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Evaluation and Improvement of Bubble Point Pressure Correlations for Yemeni Crude Oils

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Abstract: One of the most important PVT properties is the bubble point pressure. Ideally, in the laboratory the bubble point pressure is determined experimentally. Empirical PVT correlations becomes the best alternative when laboratory PVT analysis is not readily. This study evaluates and improves the most frequently used bubble point pressure empirical correlations for Yemeni crude oils using both Microsoft Excel and MATLAB. To validate and compare the performance and accuracy of the improved bubble point pressure correlations, an average absolute percent relative error (AAPRE) was applied. A total of 138 data sets of different crude oils from Yemeni reservoirs were used. The results showed that Levitan and Murtha modified correlation outperforms the most common published empirical correlations with least an average absolute percent relative error (AAPRE) followed by Labedi and Hassan correlations for predicting the bubble point pressure for Yemeni crude oils.

Keywords: Bubble point pressure, PVT correlations, Yemeni crude oil

I. INTRODUCTION

Different methods such as published correlations and laboratory experiments have been proposed to determine PVT parameters [4]-[11]. However, laboratory experiments that required generating the correlations are expensive and time-consuming so it is not applicable to carry out these experiments for each field [12, 13]. Additionally, these presented correlations are either too simple or too complex and most, if not all of them, are region-based and thus cannot be used for Yemeni fields and to evaluate the messing data in petroleum reports. Therefore, there is an urgent need for an effective and efficient optimization of the PVT correlations for Yemeni fields. The main objective of this paper is to evaluate and improve the correlation of bubble point pressure for Yemeni fields using least square curve-fitting method and Excel solver.

II. METHODOLOGY

To achieve this work, least-square curve-fitting method and Excel solver based on Yemeni field-data were used for predicting the bubble point pressure. In this study, the bubble point pressure correlation for crude oil properties were evaluated based on 138 data sets of Yemeni crude oils that have been collected from several PVT reports from different Yemeni oil fields as tabulated in Table I. These data consist of specific oil gravity (γ_o), reservoir temperature (T), oil density (API), solution gas-oil ratio (R_s), specific gas gravity (γ_g), and oil formation volume factor (B_{ob}). All these parameters were measured at the bubble point pressure (P_b). Data ranges of the Yemeni crude oils such as minimum (MIN), maximum (MAX), and average are presented in Table I.

TABLE I DATA RANGE OF THE YEMENI CRUDE OIL

PVT Property	R_s scf/stb	γ_g	T, °F	API	P_b, psia	B_{ob}, bbl/day	γ_o
Minimum	42	0.602	58	21.9	238	1.070	0.755
Maximum	1440	1.397	280	55.9	4194	1.954	0.922
Average	631.95	0.891	176	36.5	2110	1.368	0.844

III. RESULT AND DISCUSSION

In this section, the evaluation results of estimating the bubble point pressure by using empirical correlations were presented and discussed. In addition, the top three empirical correlations which gives the least average absolute percent relative error (AAPRE) were optimized and compared before and after optimization.

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A. Evaluation of Empirical Correlations

For estimating the bubble point pressure, the empirical correlations have been evaluated based on 138 Yemeni data sets. The study calculates and compares average absolute percent error to choose the best and accurate empirical correlation.

B. Bubble Point Pressure Correlations Evaluation

The statistical accuracy for the best three bubble point pressure correlations for Yemeni data sets has been summarized in Table II. As can be seen from this table, Labedi [2] correlation have the least average absolute percent relative error, followed by Hassan [3] and Levitan and Murtha [1]. The statistical error analysis of bubble-point pressure for all correlations used in this study are summarized in Table III. The cross plots of estimated values against experimental values for the best three performing bubble point pressure empirical correlations were presented from "Fig. 1" through "Fig. 3" respectively.

TABLE II BUBBLE POINT PRESSURE CORRELATIOS EVALUATION SUMMARY

Correlations	AAPRE
Labedi [2]	8.159
Hassan [3]	8.986
Levitan and Murtha [1]	9.583

TABLE III STATISTICAL ERROR ANALYSIS OF BUBBLE POINT PRESSURE CORRELATIONS

Correlation	MAX	MIN	AAPRE
Al-Marhoun [14]	66.144	0.0411	12.572
Al-Marhoun [15]	55.098	0.060	13.209
Almehaideb [16]	79.571	0.078	15.143
Al-Shammasi [17]	72.221	0.085	9.790
Doklah and Osman [18]	100.237	0.033	17.915
Elsharkawy and Alikhan [19]	94.240	0.131	32.093
Hanafy et al. [20]	129.108	0.088	25.204
Hassan [3]	58.026	0.0163	8.986
Khamehchi and Ebrahimian [21]	77.161	0.359	22.724
Labedi [2]	54.890	0.057	8.159
Levitan and Murtha [1]	48.467	0.028	9.583
Macary and El-Batanoney [22]	129.143	0.094	25.218
Mazandarani and Asghari [23]	88.234	0.209	23.049
Omar and Todd [24]	127.780	0.135	18.018
Owolabi [25]	107.780	0.033	32.204
Petrosky and Farshad [26]	370.838	0.364	25.757
Petrosky and Farshad [27]	370.810	0.341	25.764

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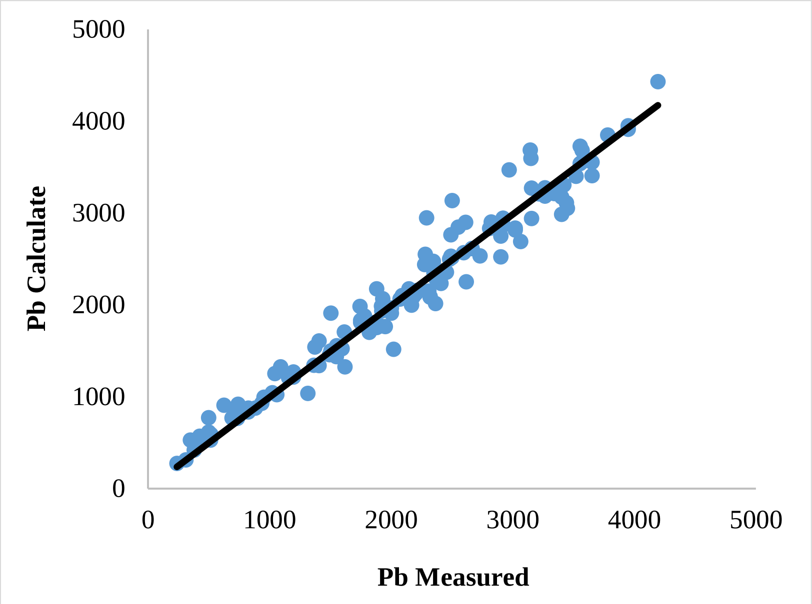

Fig. 1 Calculated bubble point pressures (Pb) from Labedi [2].

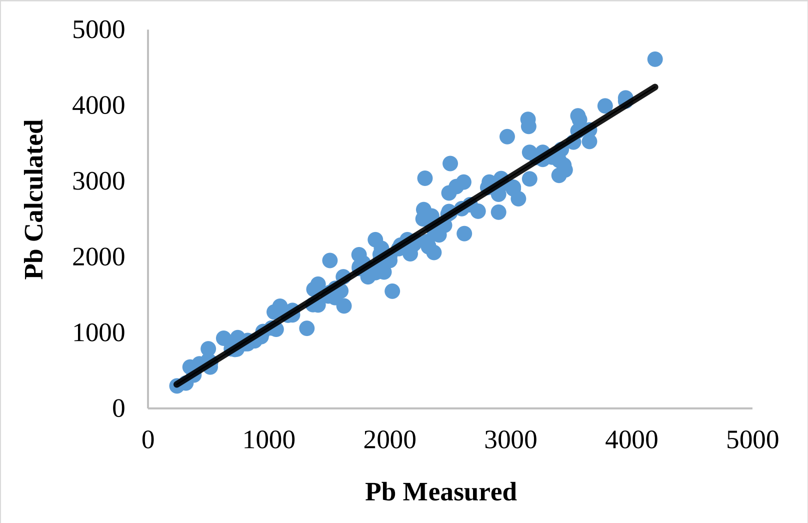

Fig. 2 Calculated bubble point pressures (Pb) from Hassan [3].

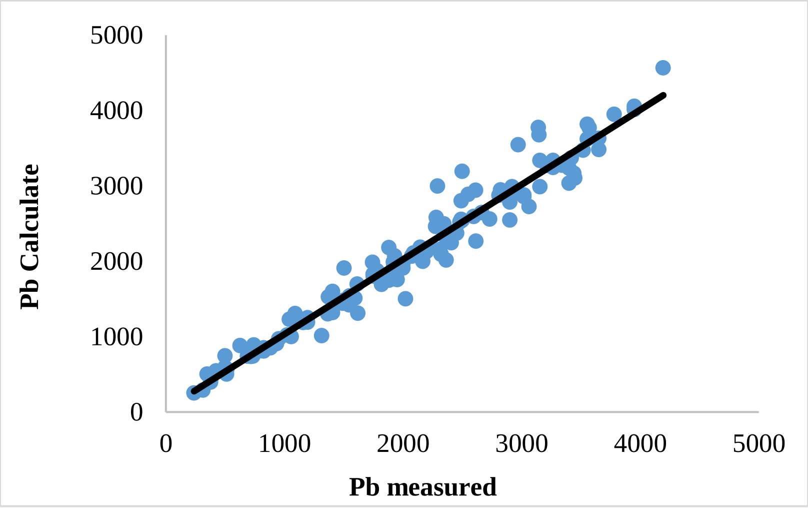

Fig. 3 Calculated bubble point pressures (Pb) from Levitan & Murtha [1].

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C. Optimizing of Bubble Point Pressure Empirical Correlations for Yemeni Crude oil

For PVT properties, Improvement of the existing correlations is another practical step to reduce the error and improve the performance of correlations for Yemeni data sets by using one of the optimization tools (Least Square Curve Fitting method and Excel solver) to generate new coefficients for the nominated correlations.

Coefficients for bubble point pressure correlations were recalculated using Solver Function of Microsoft Excel and Least Square Curve Fitting using MATLAB. Based on the resulted AAPRE, Levitan and Murtha [1] empirical correlation is recommended for Yemeni data. The statistical comparison for the chosen bubble point pressure correlations for Yemeni data sets has been summarized in Table IV. The order of the bubble point pressure correlations for Yemeni data are as follows:

1) Hassan [3]

$$P_b = a1 \times \left[\left(\frac{R_s}{\gamma_g}\right)^{a2} \times 10^{(a3\times T - a4\times\gamma_{API})} + a5\right] P_b = a1 \times \left[\left(\frac{R_s}{\gamma_g}\right)^{a2} \times 10^{(a3\times T - a4\times\gamma_{API})} + a5\right] \quad (1)$$

2) Labedi [2]

$$P_b = a1\left(\left(\frac{R_s}{\gamma_g}\right)^{a2} \times 10^{(a3T - a4°API)}\right)^{a5} P_b = a1\left(\left(\frac{R_s}{\gamma_g}\right)^{a2} \times 10^{(a3T - a4°API)}\right)^{a5} \quad (2)$$

3) Levitan and Murtha [1]

$$P_b = a1\left(\frac{R_s}{\gamma_g}\right)^{a2} \gamma_O^{a3}\left(\frac{T+459.67}{a4}\right)^{a5} P_b = a1\left(\frac{R_s}{\gamma_g}\right)^{a2} \gamma_O^{a3}\left(\frac{T+459.67}{a4}\right)^{a5} \quad (3)$$

Table V show the original and recalculated coefficients by Excel solver and least square curve fitting of the best three correlations for bubble point pressure. “Fig. 4” through “Fig. 9” illustrate the cross plots of estimated values against experimental values for the best three performing bubble point pressure modified empirical correlations for both Excel Solver and Least Square Curve fitting.

TABLE IV BUBBLE POINT PRESSURE CORRELATIONS EVALUATION SUMMARY (MODIFIED)

Correlation	**Method**	**AAPRE**
Levitan and Murtha [1]	Original	9.583
	Excel Solver	6.513
	Least Square	6.693
Labedi [2]	Original	8.159
	Excel Solver	6.710
	Least Square	7.940
Hassan [3]	Original	8.986
	Excel Solver	6.718
	Least Square	7.528

TABLE V THE ORIGINAL AND RECALCULATED COEFFICIENTS OF HASSAN CORRELATION [3]

Coeff.	**Hassan Correlation [3]**			**Labedi Correlation [7]**			**Levitan & Murtha Correlation [1]**		
	Original	**Excel Solver**	**Least Square**	**Original**	**Excel Solver**	**Least Square**	**Original**	**Excel Solver**	**Least Square**
a1	18.2	13.9	37.9	21.38	15.7	21.38	14.7	13.82	14.3
a2	0.83	0.885	0.748	0.83	0.875	0.591	0.85	0.868	0.863
a3	9E-04	6E-04	5E-04	0.001	6E-04	0.0005	5	4.865	5.041
a4	0.013	0.012	0.012	0.013	0.012	0.008	519.7	524.5	529.7
a5	2.2	1.708	-5.76	0.965	0.991	1.352	1.5	0.901	1.087

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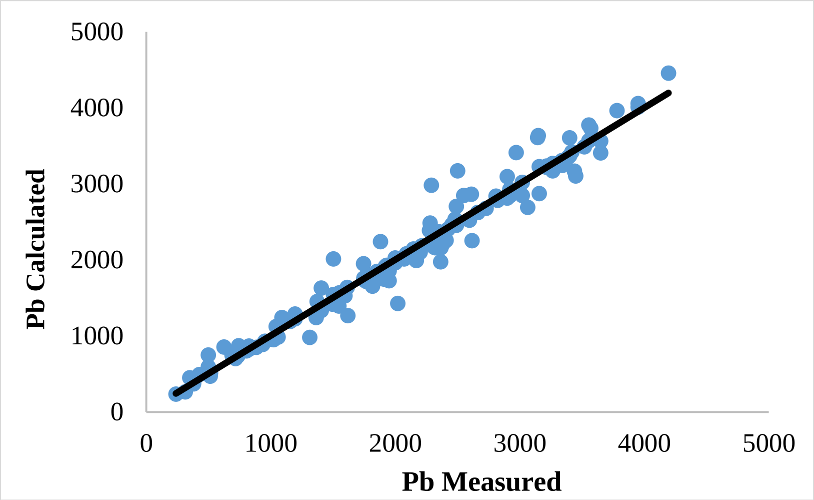

Fig. 4 Cross plot of modified Hassan [3] correlation, (Excel Solver).

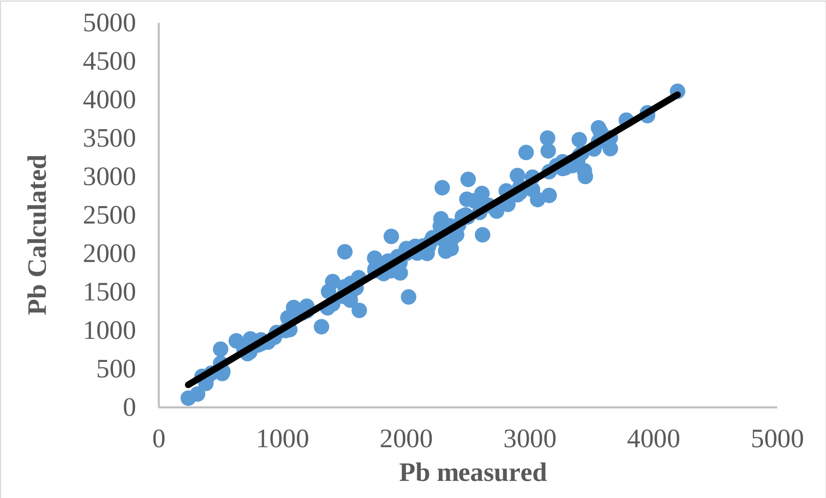

Fig. 5 Cross plot of modified Hassan [3] correlation, (Least Square).

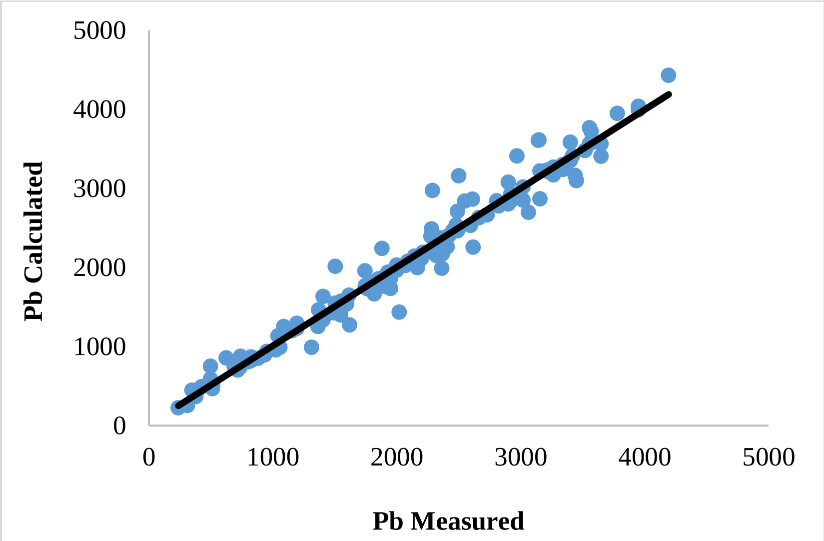

Fig. 6 Cross plot of modified Labedi [2] correlation, (Excel Solver).

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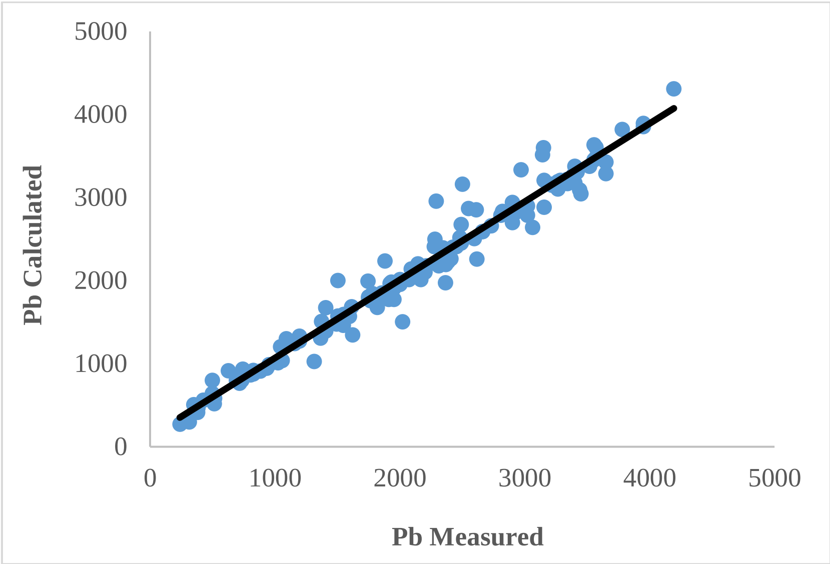

Fig. 7 Cross plot of modified Labedi [2] correlation, (Least Square).

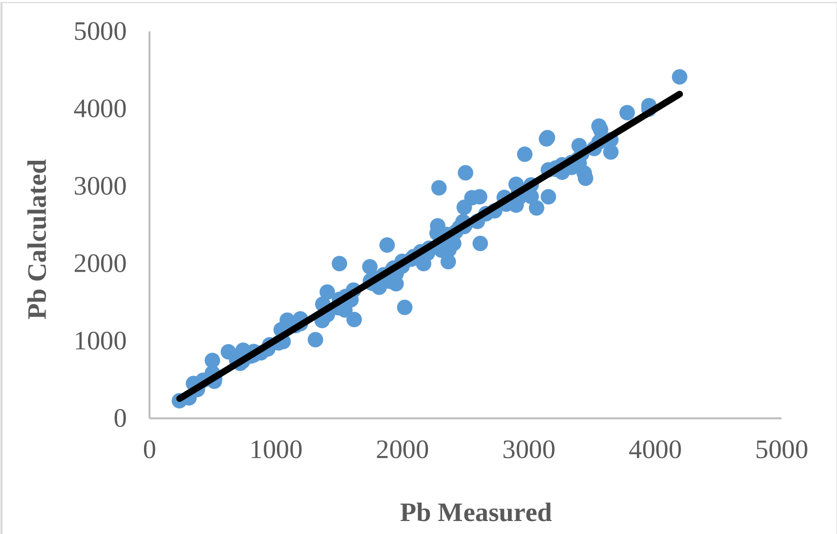

Fig. 8 Cross plot of modified Levitan and Murtha [1] correlation, (Excel Solver).

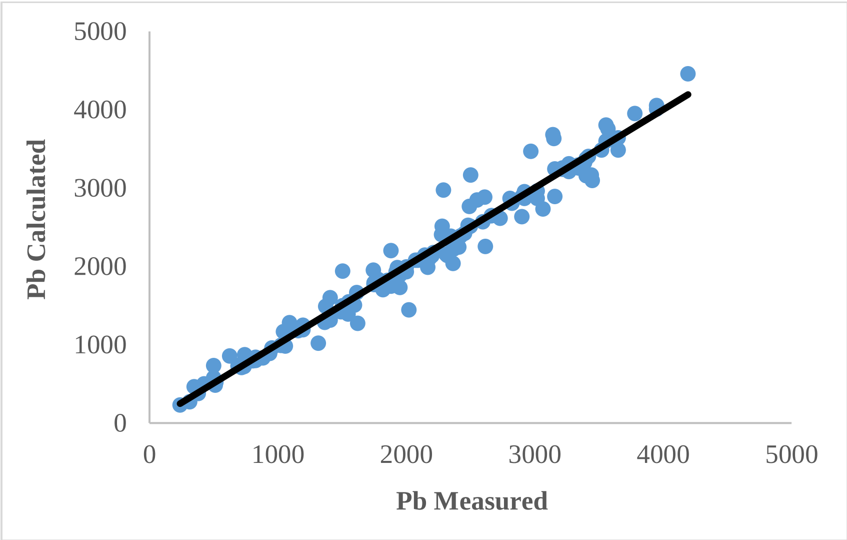

Fig. 9. Cross plot of modified Levitan and Murtha [1] correlation, (Least Square).

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IV. CONCLUSION

From this evaluation study, the following conclusions were drawn for Yemeni crude oils:

1. Many published bubble point pressure empirical correlations has been identified from the literature and evaluated based on Yemeni PVT data using MATLAB and Microsoft Excel.
2. Levitan and Murtha [1] modified correlation outperforms the most common published bubble point pressure empirical correlations with least an average absolute percent relative error (AAPRE) of 6.513%.
3. In general, the correlation of Levitan and Murtha [1] is recommended as the best correlation to predict bubble point pressure for Yemeni fields.

Nomenclature

AAPRE Average absolute percent relative error
API Oil density
P_b Bubble point pressure**,** psia
B_{ob} Oil formation volume factor at the bubble point pressure, bbl/STB
R_s Solution gas oil ratio, SCF/STB
γ_o Oil specific gravity(60 ˚F and 14.7 psia)
γ_g Gas relative density (air = 1.0)
T Reservoir temperature, ˚F

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