PVT correlation for Libyan Crude Oils

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Abstract

The aim of this study is developing a correlation for gas/oil ratio as function gas oil gravity, gas gravity, bubble point pressure, and reservoir bottom hole temperature which can applicable for Libyan crude oils. The PVT data were collected from different Libyan oil fields, and new correlation was based on 81 different crude oil fields. A multiple regression analysis technique was utilized for this study to create a reasonable model that could predicate the different fluid properties. A lot of sensitivity analyses were performed in order to check the parameters sensitivity to build a proper mathematical expression for PVT fluid properties. This study has produced a useful correlation which could be used for Libyan oil field. However, this correlation found to be the best for the Libyan oil compared with six other published correlations.

Keywords: PVT Correlations; Gas/oil ratio; Bubble point pressure; Gas gravity, Oil gravity; Libya.

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Introduction

The phase behavior of multi-component hydrocarbon systems in the liquid-vapor region is very similar to that of binary systems. However, as the system becomes more complex with a greater number of different components, the pressure and temperature ranges in which two phases exist increase significantly.

A PVT correlation is commonly used in the oil industry which is important tools in reservoir performance calculations. The most important factors of oil business activities, specifically in petroleum, production and exploration is characterization of hydrocarbon properties which are bubble point pressure, solution gas oil ration and formation volume, so in case of lack of those keys, the correlation can be utilized to estimate and predicted these physical properties through the conventional technique such as multiple regression analysis. The published correlations are available in the literature which have generated from different places of the world, different fluid properties and different collecting condition.

In 1947 Standing presented empirical PVT correlations for determining bubble point pressure and oil FVF at the bubble point pressure. Standing correlations were based on laboratory flash vaporization data 22 different crude from California oil fields. These correlations were developed as a function of total gas/oil rates, dissolved gas gravity and reservoir temperature from which the bubble point pressure, bubble point oil formation volume factor, and total oil formation volume factor could be predicted. The data used in Standing's correlation were obtained as a result of a two stage flash separation at 100°F. The first stage is within the range of 250 to 450 psia, and second stage is atmospheric. In the gas/oil ratio correlation, the basic assumption employed was

$$R_S = (P_b, \gamma_g, \gamma_o, T) R_S = (P_b, \gamma_g, \gamma_o, T) \tag{1}$$

The correlation was based on 105 experimentally determined solution gas/oil ratios of California oils and gases. The gases present in the mixtures were free of N_2 and H_2S, but CO_2 was present in a few samples at concentration less than one mole%. Standing (1981) for his graphical correlation was proposed the following mathematical expression

$$R_S = \gamma_g \left[\left(\frac{P}{18.2} + 1.4 \right) 10^{0.0125API - 0.00091(T-460)} + 1.4 \right]^{1.2048}$$

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In 1980, Vazquez and Beggs published correlation for bubble point pressure that was based on 6000 data points from 600 laboratory measurements. The oil mixtures are classified into categories, above 30° API gravity and below 30° API gravity. The gas gravity is strong dependence and developed a correlation to normalize the gas gravity measurement to a reference separation pressure of100 psi. This eliminated its dependence on separation conditions.

$$R_S = C_1 \gamma_g P^{C_2} EXP\left[C_3 \left(\frac{API}{T} \right) \right] R_S = C_1 \gamma_g P^{C_2} EXP\left[C_3 \left(\frac{API}{T} \right) \right] \quad (3)$$

Values for the coefficients are as follows

Coefficient	$API \leq 30$	$API > 30$
C_1	0.0362	0.0178
C_2	1.0937	1.1870
C_3	25.7240	23.931

In 1980, Glaso presented PVT correlations for the North Sea oils based on Standings work for calculating the bubble point pressure, bubble point oil FVF, and total FVF. The input parameters for this correlation are total GOR, RS, average specific gravity of total surface gases from flash separation, $\gamma_g \gamma_g$ stock tank oil API gravity, $\gamma_o \gamma_o$ and reservoir temperature, T the same as Standing's independent variables except here Glaso don's specified the gas gravity used. A correlation for paraffinicity has been developed to convert the flashed stock oil API gravity to an equivalent value. The development of this correlations were used 45 oil samples, most of which came from the North Sea region.

$$R_S = \gamma_g \left[\left(\frac{API^{0.989}}{(T+460)^{0.172}} \right) (P_b^*) \right]^{1.2255}$$

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Where $P_b^* P_b^*$ is correlation number and is defined by the following expression:

$$P_b^* = 10^{\left[2.8869-(14.1811-.309LOG(p))^{0.5}\right]}$$

$$P_b^* = 10^{\left[2.8869-(14.1811-.309LOG(p))^{0.5}\right]} \quad (5)$$

In 1988, Al-Marhoun developed a correlation based on Standing work for bubble point pressure oil FVF at bubble point pressure and total formation volume factor he used 160 data point from 69 bottom hole samples collected from the middle east oil reservoirs the following empirical equation was developed as function of solution gas oil ratio, average gas relative density oil stock tank relative density and reservoir temperature.

$$R_S = \left[185.843208\, P_b \;\; \gamma_g^{1.87784}\; \gamma_o^{-3.1437}\; T^{-1.32657}\right]^{1.398441}$$

$$R_S = \left[185.843208\, P_b \;\; \gamma_g^{1.87784}\; \gamma_o^{-3.1437}\; T^{-1.32657}\right]^{1.398441} \quad (6)$$

In 2007, Mazandarani and Asghari developed empirical PVT correlations based on Al-Marhoun's correlations for estimating the solution gas/oil ratio, bubble point pressure and bubble point oil formation volume factor of Iran crude oils. The evaluation is performed by using data set of 55 bottom hole fluid samples collected from different locations in Iran.

$$R_S = 994.3718\, P_b^{1.45558}\; \gamma_g^{2.113367}\; \gamma_o^{-5.48944}\; (T+460)^{-1.90488}$$

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In 2015 Emara developed correlation by utilized a total of 178 data points. The data were collected from different fields in Egypt and covered of oils ranging from heavy to volatile oils.

$$R_S = \gamma_g \;\left[\left(\frac{P_b}{55.67} + 7.957\right) 10^{-x}\right]^{1/0.637}$$

$$R_S = \gamma_g \;\left[\left(\frac{P_b}{55.67} + 7.957\right) 10^{-x}\right]^{1/0.637} \quad (8)$$

Where

$x = 0.00045T - 0.0088API x = 0.00045T - 0.0088API$ (9)

Data Description

The PVT analyses of 81 bottom hole fluid samples from 81 Libyan oil reservoirs were made available for this study. Data used for this work consist of reservoir bubble point pressure, temperature, oil gravity, gas gravity and solution gas oil ratio. The data covered a wide range of crude oils ranging from heavy to volatile oils as shown in Table (1).

Table (1) data description of Libyan crude oils

PVT property	Minimum	Maximum
$R_S R_S$, SCF/STB	8	2536
$P_b P_b$, psi	55	6344
Oil API gravity	27.7	93.5
Gas gravity	0.682	1.925
Reservoir Temperature, °F	117	305

Libyan Correlation Development

The new correlation for Libyan crude oils was developed based on Standing's correlation. This correlation was obtained by the linear and nonlinear multiple regression analysis using Excel software.

The following general relation of gas/oil ratio was proposed:

$$R_S = (P_b, \gamma_g, \gamma_o, T) R_S = (P_b, \gamma_g, \gamma_o, T) \quad (10)$$

In this correlation, the gas oil ratio is predicted as a direct function of bubble point pressure, specific oil and gas gravity, and temperature as shown

$$R_S = 1197.49\, P_b^{1.777}\ \gamma_g^{0.0386}\ \gamma_o^{-0.23942}\ T^{-2.6507}$$

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Statistical Error Analysis

There are two main statistical parameters that are begun considered in this study by Chapra, (2010). These parameters help to estimate the accuracy of the gas oil ratio correlations used in this study.

Average Percent Error (AE)

This is an indication of relative deviation in percent from the measured values and given as:

$$E_r = \left(\frac{1}{n_d}\right)\sum_{i=1}^{n_d} E_i$$

$E_i E_i$ is the relative deviation in of an estimated value from an measured value and is defined by:

$$E_i = \left(\frac{x_{est} - x_{mea}}{x_{mea}}\right)_i \times 100 E_i = \left(\frac{x_{est} - x_{mea}}{x_{mea}}\right)_i \times 100, \quad i = 1, 2, \ldots\ldots n_d$$

Where x_{est} and x_{mea} represent the estimated and measured values, respectively. The lower the value of E_r, the more equally distributed is the errors between positive and negative values.

Average Absolute Percent Relative Error (AAE)

This parameter is to measure the average value of the absolute relative deviation of the measured value from the percent. The parameter can be defined as:

$$E_a = \left(\frac{1}{n_d}\right)\sum_{i=1}^{n_d} |E_i|$$

This parameter indicates the relative absolute deviation in percent from the measured values. A lower value of AAE implies better agreement between the estimated and measured values.

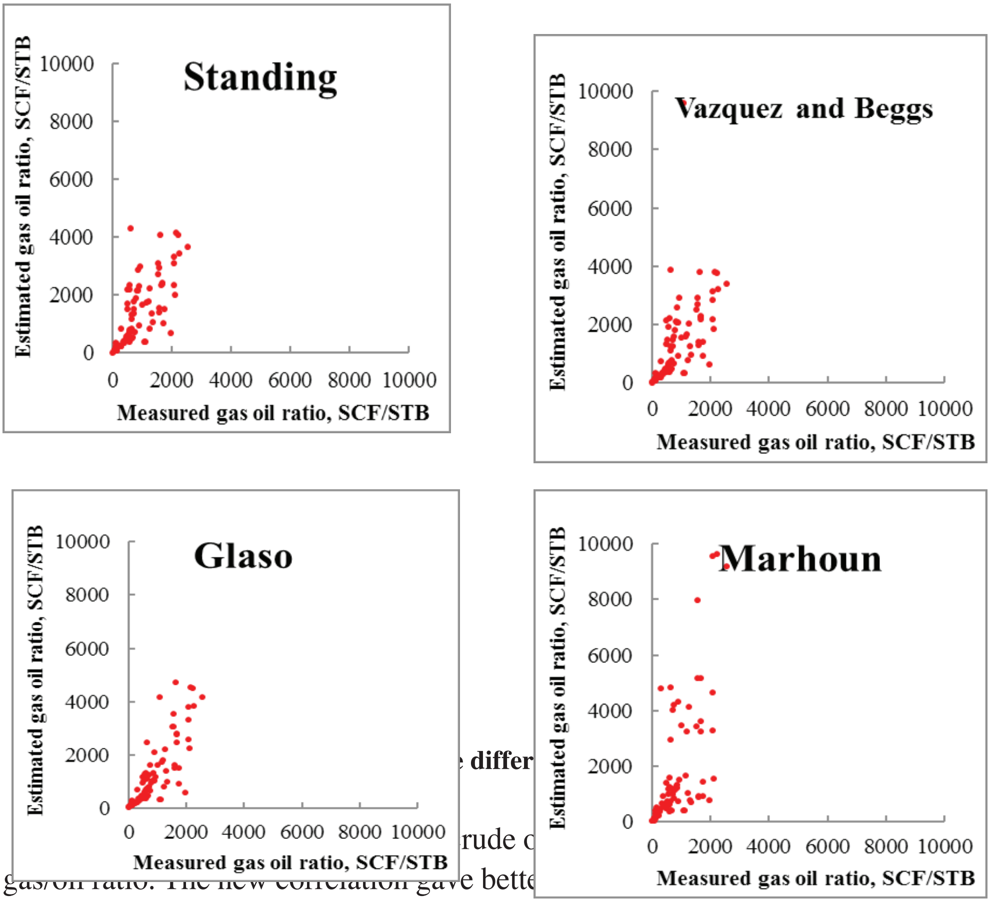
Results and Discussion

In Table (2) as shown the average percent relative error and average absolute percent error were predicted for each correlation. It can be seen from this Table, the results of statistical error analysis of the developed gas/oil ratio correlation in this study and other correlations. The values of average percent relative error (AE %) and absolute average percent relative error (AAE %) of this study correlation obtained lower than other correlations. The correlation shows that a good agreement between measurement and estimated gas/oil ratio. The gas/oil ratio for Libyan crude oils better predicts than any other correlations.

Table (2) Statistical Error Analysis

Gas/Oil Ratio correlations	AE%	AAE%
Standing	74	87
Vazquez and Beggs	57	76
Glaso	-14	47
Al-Morhoun	146	161
Mazandarani and Asghari	121	139
Emara	173	177
Libyan	2.5	12

The cross plot of the measured against the calculated gas/oil ratio using the Libyan new correlation and other correlations used in this study as shown in Figure (1). It can see that this correlation predicts better gas/oil ration crude oils than any other correlations.



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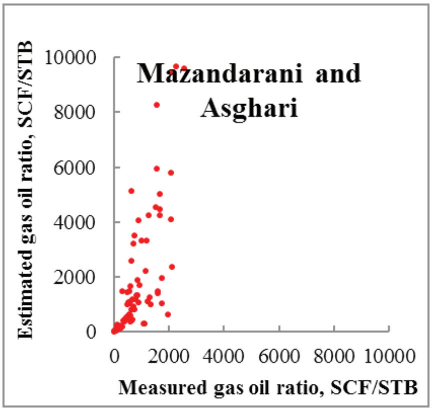

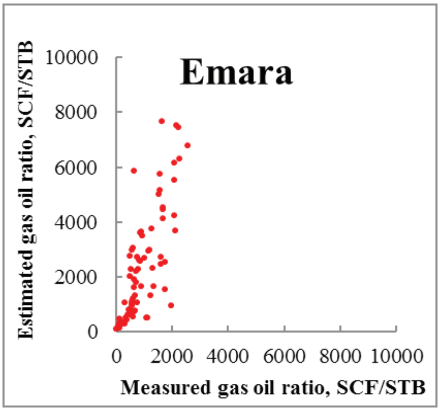

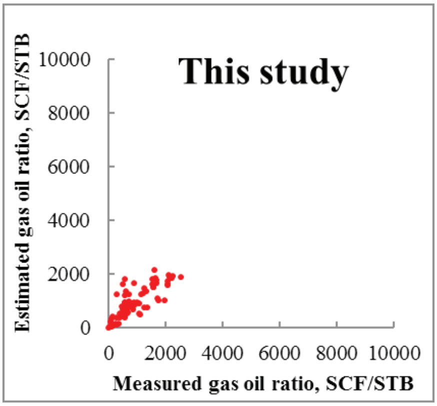

of Libyan crudes as compared with other correlations available in the literature.

Nomenclature

API	Oil API gravity
P_b	Bubble point pressure, psi
PVT	Pressure. Volume, Temperature.
R_s	Gas/Oil ratio, SCF/STB
SCF	Standard cubic feet.
STB	Stock tank barrels.
T	Temperature, °F
γ_g	Gas gravity, (air = 1)
γ_o	Oil gravity, (water = 1)

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