strong function of dead oil viscosity. Generally the correlations for estimating the oil viscosity can be classified into two categories. The first type is those that use oil field data that usually are available, such as reservoir temperature, oil API gravity, solution gas/oil ratio, saturation pressure and pressure. While the second type is used some parameters other than those used in the first type; such as reservoir fluid composition, pour point temperature, molar mass, normal boiling point, critical temperature, and a centric factor of components, it is named as the empirical and/or semi- empirical correlations [7].

The purpose of this investigation is to test the performance of the dead (μ_{od}) oil viscosities using the most common published oil viscosity correlations for selected Libyan crude oils under reservoir condition and then compared with the experimental viscosities data collected from our labs. Statistical analysis is the criteria adopted for the evaluation in this study.

2. Experimental data

To test the proposed models, viscosity experimental data of six oil samples derived from Libyan oil reservoirs have been used. These data also includes, oil reservoir temperature, API gravity at reservoir temperature. Details of these data are listed in Table 1. Reservoir oil viscosities have been measured at various pressures above and below the bubble point pressure. A typical viscosity plot (Oil 4) as a function of pressure is shown in Figure 1. It can be seen from Figure 1 that, the oil viscosity decreases with pressure reduction in single phase (undersaturated condition). This reduction continues to bubble point. As the pressure decreased below the bubble point pressure causes gas release. Therefore the oil viscosity has been increased. It can be concluded that the minimum value of the viscosity is at bubble point pressure.

Table 1 Range of statistical experimental data of oil samples

Property	°API	T (°F)	SG_{gas}	μ_{od} (cp)
Range	36.51- 47.8	161-200	0.9808-1.5863	0.8617-1.94

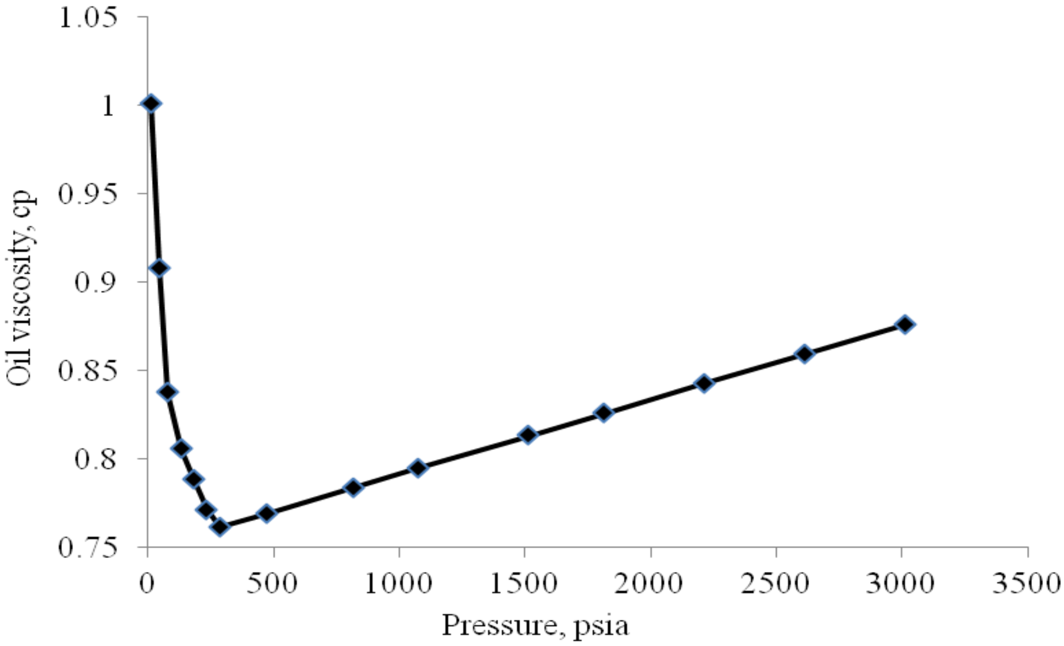

Figure 1 Oil viscosity as a function of pressure

3. Empirical correlations for crude oil viscosity

As shown in the literature that oil viscosity correlations all belong to three categories: dead oil, which are used to predict the crude oil viscosity at atmospheric pressure condition as a function of oil API gravity and reservoir temperature. Saturated oil viscosity correlations that used usually the dead oil viscosity and solution gas–oil ratio (R_s) at bubble point pressure to estimate the oil viscosity and undersaturated oil viscosity correlations where it is estimated based on the saturated oil viscosity and pressure above the bubble point pressure.

The most forms of the empirical correlations that were used for dead oil viscosity (stock tank) in petroleum engineering against the source of samples are summarized in Table 2. It includes the correlations and the source of data.

A brief survey can be presented herein. Beal [1] reported a correlation by applying 753 data points using a gravity and temperature covering a range of l00-220°F, Glasø [6] also developed a correlation using a temperature range of 50-300°F for 26 crude oil samples, Labedi [3] has published a correlation for light crude oil sampled from Libyan reservoirs, Petrosky & Farshad [4] developed their correlations for different types of crude oils, Elsharkawy and Alikhan [10] have also presented other empirical correlations for estimating dead oil viscosity of Middle East crude, Naseri *et al.* [7] have developed a correlation for prediction of Iranian dead oil viscosity, and recently M. Sattarin [8] has developed a correlation for prediction of some Iranian dead crude oil viscosity.

Any correlation for dead-oil viscosity usually introduces a larger error when applied to a different base of data. The difference in the results is related to the difference in the oil-base [3].

Table 2 Dead Oil Viscosity Correlations

Reference Correlation	Source of Samples
Beal [5] (1946)	USA
Beggs and Robinson [2] (1975)	Unknown
Glasø [6] (1980)	North Sea
Egbogah-Jacks [2] (without pour point) (1990)	
Labedi [3] (1992)	Africa
Kartoatmodjo and Schmidt [1] (1994)	Data Bank
Petrosky and Farshad [4] (1995)	Gulf of Mexico
Mahmood and AI-Marhoun, (1996)	Pakistan
Elsharkawy and Alikhan [1] (1999)	Middle East
Naseri et al. [7] (2005)	Iran
Sattarin et al. [8] (2007)	Iran
Omole et al. [9] (2009)	Nigeria
This work	Libya

3. Prediction of the dead oil viscosities

It can be noticed that all of these correlations have expressed dead oil viscosity (μ_{od}) as a function of both oil API gravity and reservoir temperature (Further details for the selected correlations can be seen in Appendix A). Several researchers reviewed and discussed most popular published correlations for estimating the viscosity of crude oils. (Elsharkawy and Alikhan, [10]; Naseri *et al.* [7]; Sattarin *et al*.[7]). Dead oil viscosities have been predicted using some of the correlations presented in Table 1 for six Libyan crude oils under reservoir condition. These are: Beal’s, Beggs-Robinson, Glaso’s, Egbogah-Jacks (without pour point), Labedi and Petrosky & Farshad correlations.

In order to analyze and evaluate the performance of the considered viscosity models, the % absolute deviation (AD) and percent absolute average deviation (% AAD) are used and defined as follows:

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

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

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 discussion

Oil viscosity should be determined by laboratory measurements at reservoir temperature and pressure. The viscosity is usually reported in standard PVT analyses. If such laboratory data are not available, engineers may refer to published correlations, which usually vary in complexity and accuracy depending upon the available data on the crude oil.

Here to test the performance of selected correlations to predict the viscosity of some Libyan crude oils, the collected experimental data was used. It should be noticed here that the same viscosity database was used to test all the correlations involved. The statistical accuracy of the investigated correlations is summarized in Figure 2. It can be seen that most of the points close to diagonal. Figure 3 shows the stark differences in the predictive capabilities of the models tested.

A comparison of the predictive equations using viscosity data is shown in Figure. 4. The AAD bars in this figure are placed in ascending order. It can be noticed that % AAD bar is placed in the above bars. From Figure 4 can be seen that, the values of the overall %AAD resulting from Beggs & Robinson [1], Egbogah-Jacks [2], Labide [3], Petrosky & Farshad [4], Beal's [5] and Glaso [6] models are 9.58, 11.22, 17.35, 17.86, 21 and 26.89 % respectively. According to that figure, the lowest % AADs of the prediction were obtained when the Beggs & Robinson model was used. The reasonable accuracy obtained in predicting the viscosity indicates that the Beggs & Robinson model has a good and reliable predictive model and it can be recommended when the viscosity cannot be measured for Libyan crude oil compared with the other models.

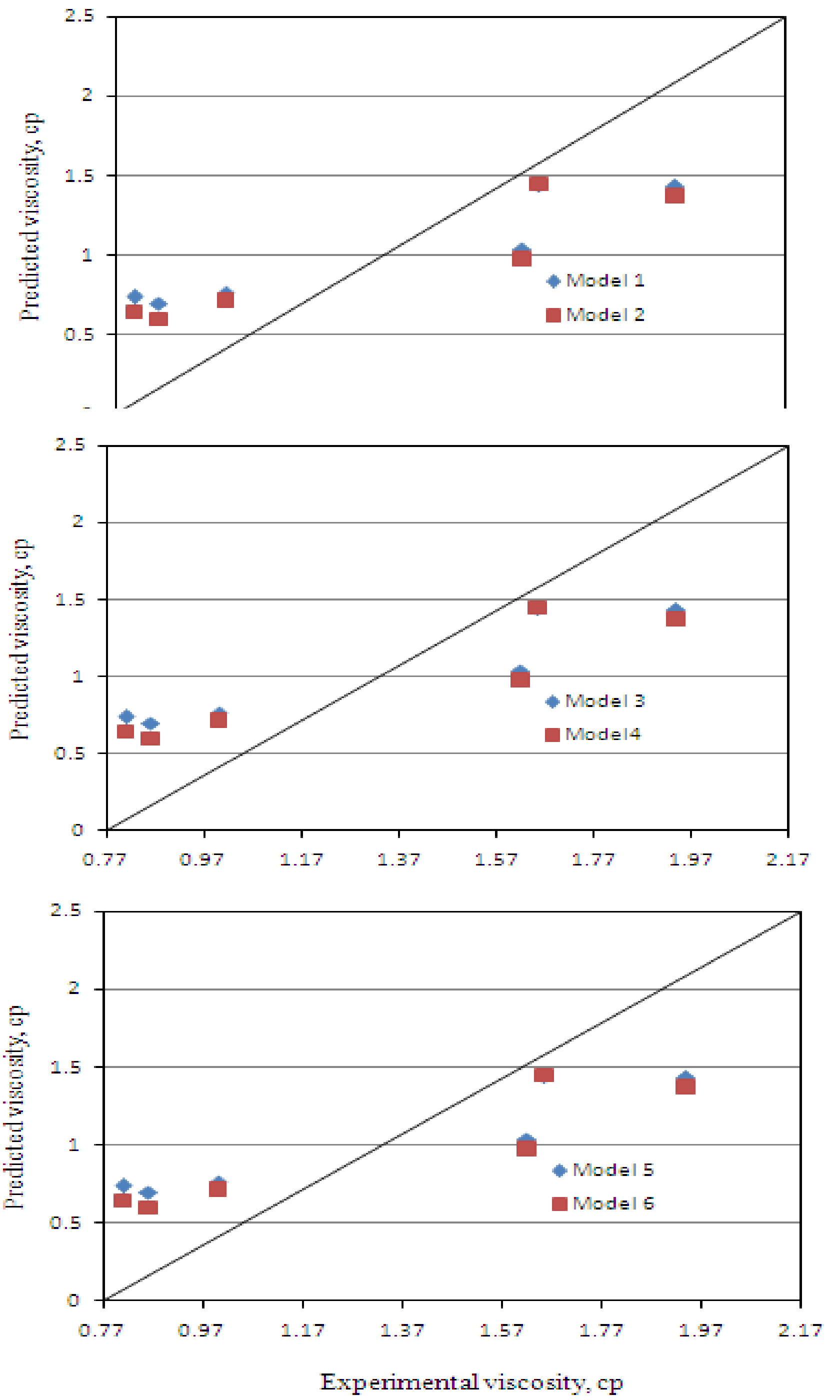

Figure 2 Statistical accuracy of the investigated dead oil viscosity correlations

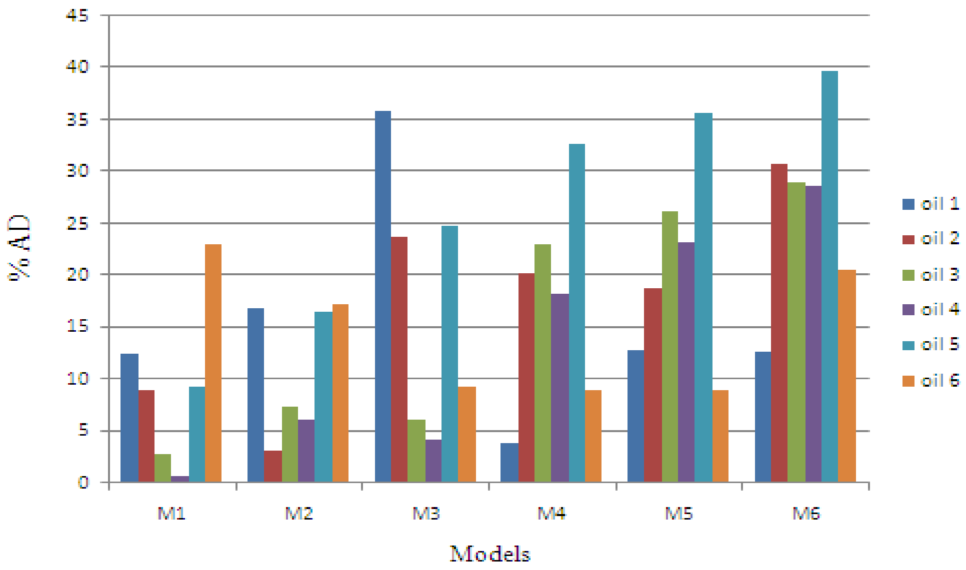

Figure 3 % AD of the different predictive models

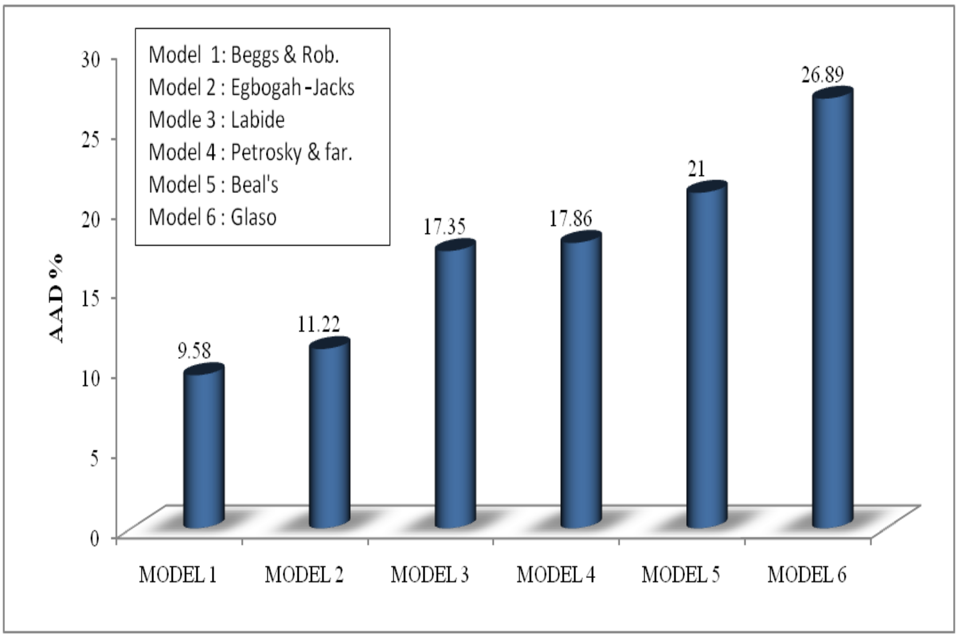

Figure 4 Summary of the results of testing the various viscosities models

4. Conclusion

Generally the most common method for calculating viscosity of crude oils is viscosity correlations. However these correlations fail to predict oil viscosities at wide range of operating conditions such as pressure and temperature. Testing the performance of some dead oil viscosity correlations has been considered. The results have been tested against the experimental viscosity data of the samples which were collected from our laboratory at reservoir condition.

Good agreements between the predicted and experimental values have been observed and it can be concluded from the observation results that, the best estimate of the dead oil viscosity (μ_{od}) for six Libyan crudes examined in this study was found to be by Beggs & Robinson with AAD % of 9.58.

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Appendix

The Beggs-Robinson Correlation

$$\mu_{od} = 10^{x} - 1$$

Where: $x = 10^{(3.0324 - 0.02023 \times API)} \times T^{-1.163}$; T= temperature of the fluid, F; API= oil gravity

Egbogah-Jacks(without pour point) correlation

$$\mu_{od} = 10^{10^{\left(-1.7095 + \left(\frac{389.45}{API^{\circ}+131.5}\right) + \left(-1.2943 + \left(\frac{135.585}{API^{\circ}+131.5}\right)\right)\right) * \log\left((T-32)*\frac{5}{9}\right)}} - 1$$

Where: T= temperature of the fluid, F; API= oil gravity

Labedi correlation

$$\mu_{od} = \frac{10^{9.224}}{API^{4.7013} * T^{0.6739}}$$

Where: T= temperature of the fluid, F; API= oil gravity

Petrosky and Farshad correlation

$$\mu_{od} = 2.3511 * 10^{7} * T^{-2.10255} * (\log API)^{(4.59388*(\log T) - 22.82792)}$$

Where: T= temperature of the fluid, F; API= oil gravity

Beal's Correlation

$$\mu_{od} = \left(0.32 + \frac{1.8(10^{7})}{API^{4.53}}\right)\left(\frac{360}{T + 200}\right)^{a}$$

Where: $a = \text{antilog}(0.43 + \frac{8.33}{{}^{\circ}API})$; T= temperature of the fluid, F; API= oil gravity

Glasø's Correlation

$$\mu_{ob} = (3.141 \times 10^{10}) \times T^{-3.444} (\log {}^{\circ}API)^{(10.313 \times (\log T) - 36.447)}$$

Where: T= temperature of the fluid, F; API= oil gravity

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