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NEW CORRELATION FOR OIL FORMATION VOLUME FACTOR AT AND BELOW BUBBLE POINT PRESSURE

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ABSTRACT

The best source of oil properties data is the laboratory PVT analysis of a reservoir fluid sample. However, in the absence of experimentally measured properties of reservoir fluids, these physical properties must be estimated from correlations.

This paper employs more than thirty PVT reports that have been taken from different Iraqi fields. These reports contain about four hundred experimental points.

The paper suggests new correlation to calculate oil formation volume factor at and below bubble point pressure. All of the previous correlations did not take the pressure as a factor or independent variable because they calculate the oil formation volume factor at bubble point pressure only. The new correlation introduce the pressure while omit the solution gas-oil ratio which has been employed in all previous correlations.

The accuracy of the proposed correlation of the experimental data is assessed through various statistical tests and comparing them with those achieved for some published correlations. These tests show that the new correlation has the best fitting with the experimental data for Iraqi oils. Cross plot technique is also applied to check the performance of the correlation and it gave the same index of the statistical criteria method.

The new correlation reported absolute average error of 1.876%, sum of squared residuals of 0.395327, variance of 0.0093 and standard deviation error of 0.096337288.

KEY WORDS

Formation volume factor, bubble point, correlation, Iraqi oils, Experimental data.

INTRODUCTION

The oil formation volume factor, Bo, is defined as the ratio of the volume of oil (plus the gas in solution) at the prevailing reservoir temperature and pressure to the volume of oil at standard conditions. Evidently, Bo always is greater than or equal to unity. (Ahmad 2007)

Many correlations for estimating oil formation volume factor have been published in the past seven decades. Most of these correlations yield reasonably accurate results when applied at the bubble-point pressure. But, for pressures below the bubble point, the calculated oil formation volume factor may yield considerable error.

Most of the published empirical Bo correlations employ the following generalized relationship:

$$B_o = f\left(R_s, \gamma_o, \gamma_g, T\right)$$

Some of the empirical correlations for predicting oil volume factor are presented in this paper:

Standing (1947) constructed correlation for calculating oil formation volume factor of oils using field data of reservoir temperature, solution gas oil ratio at bubble point and oil and gas gravities. Standing used more than one hundred experimental data points.

Vasquez and Beggs (1976) developed empirical correlation by using approximately six thousand data points- measured over wide ranges of pressure, temperature, specific gravity of oil and specific gravity of gas. They found that the specific gravity of gas was a strong correlating factor and, unfortunately, this is often one of the variables measured with the least degree of consistency. The specific gravity of gas depends on the pressure and temperature of the separators, which may not be available.

Glaso (1980) suggested a new approach that based on the concept that the paraffinicity of the oil influences the gas / liquid equilibrium of black oil mixtures containing methane. Glaso used the regression analysis to develop his correlation.

Al-Marhoun (1985) developed correlation for calculating oil formation volume factor for Middle East crude oils at the bubble point pressure. This correlation was developed from database of more than seventy bottom hole fluid samples and expressed as functions of reservoir temperature, gas gravity, solution gas – oil ratio at bubble point and stock tank oil gravity. Al-Marhoun employed nonlinear regression method to build the correlation.

Petrosky (1990) developed empirical correlation for Gulf of Mexico crude oils. His relationship correlated the oil formation volume factor versus solution gas-oil ratio at bubble point, specific gravity of gas, specific gravity of oil and reservoir temperature.

Omar and Todd (1993) suggested a correlation for calculating oil formation volume factor at bubble point using data from Malaysian offshore oil fields at South China Sea. They used linear and nonlinear regressions.

NEW OIL FORMATION VOLUME FACTOR CORRELATION

The correlation is developed through some sequential steps which can be summarized as follows:

- Detection of the objective of the study which is suggestion of new correlation to calculate oil formation volume factor at and below bubble point pressure.
- Identification of the important factors that affect the value of oil formation volume factor. The paper proposed that these factors are pressure, reservoir temperature, stock tank oil gravity and specific gravity of gas.
- Presentation of a statistical model to correlate the objective function (oil formation volume factor) versus the factors that illustrated in Step.2.
- Collecting the required experimental data for Iraqi oils to employ them in the correlating process.
- Refining the collected experimental data.
- Suggestion of many mathematical forms of the correlation to choose the best.

These steps lead to the suitable correlation. Nonlinear multiple regression has been done to form the new correlation.

The following form is selected to represent the new oil formation volume factor

$$B_o = a_1 P^{a_2} T^{a_3} API^{a_4} \gamma_g{}^{a_5} + a_6 \quad (1)$$

Table (1) lists the values of the coefficients of equation (1)

Table (1)

Coefficient	The Value
a_1	0.000005
a_2	0.639887
a_3	0.604183
a_4	0.961566
a_5	1.041364
a_6	1.079483

This form has been chosen according to its statistical indices and the difference between its results and the measured data.

CHECKING THE VALIDITY OF THE NEW CORRELATION

Two checking methods were attained to evaluate the performance of the new correlation which are statistical criteria and cross plot:

- DATA BASE

In this section, all of experimental data that were employed to develop the new correlation was used for checking the validity of the correlation

A-STATISTICAL CRITERIA

Table (2) shows comparison between the statistical criteria for the new correlation and the published ones.

The indices explain that the new correlation is the best among them to correlate Iraqi oils.

Table (2) The Statistical Criteria

The Correlation	Average Absolute Error %	Sum of Squared Residuals	Variance	Standard Deviation Error
New	1.876	0.395	0.0093	0.096
Standing	2.881	0.788	0.0104	0.102
Vasquez and Beggs	8.179	4.833	0.0158	0.126
Glaso	5.125	2.011	0.0125	0.112
Al-Marhoun	4.439	1.688	0.0096	0.098
Petrosky	4.134	1.292	0.0115	0.107

B- CROSS PLOT METHOD

In this technique, the estimated oil formation volume factors are plotted versus the experimental values to create the cross plots . A 45^{o} straight line is drawn on the cross plot which passes through the points of coincidence of experimental and calculated values. The closer the plotted data points are to this line, the better the correlation.

Figures (1) through (6) show that the current correlation is the best among the others used. Vasquez and Beggs correlation is the worst fitting correlation to the experimental data.

Therefore the new correlation gives improvement in the estimation of oil formation volume factor at and below bubble point pressure for Iraqi oils.

- EXTERNAL IRAQI OIL SAMPLE

In this section, external oil sample (sample which was not used to generate the correlation) used to evaluate the new correlation.

Table (3) includes the statistical criteria of the correlations with this sample. These criteria show the superiority of the new correlation for Iraqi oils and the others .

Table (3) The Statistical Criteria

The Correlation	Average Absolute Error %	Sum of Squared Residuals	Variance	Standard Deviation Error
New	2.116	0.013	0.016	0.128
Standing	3.545	0.029	0.019	0.138
Vasquez and Beggs	10.574	0.234	0.025	0.157
Glaso	6.123	0.081	0.019	0.137
Al-Marhoun	5.236	0.064	0.018	0.135
Petrosky	4.355	0.038	0.017	0.132

CONCLUSIONS

A new correlation presented in this work for oil formation volume factor at and below bubble point is proper for application in petroleum engineering, specially for Iraqi oils.

It is new approach that the pressure is introduced in development of the correlation for calculating oil formation volume factor at and below bubble point.

The new correlation has been done by nonlinear regression technique to correlate oil formation volume factor with four input variables which are pressure, reservoir temperature, oil gravity, and specific gravity of gas.

NOMENCLATURE

API : API gravity
B_o : Oil formation volume factor, bbl/STB
P : Pressure, psig
R_s : Solution gas-oil ratio, scf/STB
T : Reservoir Temperature, ^oF
γ_g : Specific gravity of gas
γ_o : Specific gravity of oil

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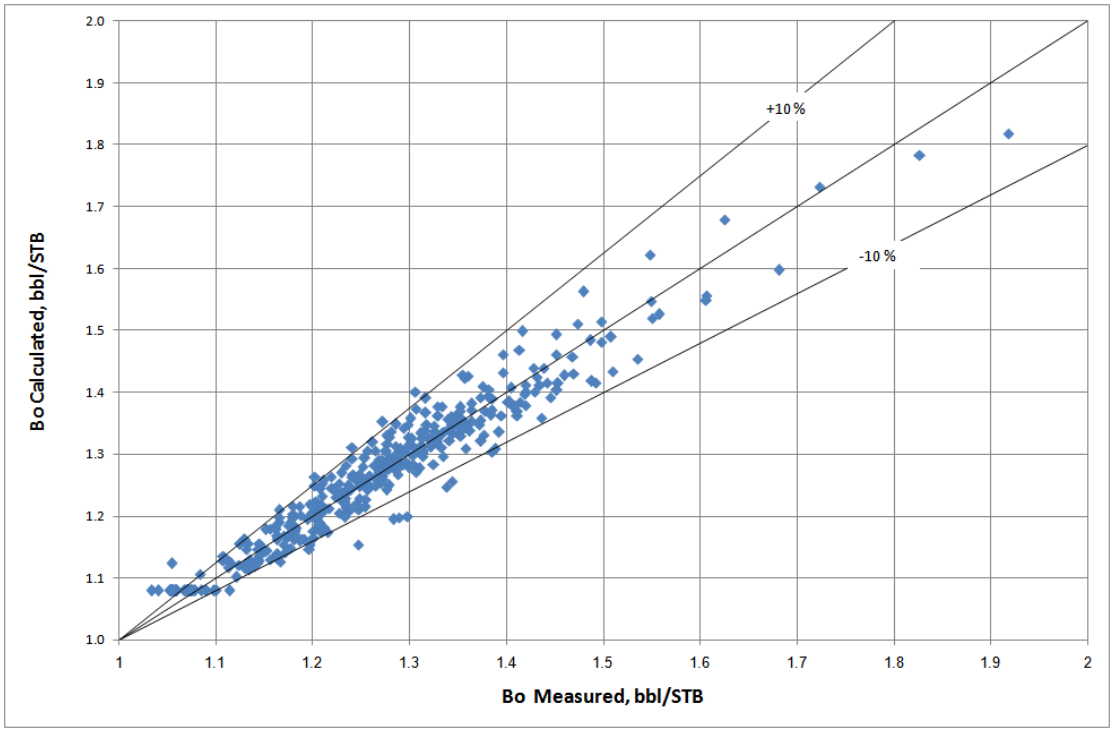

Figure (1) Cross Plot of the oil formation volume factor (Experimental data versus the values from new correlation)

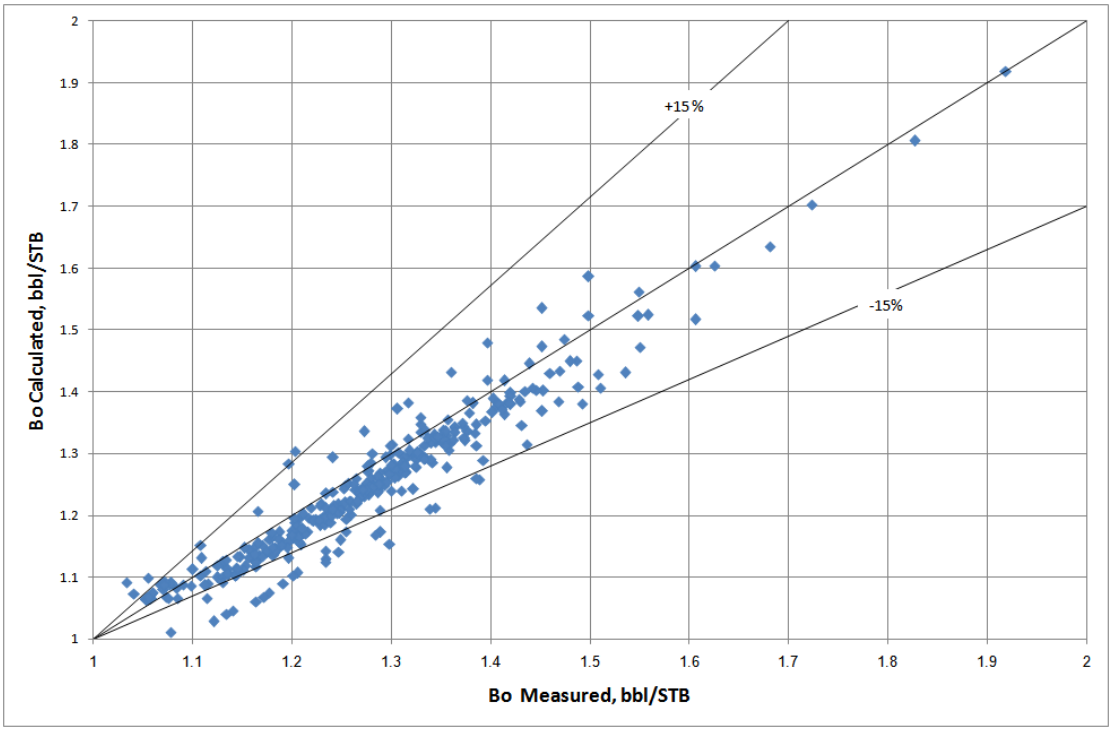

Figure (2) Cross Plot of the oil formation volume factor (Experimental data versus the values from Standing correlation)

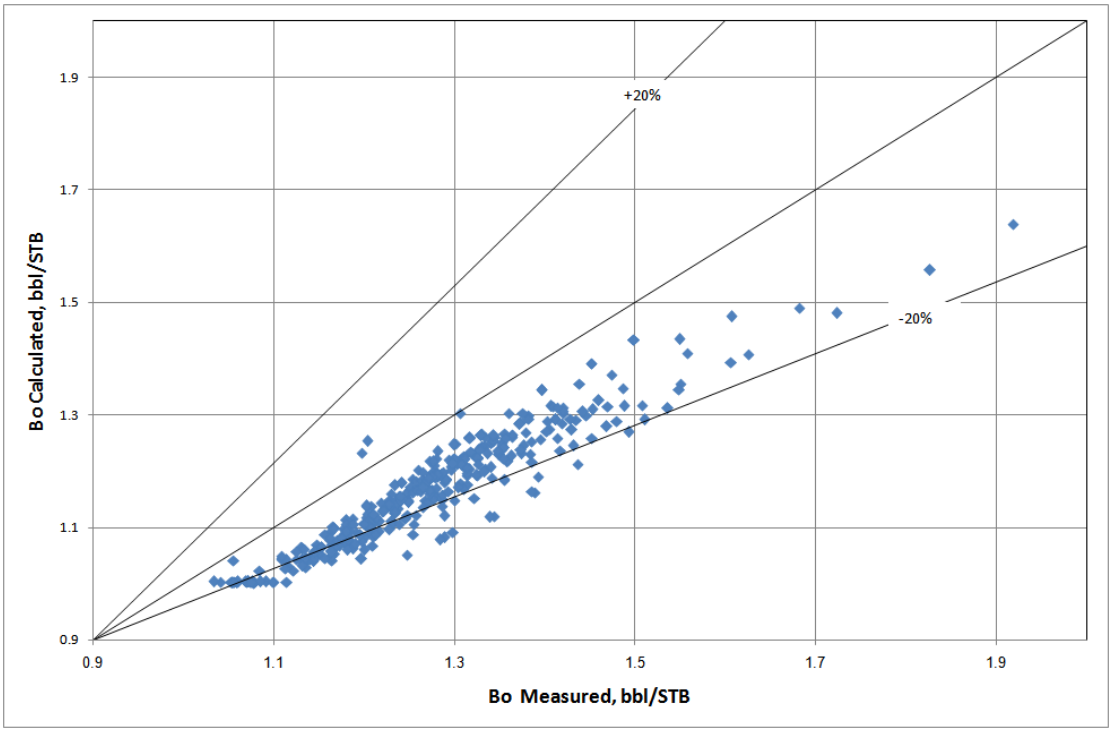

Figure (3) Cross Plot of the oil formation volume factor (Experimental data versus the values from Vasquez and Beggs correlation)

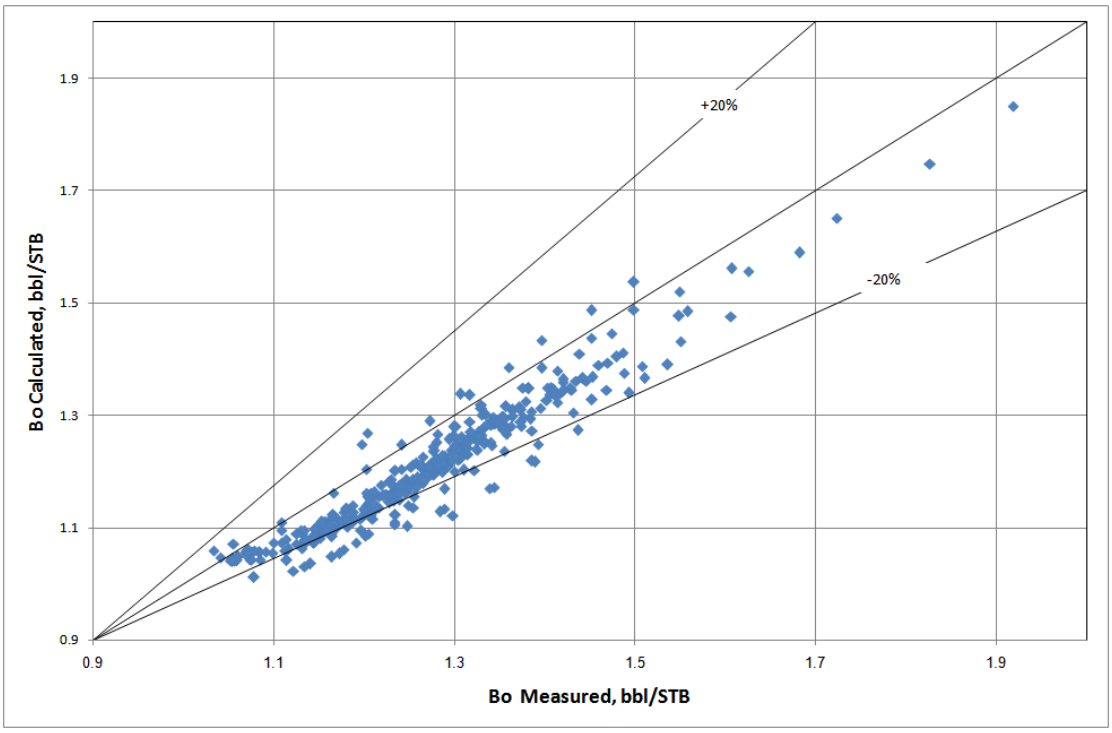

Figure (4) Cross Plot of the oil formation volume factor (Experimental data versus the values from Glaso correlation)

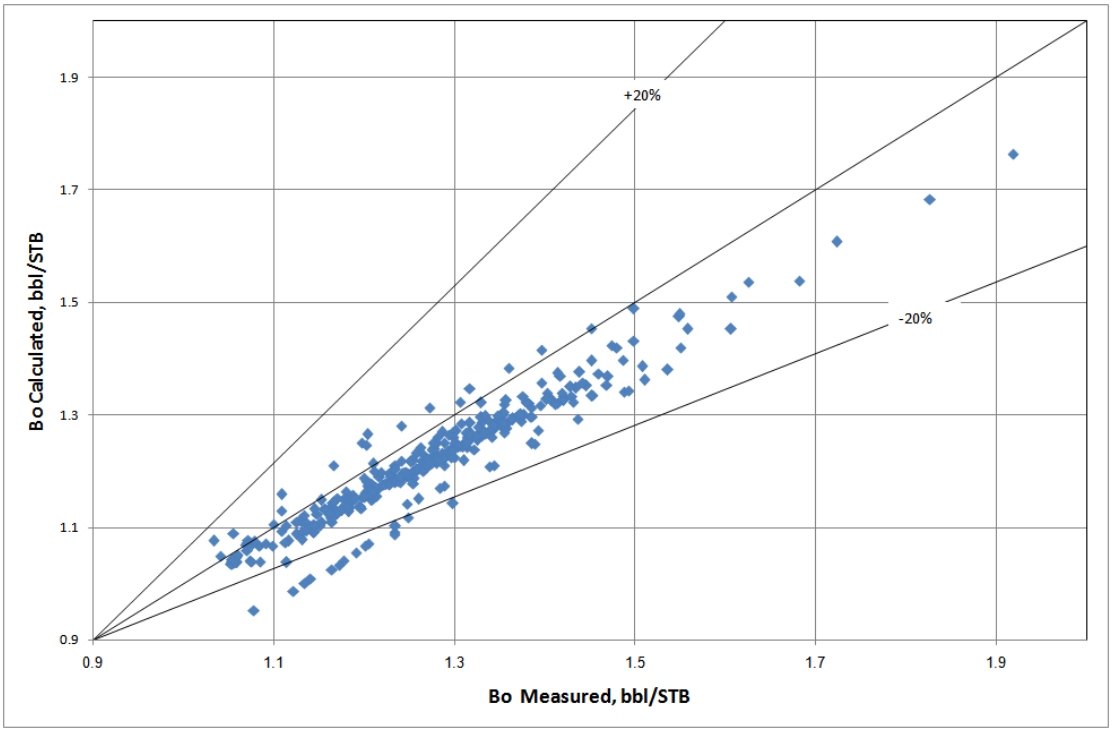

Figure (5) Cross Plot of the oil formation volume factor (Experimental data versus the values from Al-Marhoun correlation)

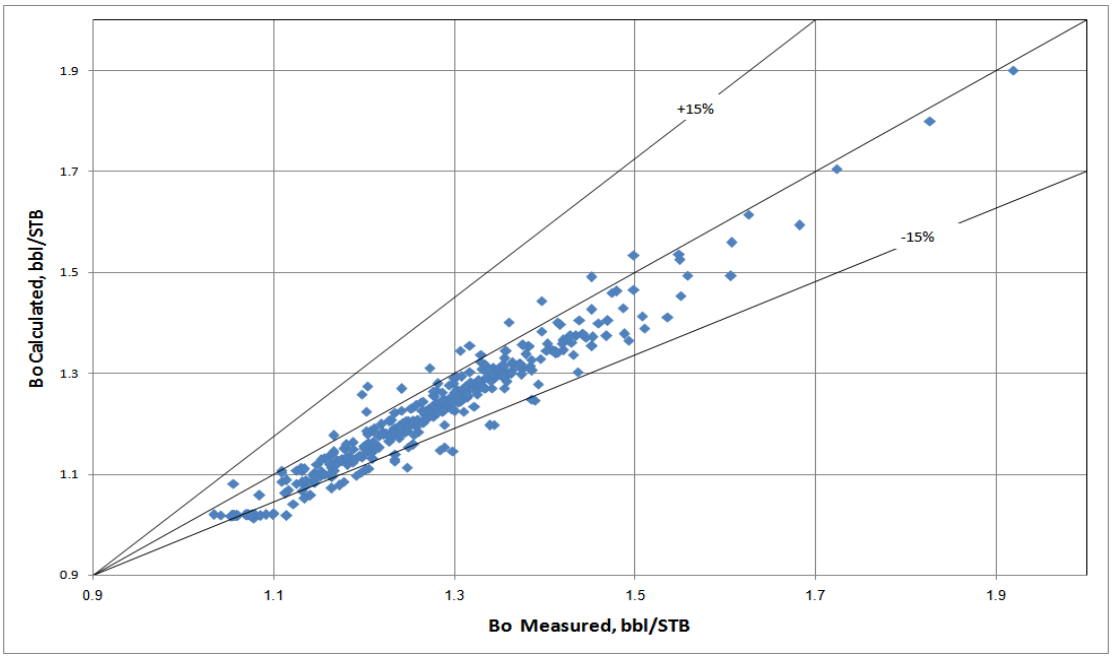

Figure (6) Cross Plot of the oil formation volume factor (Experimental data versus the values from Petrosky correlation)