Evaluation of Three Different Bubble Point Pressure Correlations on Some Libyan Crude Oils

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Abstract:

Bubble point pressure is considered as one of the most important PVT properties in petroleum engineering especially in reservoir and production engineering calculation. A numerous empirical derived correlations for estimating the bubble point in the absence of the experimental measured one are proposed in the literature.

Three different empirical correlations to estimate the of bubble point pressure to evaluate were selected in this study. Those correlations namely are Standing's correlation, Labedi's correlation and Al-Shammsi's correlation.

This study is to make a comparison between these three derived correlations and to evaluate their applicability for some crude oils collected their data from some Libyan oilfields.

Forty six well from seventeen Libyan oilfields were selected to perform this study. The results show that Standing's correlation gave the lowest value of both the Average Absolute Relative Error (AARE) and standard division (STDEV) of **7.54%** and **6.91%** respectively with the highest Coefficient R^2 of **0.989**.

1. Introduction:

The reservoir fluid study involves series of laboratory designed works to provide values of the physical properties of the crude oil and the produced gas, these physical properties called PVT which is an abbreviation of pressure-volume-temperature. These PVT properties for the real gases and the crude oils, which are very important and required in the reservoir and production engineering calculations, are: fluid gravity, specific gravity, oil density, gas solubility, bubble-point pressure, oil formation volume factor, and isothermal compressibility coefficient of under saturated crude oil, under saturated oil properties, total formation volume factor, crude oil viscosity, surface tension [1-2]. The PVT fluid properties usually measured experimentally in the laboratory.

1.1 Bubble Point Pressure (P_b):

This important property can be measured experimentally for any crude oil system by conducting a constant-composition expansion test. In the absence of the experimentally measured bubble-point pressure, it is necessary for the engineer to make an estimation of this crude oil property from the readily available measured producing parameters. During the last four decades various graphical and mathematical correlations have been presented for predicting (P_b).Based on the assumption that the bubble-point pressure is a strong function of gas solubility (R_s), gas gravity (γ_g), oil gravity (API) and temperature (T) [2] with other words:

$$P_b = f(Rs, API, \gamma_g, T)$$

1.1.1 Standing's Correlation (1947):

Standing (1981) expressed his graphical correlation in a mathematical form by the following expression [2]:

$$P_b = \left(18.2 \left(\frac{Rs}{\gamma_g}\right)^{0.83} 10^{(0.00091(T-460)-0.125API)} - 1.4\right) \quad eq.1$$

Where:-

R_s = gas solubility, Scf/STB P_b= bubble-point pressure, Psia

T = system temperature, °F

In the presence of non-hydrocarbon components standing's correlation should be used with caution. This correlation covered the following ranges**:**

$130 < P_b < 7000$ Psia $20 < R_s < 1425$ Scf/STB $100 < T < 258$ °F

$16.5 < API < 63.8$ °API $0.59 < \gamma g < 0.95$ (air=1)

1.1.2 Labedi Correlation (1990):

Labedi (1990) collected laboratory measurement samples from 3 major oil producers in Africa, namely Libya (97sample), Nigeria (27sample) and Angola (4 sample) he developed correlation to estimate the bubble-point pressure as a function of solution gas/ oil ratio, stock-tank oil gravity, the gas gravity, and reservoir temperature [4].

$$P_b = 21.38\left[\left(\frac{Rs}{\gamma_g}\right)^{0.83} 10^{(0.00091\,T - 0.0125API)}\right]^{0.9653} \qquad eq.2$$

Where:

R_s = gas solubility, Scf/STB P_b = bubble-point pressure, Psia

T = system temperature, °F   API= oil gravity

γ_g= gas gravity

The correlation was computed over the following ranges:

121 < Pb < 6557 Psia   13 < Rs < 3366 Scf/STB   100 < T < 306 °F

0.579 < γg < 1.251 (air=1)   22.9 < API < 52.0 °API .

1.1.3 Al-Shammasi Correlation:

Al-Shammasi (1999) developed a numerical correlation from published global data bank 1243 measurements published in the literature [4].

$$P_b = \gamma_o^{5.527215}\left(Exp\left(-1.841408(\gamma_g\gamma_o)\right)\right)\left(Rs(T+460)\gamma_g\right)^{0.783716} \qquad eq.3$$

Where:-

R_s = gas solubility, Scf/STB P_b = bubble-point pressure, Psia

T = system temperature, °R γ_g= gas gravity

γ_o= oil gravity

The data range used to develop this correlation as the following:

31.7 < Pb < 7127.0 Psia   6 < Rs < 3298.6 Scf/STB   74 < T < 341.6 °F

6 < API < 63.7 °API   0.51< γg < 3.44 (air=1).

1.2 Objectives of This Study:

Several Correlations presented in the literature to estimate the bubble point pressure (P_b). Most of those Correlations for estimating the bubble point pressure (P_b) required the oil gravity (API), gas specific gravity (γ_g), gas solubility (R_s) and Temperature (T).

In this study, we evaluated the applicability of Standing's Correlation (1942), Labedi's Correlation (1990), and Al-Shammasi's Correlation (1999), for estimating bubble point pressure, for some Libyan crude oils to visualize their applicability for the oilfields studied.

2. Literature Review:

In 2012 Raffie Hosein, and Tricia Singh, performed a comparative study included Standing, Vasquez correlation and Beggs, Glaso correlation, Al-Marhoun, Petrosky-Farshad correlation and Velard Correlation. They used data were collected from twelve laboratory PVT reports that were available for their study, the range of their used data was as (2100 <Pb<5600 Psia), (140<T <216 °F), (288<Rs<1261Scf/STB), (17.6<API<34.4 °API), and (0.621<γg<0.834 (air = 1)). By the end of their study they concluded that the minimum average absolute deviation (AAD) was 4.2% by Velard Correlations, and the maximum (AAD) was 18.8% by Glaso correlation for bubble point pressure [5].

In 2012 Ahmed Al-Zahaby, Ahmed El-banbi, and Mohammed H.sagyouh used 35 bottom hole fluid samples from different locations in Egypt. They developed guide lines on which correlations to use for each PVT property for the reservoir input data for black oils. The targeted correlations used in their study were Vasquez and Beggs correlation, Al-Marhoun correlation, Petrosky and Farshad correlation, laster correlation, Standing and et al correlation. The data range used in the study can be describe as ($1.049 < B_o < 4.47$ bbl/STB), ($49 < P_b < 4739$ Psia), ($40 < T < 270.9$ °F), ($8 < R_s < 7803$ Scf/STB), ($17.2 < API < 51.2$ °API), and ($0.627 < \gamma_g < 1.93$ (air = 1)). They concluded that the lasater correlation has given the best result for bubble point pressure calculations with an average error of 7.9% [6].

In, 2007, M.N. Hemmati and R, Kharrat studied both of bobble point pressure and gas solubility using Standing correlation, Glaso correlation, Al-Marhoun correlation, Hanafy correlation, Dindoruk correlation, Dokla correlation, and Petrosky correlation for 287 laboratory PVT analyses from 30 Iranian oilfields to develop the correlation within the range of data of ($348<P_b< 5156$ Psia), ($77.5< T <290$ °F), ($125<R_s<2189.25$Scf/STB), ($18.8< API <48.34$ °API), and ($0.523<\gamma_g<1.0415$ (air = 1))selected from naturally produced black oil crudes and the complete PVT reports were available which are necessary for the evaluation and development of the black oil correlations. The results of the bubble point pressure property give the minimum ARE of 7.51% for the Dokla correlation and the minimum STDEV of 10.57% for Al-Marhoun and the maximum ARE of 8.00% for Al-Marhoun and the maximum STDEV of 44.65% by Dindoruk correlation. For the gas solubility results show the minimum ARE of 7.53% for Dindoruk and the minimum STDEV of 11.01% for Standing and the maximum ARE of 13.43 % for Al-Marhoun and the maximum STDEV of 24.21% for Dindoruk correlation [7].

1996 Mohammed Aamir Mahmood, and Muhammad Ali Al-Marhoun, Presented paper to evaluate the bubble point pressure property by using the Standing (1947), Vazquez & Beggs (1980), Glaso (1980), Al-Marhoun (1988) and Al-Marhoun (1992) correlations**.** This evaluation study collected 22 bottom hole fluid samples consists of 166 data points from different Pakistan oilfields for evaluating bubble point pressure correlations. The range of data used in this study described as ($79 < P_b <$ 4975 Psia), (182< T <296 °F), ($92 < R_s < 2496.25$Scf/STB), (29.0< API <56.5 °API), and ($0.825 < \gamma_g < 3.445$ (air = 1)). They concluded that the minimum ARE was 31.50% with STDEV of 20.24%for the Al- Marhoun (1988) correlation and the maximum ARE was 55.31% with STDEV of 70.30% for the Vazquez & Beggs (1980) [8].

1.3 Statistical Error Analysis:

There are three main statistical parameters that are being considered in this study, these parameters help to evaluate the accuracy of the predicted fluid properties obtained from the black oil correlations [3].

1.3.1 Average Absolute Percent Relative Error (AARE):

This parameter is to measure the average value of the absolute relative deviation of the measured value from the experimental data. The value of AAPRE is expressed in percent. The equation of the AARE can be defined as:

$$E_a = \left(\frac{1}{nd}\right) \sum_{i=1}^{nd} Ei \qquad eq.4$$

E_i is the relative deviation in percent of an estimated value from an experimental value and is defined as:

$$Ei = \left[\frac{X_{est} - X_{exp}}{X_{exp}}\right] i \times 100 \text{ ,} \qquad i = 1, 2 \ldots n_d \qquad eq.5$$

Where X_{est} and X_{exp} represent the estimated and experimental values, respectively, and indicate the relative absolute deviation in percent from the experimental values.

A lower value of AAPRE implies better agreement between the estimated and experimental values.

1.3.2 Standard deviation

Standard deviation of the estimated values with respect to the experimental values can be calculated using the following equation:

$$S_x{}^2 = \left[\frac{1}{n_d - 1}\right] \sum_{i=1}^{n_d} E_i^2 \qquad eq.6$$

The symbol ***x*** represents the physical property.

A lower value of standard deviation means a smaller degree of scattering.

The accuracy of the correlation is determined by the value of the standard deviation, where a smaller value indicates higher accuracy. The value of standard deviation is usually expressed in percent.

1.3.3 Cross Plot

In this technique, all the estimated values are plotted against the experimental values, and thus a cross plot is formed by a 45° (0.79-rad) straight line well be drawn on the cross plot on which the estimated value is equal to the experimental value.

3. Correlation of the Bubble Point Pressure

This chapter will discuss only the correlations used in this project.

4. Result and Discussion

In this study we used three empirical correlations, Standing correlation, Labedi correlation and Al-Shammasi correlation. Forty six wells from seventeen Libyan oil fields were selected in this work to evaluate the up mentioned correlations.

Table 4-1 Abbreviations of names of all correlations in the figures and tables

Shortcut	Meaning
St	Standing's Correlation
Lad	Labedi's Correlation
AlShm	Al-Shammasi's Correlation

We divided our study in two parts, the first one studied each well separately, and the second part studied the wells together.

1.4 Evaluation of the results of each well separately by using AARE

Form our calculation of the each well separately it's clear that the wells can be divided in to three main group depended on the result of absolute average relative error for each well, these groups are (group "A" consists of 21 wells, group "B" consists of 12 wells, and group "C" consists of 13 wells).

Figures 4-1, 4-2, and 4-3 illustrate the Absolute Average Relative Error (AARE) calculated from the three empirical bubble point pressure correlations, the results showed that Standing correlation is the best one for the 21 wells, group "A", form the 46 wells these wells are: M3, M4, M7, M10, M13, M14, M15, M18, M19, M20, M21,M22,M23,M24,M25, M26,M27 ,M30,M31,M35 and M41.The lowest AARE for standing correlation in the group "A" is 0.021%, and the highest AARE is 12.74%.

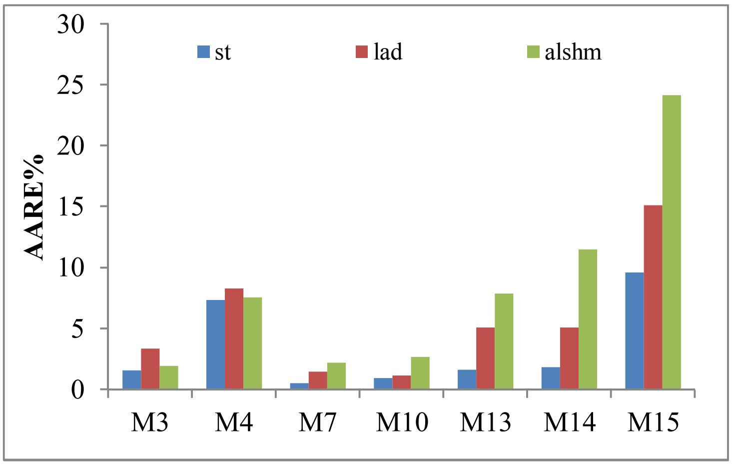

Figure 1 AARE for M3, M4, M7, M10, M13, M14, and M15

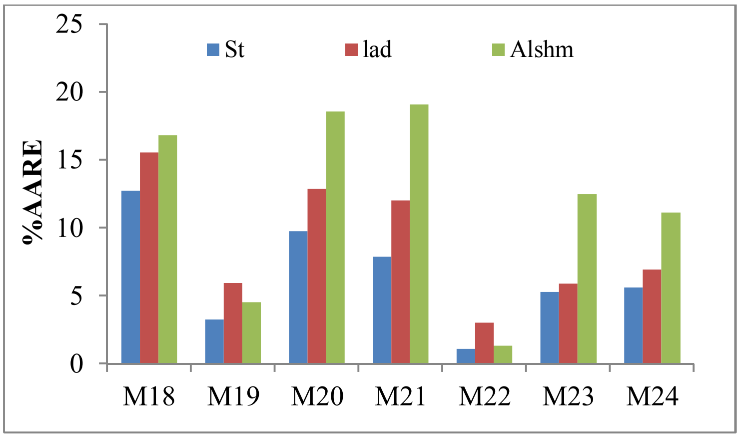

Figure 2 AARE for M18, M19, M20, M21, M22, M23, and M24

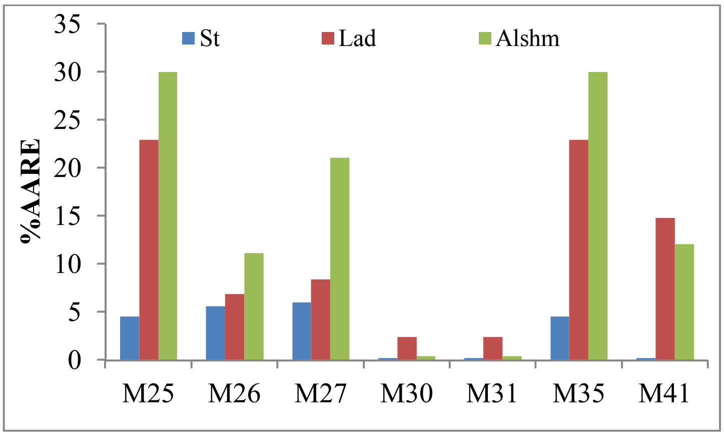

Figure 3 AARE for M25, M26, M27, M30, M31, M35, and M41

Figures 4-4, and 4-5 show the average absolute relative error obtained from three empirical correlations studied in this work, we found that the best correlation is Labedi correlation in 12 wells, group “B”, form the 46 wells, the wells are M1, M9, M11, M28, M32, M34, M38, M39, M42, M43, M44, and M45, the lowest calculated AARE for Labedi correlation for group “B” is 0.207%, and the highest AARE is 5.77%.

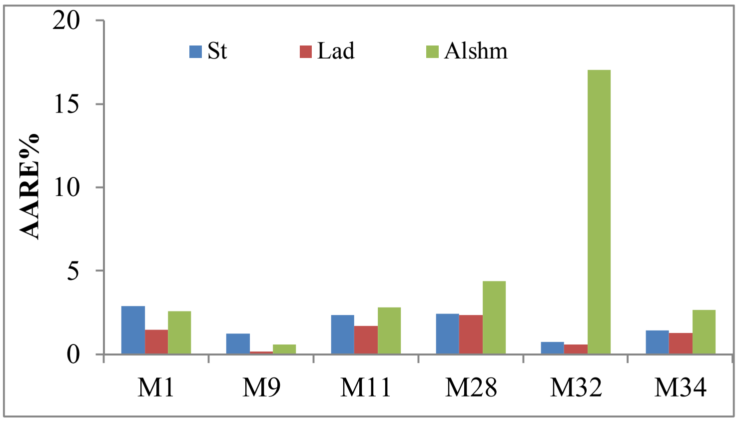

Figure 4 AARE for M1, M9, M11, M25, M29, and M32

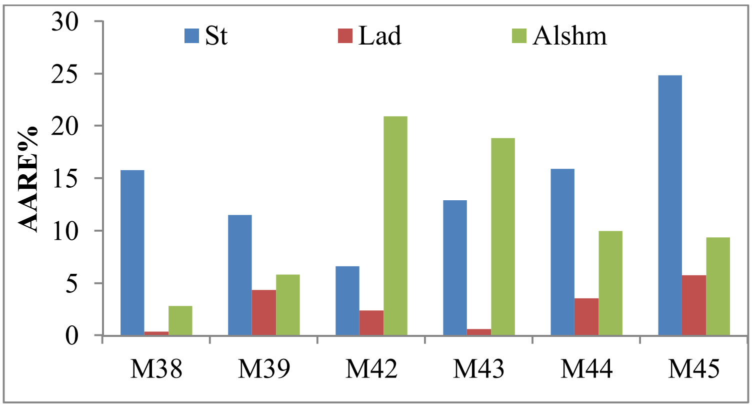

Figure 5 AARE for M38, M39, M42, M43, M44, and M45

Figures 4-6, and 4-7 show the average absolute relative error obtained from the three correlations in our study, these figures showed the best correlation was Al-Shammsi correlation in the 13 wells, group "C", form the 46 wells, these wells are M2, M5, M6, M8, M12, M16, M17, M29, M33, M36, M37, M40, and M46, the lowest AARE for Al-Shammsi correlation in group "C" is 0.046 %, while the highest AARE is 12.56 %.

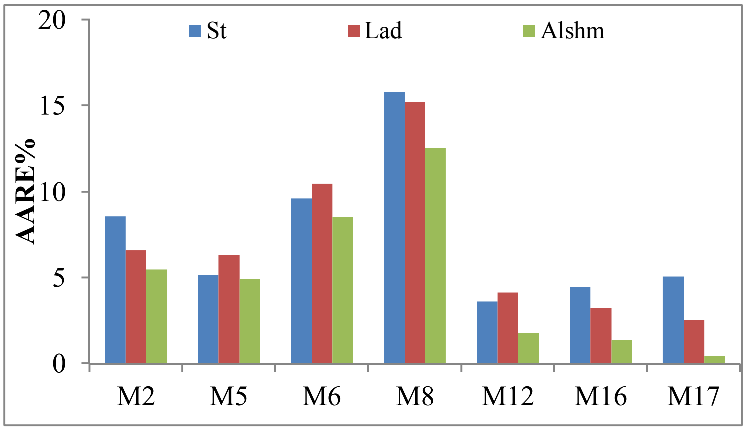

Figure 6 AARE for M2, M5, M6, M8, M12, M16, and M17

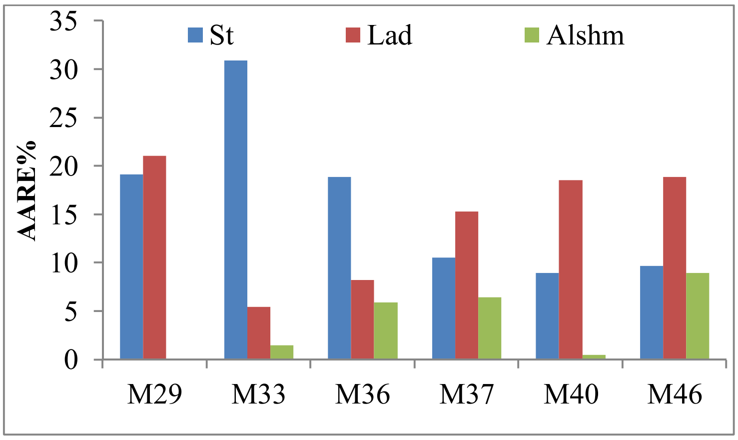

Figure 7 AARE for M29, M33, M36, M37, M40, and M46

1.5 The comprehensive study for the all wells together

A comprehensive study was performed to compare between these three targeted empirical correlations. In this part we used the Graphic Error Analysis to help visualizing the accuracy of the studied correlations.

In this technique the calculated values of the bubble point pressure were plotted against the measured bubble point pressure with a 45° straight line, the closer the plotted data points are to this line, better the correlation.

Figures 4-8, 4-9, and 4-10 illustrate the behavior of the calculated bubble point pressure (P_b) by the Standing, Labedi and Al-Shammasi correlation respectively compare with the lab points for all wells together.

Most of the calculated points of the all three targeted empirical correlations fall very close to the 45° line.

Second step in this part we performed a comprehensive study for the three correlations in one figure to be decided the exits perfect correlation.

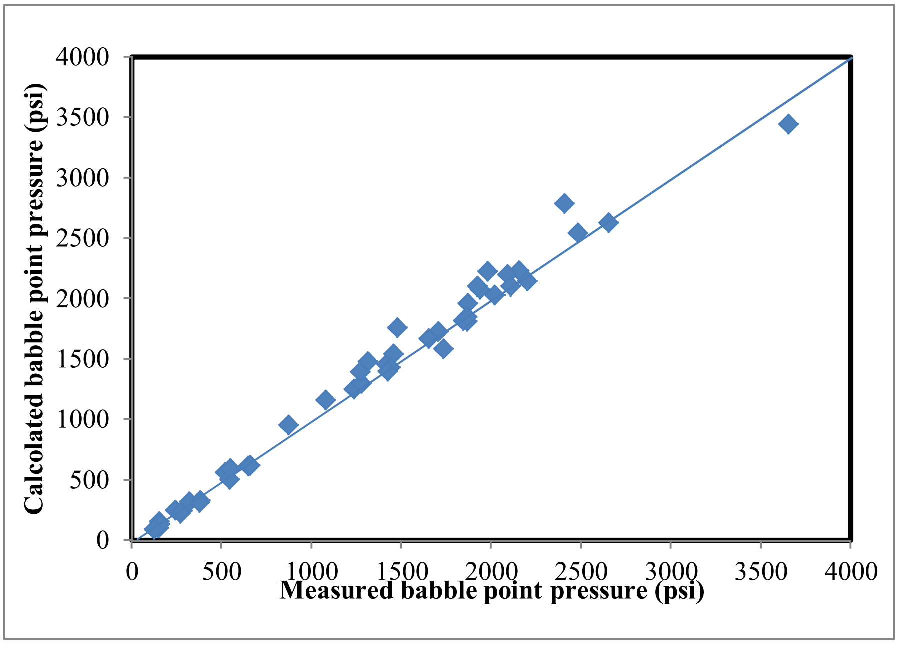

Figure 8 Cross plot of Bubble point pressure for standing correlation

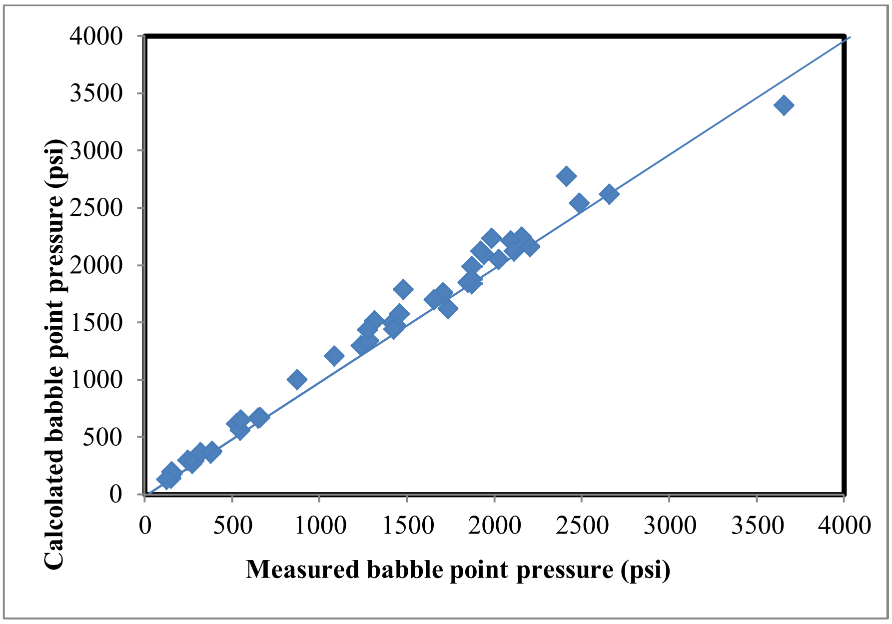

Figure 9 Cross plot of Bubble point pressure for Labedi correlation

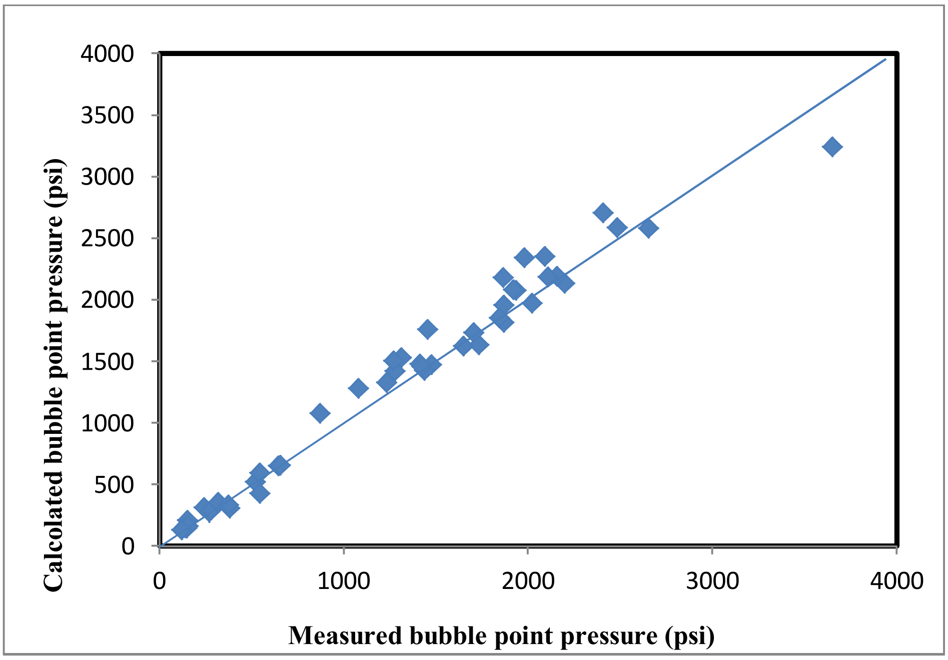

Figure 10 Cross plot of Bubble point pressure for Al-Shammasi correlation

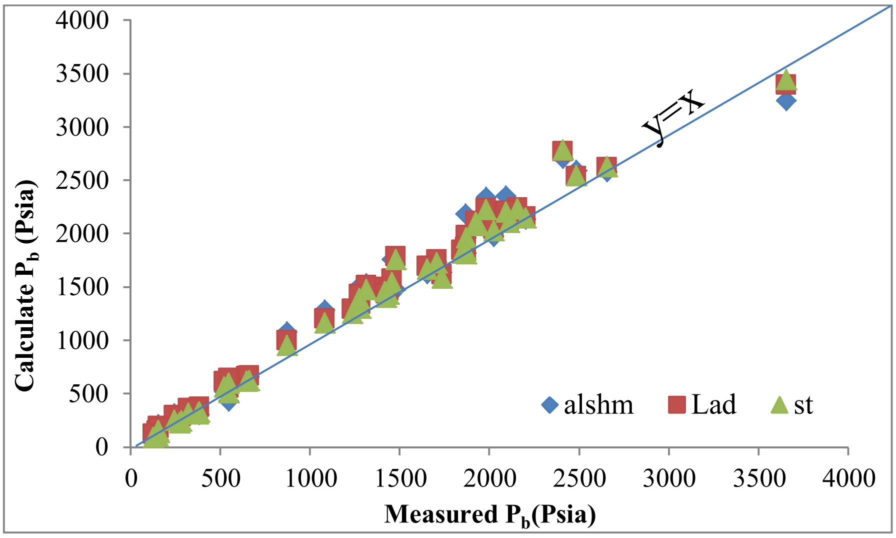

Figure 11 Cross plot of Bubble point pressure for three mentioned correlations

Figure 4-11 shows the scheme of the expected values of the bubble point pressure by correlations which used in this study vs. the lab measured data (measured bubble point pressure).

The results showed that in general most of correlations presented results close to the 45° line, it's clear that from the figure Standing's correlation was the closest one to the 45° line followed by Labedi and Al-Shammasi correlations.

To be more precise, we do other Statistical Error Analysis which is Average Absolute Relative Error, Standard Deviation and Coefficient R^2. Table 4-2 describes the results of the all Statistical Error Analysis for the bubble point pressure for all wells studied together.

Table 2 Statistical Error Analysis for bubble point pressure for all wells studied together

Correlation	Correlation CoefficientR^2	Absolute Relative Error (AARE %)	Standard deviation (STDEV %)
Standing	0.9890	7.5400	6.9091
Labedi	0.9864	7.7631	7.1711
Al-Shammsi	0.9791	9.2441	8.8817

Table 2 demonstrates that Standing correlation have the lowest value of both the AARE, standard division of 7.54%, 6.9%, respectively and the highest regression factor R^2 of 0.989. Therefore the Standing correlation is the most appropriate correlation for estimating the bubble point pressure for the selected Libyan oilfields in this study.

Conclusion:

Forty six well were selected from seventeen different Libyan oilfields, a total of 46 laboratory measured data point of bubble point pressure were used in this study with three empirical correlations to estimate the bubble point pressure. The Evaluation study was performed for Standing's correlation, Labedi's correlation and Al-Shammsi's correlation for bubble point pressure.

The Statistical analysis results showed that Standing's correlation had the lowest value of both the AARE of **7.54%** and standard deviation of **6.91%** with the highest regression factor R^2 of **0.989**.

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