IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology
Vol. 2, Issue 12, December 2015

A New Bubble point Pressure Correlation of Egyptian Crude Oils

Ramadan Emara[1,2]

(Home) Al Azhar University, Faculty of Engineering, Mining and Petroleum Engineering Department[1]

(Secondment) The Britich University in Egypt, Faculty of Engineering, Petroleum and Natural Gas Technology Dept.[2]

Abstract: Bubble point pressure is an important reservoir fluid property. Many reservoir engineering calculations are bubble point pressure dependable, such as reserve estimation. In circumstances, laboratory PVT analysis is not available, empirical PVT correlations becomes the best alternative. In this study, correlation for bubble point pressure of Egyptian crude oils was developed using non- linear multiple regression. This was done by utilized a total of 178 data points were used to develop this correlation. The data were collected from different fields in Egypt and covered a wide range of crude oils ranging from heavy to volatile oils. The data included oils with bubble point pressures ranging from 180 to 4999 Pisa, ^{o}API of 16.5 to 49.8, gas oil ratio of 62 to 2647 scf/STB, gas gravity of 0.6 to 1.474 and temperature of 107 to 316 ^{o}F. The developed correlation was taken as a function of solution gas oil ratio, oil API gravity, gas relative density and reservoir temperature. Statistical and graphical analyses have been used to assess the performance of the correlation. Correlation performance was also compared with published correlations. The new correlations developed by this study performed better than existing published bubble point pressure correlations.

Key words: PVT Correlations; Bubble point pressure; Egypt.

I. INTRODUCTION

Reserve estimation, performance prediction and many petroleum engineering calculations in an oil reservoir require demand perfect information of the fluid physical properties. Bubble point pressure is of primary significance in reservoir and production engineering calculation. PVT data can be obtained either by conducting a laboratory study on reservoir fluid samples or estimated by using empirically derived PVT correlations. The accuracy of laboratory results is dependent on the reservoir fluid sample, particularly when the reservoir has depleted below the bubble point pressure. In case where the experimental data are not obtainable, empirically derived correlations are used to estimate the physical reservoir fluid properties. In fact, two different types of correlations in the literature are existing. The first set of correlations is known as worldwide correlations which were developed with selected data sets at random. The second set of correlations was developed with data sets for a specific region in the world or for specific oil.

So far there is no general bubble point pressure correlation valid for all types of crude oils over the world. The reason is every crude oil has a unique composition. So the aim of this paper is to evaluate the existing bubble point pressure correlation from the literature and if there is no one valid for Egyptian crude oils, then further modification will be proposed in order to improve the current correlations.

II. LITERATURE REVIEW

The following presents a review of the best-known correlation models published in the literature. Also Table 1 illustrates the literature bubble-point pressure correlations. It shows authors, published year, sample origin, number of data points and the range of bubble point pressure.

In 1947, Standing[1] published correlations for p_b and for B_o that were based on laboratory experiments carried out on 105 samples from 22 different crude oils in California, U.S.A. The correlations treated the Pb as a function of the reservoir temperature, GOR, oil gravity, and gas gravity. Actually, these correlations are the most widely used in the oil industry.

In 1958 Lasater[2] used Henry's law constant and the observation that the bubblepoint ratio at different temperatures is equal to the absolute temperatures ratio for hydrocarbon systems not close to the critical point to develop a p_b correlation. This correlation based on 158 samples from 137 reservoirs in Canada, the U.S., and South America.

In 1980, Vazquez and Beggs[3] published correlation for p_b that was based on 6,000 data points from 600 laboratory measurements. They classified oil mixtures into two categories, above 30°API gravity and below 30°API gravity. They also pointed out the strong dependence on gas gravity and developed a correlation to normalize the gas-gravity measurement to a reference separation pressure of 100 psi. This eliminated its dependence on separation conditions.

In 1980 Glaso[4] presented P_b and other PVT correlations of North Sea hydrocarbon mixtures. The main feature of Glaso's correlations is that they account for paraffinicity by correcting the flash stock-tank-oil gravity to an equivalent corrected value with reservoir temperature and oil viscosity. A total of 45 oil samples, most of which came from the North Sea region, were used in the development of this correlations.

In 1988, Al-Marhoun[5] published new correlations for estimating p_b and B_o for Middle East oils. A total of 160 data sets from 69 Middle Eastern reservoirs were available for the correlation development.

In 1992, Dokla and Osman[6] published a new set of correlations for estimating pb, and Bo for United Arab

Emirates crudes. They used 51 data sets to calculate new coefficients for Al-Marhoun's[5] 1988 Middle East correlations.

In 1992, Macary and El-Batanoney[7]presented new correlations for Pb, Bo, and GOR. Ninety data sets from 30 independent reservoirs in the Gulf of Suez, Egypt, were used to develop the correlations. The new correlations were tested against other Egyptian data and showed improvement over published correlations.

In 1993 Omar and Todd[8] developed a Pb correlation that uses the Bo in addition to oil gravity, gas gravity, GOR and reservoir temperature. The new correlation was based on 93 data sets from Malaysian oil reservoirs.

In 1993, Petrosky and Farshad[9] developed new correlations for Gulf of Mexico crudes. Standing's[1] correlations for Pb, GOR and Bo were taken as the basis for developing the new correlation coefficients.

In 1994, Kartaotmodjo and Schmidt[10] used a global data bank to develop new correlations for all PVT properties. Standing's[1] correlation models were taken as the basis for Pb and GOR correlations. Data from 740 different crude oil samples gathered from all over the world provided 5392 data sets for correlation development.

In 1997, Almehaideb[11] published a new set of correlations for UAE crudes. He used 62 data sets from UAE reservoirs to develop the new correlations, for Pb, Bo, oil viscosity, and oil compressibility. The Pb correlation, like Omar and Todd's[6] uses the Bo as input in addition to oil gravity, gas gravity, GOR and reservoir temperature. Improvement over published correlations was achieved with this work.

In 1997, Hanafy et al. Al.[12] presented new correlations of PVT properties. He used 324 data sets from 75 oil fields distributed along three different regions of Egypt.

In 2001 Al-Shammasi[13] published correlations and neural-network models for bubblepoint pressure (Pb) and oil formation volume factor (Bo) for their accuracy and flexibility in representing hydrocarbon mixtures from different locations worldwide.

In 1999 Velarde and McCain[14] developed a new bubble-point pressure correlation using the relation proposed by Petrosky[9] (which is a modification of the original form proposed by Standing[1]) using nonlinear regression method.

In 2007 Hemmati and Kharrat[15] used nonlinear regression technique to developed new Pb, Bo and Rs correlations for Iranian crudes using 287 laboratory PVT analyses.

Table 1: literature bubble-point pressure correlations

Authors	Published year	Sample origin	Number of points	Pb range, Pisa	Reference
Standing	1947	California	105	130-7000	1
Lasater	1958	Canada USA	158	48-5780	2
Vazquez and Beggs	1980	Worldwide	6004	15-6055	3
Glaso	1980	North sea	41	165-7142	4
Al-Marhoun	1988	Middle-East	160	20-3173	5
Dokla and Osman	1992	U.A.E.	51	590-4640	6
Macary and El-Batanony	1992	Gulf of Suez	90	1200-4600	7
Omar and Todd	1993	Malaysia	93	790-3851	8
Petrosky and Farshad	1993	Gulf of Mexico	90	1574-6523	9
Kartaotmodjo and Schmidt	1994	Worldwide	5392	15-6055	10
Almehaideb	1997	U.A,E.	62	501-4822	11
Hanafy	1997	Egypt	324	36-5003	12
Al-Shammasi	1999	Worldwide	1709	15-7127	13
Velarde and McCain	1999	Worldwide	2097	70-6700	14
Hemmati and Kharrat	2007	Iran	287	348-5156	15

III. DATA DESCRIPTION

Results of PVT laboratory analyses for Egyptian crude oils constituted the base of information needed for this study. Data used for this work consists of reservoir bubble-point pressure, temperature, oil gravity, gas gravity and solution gas oil ratio. A total of 178 data sets from different fields in Egypt. The data covered a wide range of crude oils ranging from heavy to volatile oils.

Table 2 shows the range of data used in this paper.

Table 2: Data Description of Egyptian Crude Oils

PVT Property	Minimum	Maximum
Pb, psi	180	4999
Rs, scf/STB	62	2647
Oil API gravity	16.5	49.8
Gas gravity	0.6	1.474
Reservoir Temperature, ^{o}F	107	316

IV. CORRELATION DEVELOPMENT

In order to develop a correlation of bubble point pressure of Egyptian crude oils, many models were tried as regression equations to obtain a bubble-point pressure correlation. It was found that, the most familiar one to industry is Standing correlation.

The new black oil correlation was based on Standing's bubble point pressure. The correlation is function of solution gas oil ratio, oil API gravity, gas relative density and reservoir temperature. Based on this correlation, using a nonlinear regression analysis, the best fit and most sensitive coefficient was determined.

The accuracy of the new improved black oil bubble-point pressure correlation was studied by conducting an error analysis (statistical and graphical) and by performing comparative study with other known black oil correlations.

$$Pb = a1 * \left[\left(\frac{Rs}{\gamma g}\right)^{a2} * 10^{x} - a5\right]$$

$$x = a3 * T - a4 * API$$

a1= 55.67
a2= 0.637
a3= 0.00045
a4= 0.0088
a5= 7.957

Statistical Error Analysis

There are three main statistical parameters that are being considered in this study. These parameters help to estimate the accuracy of the bubble-point pressure correlations used in this study.

Average Percent Relative Error[11] (AE)

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

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

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

$$E_i = \left[\frac{(x_{est} - x_{exp})}{x_{exp}}\right]_i \times 100, \qquad i = 1,2 \ldots n_d$$

Where X_{est} and X_{exp} represent the estimated and experimental 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[11] (AAE)

This parameter is to measure the average value of the absolute relative deviation of the measured value from the experimental data. The value of AAE is expressed in 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 experimental values. A lower value of AAE implies better agreement between the estimated and experimental values.

Correlation Coefficient[11]

The objective of performing correlation coefficient calculation is to characterize the extent of the connection between two variables namely experimental and estimated values obtained from the correlation.

The value of the correlation coefficient varies from -1.0 to +1. A coefficient of zero indicates no relationship between experimental and calculated values. A +1.0 coefficient indicates a perfect positive relationship and a -1.0 coefficient indicates a perfect negative relationship. The correlation coefficient can be determined using the following equation:

$$r^2 = 1 - \frac{\sum_{i=1}^{m}[(x_{exp} - x_{est})_i]^2}{\sum_{i=1}^{m}[(x_{exp} - \bar{x})_i]^2}$$

where

$$\bar{x} = \left(\frac{1}{n_d}\right)\sum_{i=1}^{n_d}(x_{exp})_i$$

Graphic Error Analysis[11]

Graphic means assist in visualizing the accuracy of a correlation. One graphic analysis technique was used in this paper.

Cross plot

In this method, all the predicted values are plotted versus the experimental values and thus cross plot is formed. A 45° straight line is drawn on the cross plot on which the estimated value is equal to the experimental value. The closer the plotted data points are to this line, better the correlation.

V. RESULT AND DISCUSSION

The average percent relative error, average absolute percent, correlation coefficient and were computed for each correlation. Also cross plot is drawn for each correlation.

Table 3 illustrates the results of statistical error analysis of the developed bubble-point pressure correlation in this study and for the other Literature correlations.

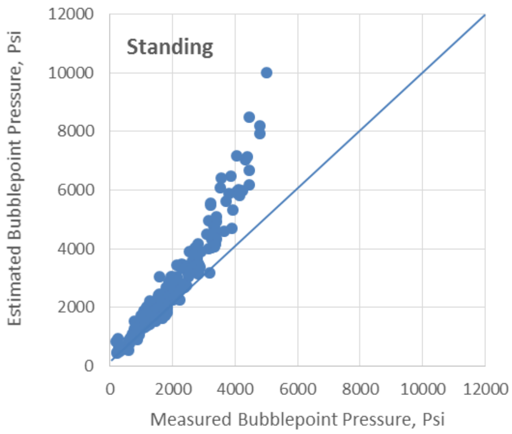
The bubble-point pressure correlation gives low values of average percent relative error (AE %), absolute average percent relative error (AAE %) and high value of correlation coefficient of 1.15 percent, 13.6 percent and 0.95 respectively. A lower value of these statistical error analysis variables indicates a better accuracy of the correlation. The correlation coefficient shows that a good agreement exists between experimental and calculated bubble point pressure.

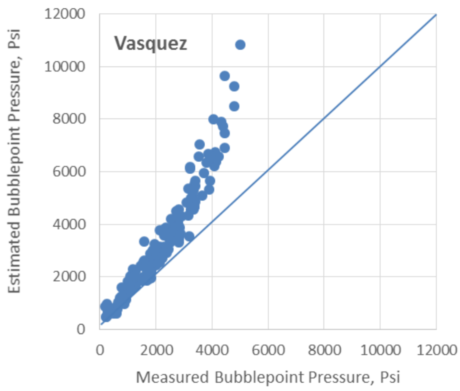
In comparison with other known correlations, the developed one in this paper gives the lowest AE % and AAE %. This shows that this correlation predicts better bubble point pressure for Egyptian crude oils than any other known correlations. The cross plot of the experimental against the calculated bubble point pressure using the new correlation and all the other correlations used in this study is presented in Figure 1. Most of the data points of the new correlation fall very close to perfect correlation of the 45^{o} line.

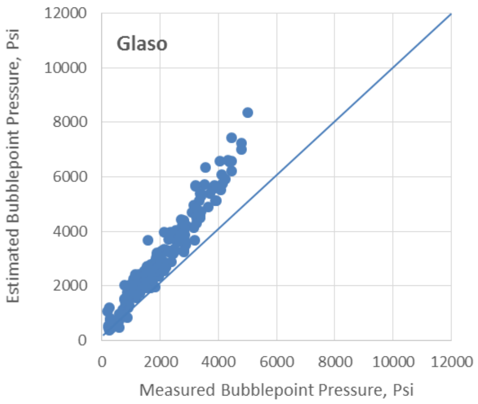
IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
Vol. 2, Issue 12, December 2015

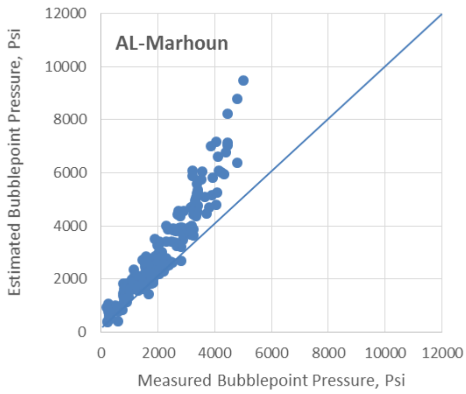
Table 3: Statistical Error Analysis

Bubble-point Pressure Correlations	AE%	AAE%	R^2
Standing	-43.8	43.9	Negative
Lasater	-106.9	106.9	Negative
Vasquez and Beggs	-55.7	55.7	Negative
Glaso	-60.1	60.3	Negative
AL-Marhoun	-52.6	53.2	0.724
Dokla and Osman	-13.1	24.4	0.772
Macary and EL-Batanony	-42.6	43.1	0.62
Omar and Todd	-45.5	45.5	0.52
Petrosky and Farshad	-39.6	52.8	Negative
Kartaotmodjo and Schmidt	-57.6	57.6	Negative
Al-Mehaideb	-17.3	22.2	0.863
Hanafy	-11.6	29.6	0.46
AL-Shammasi	-43.1	43.1	0.36
Velarde and McCain	-43.7	44.2	0.36
Hemmati and Kharrat	-31.2	32.4	0.393
This study	1.15	13.6	95

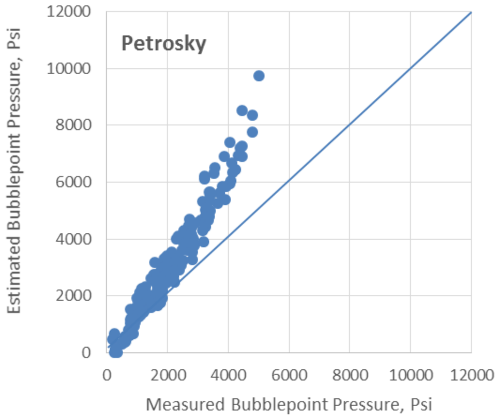


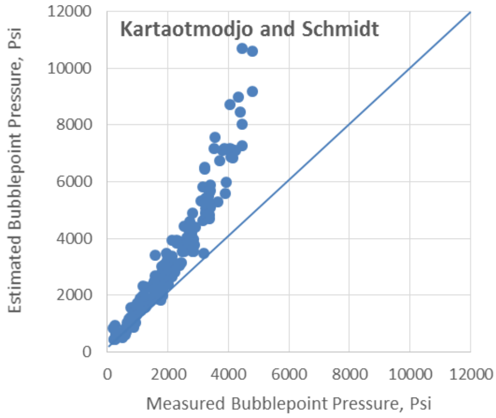


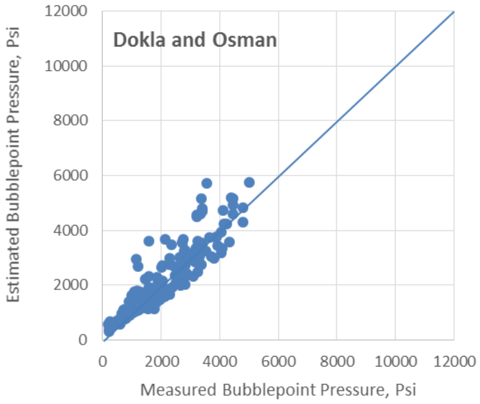


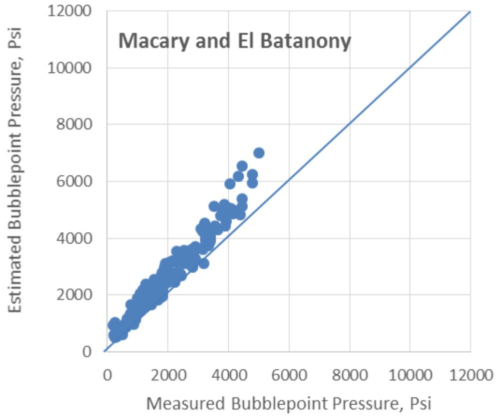


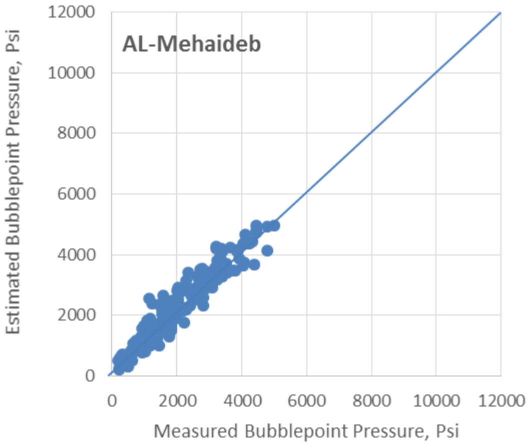
IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
Vol. 2, Issue 12, December 2015

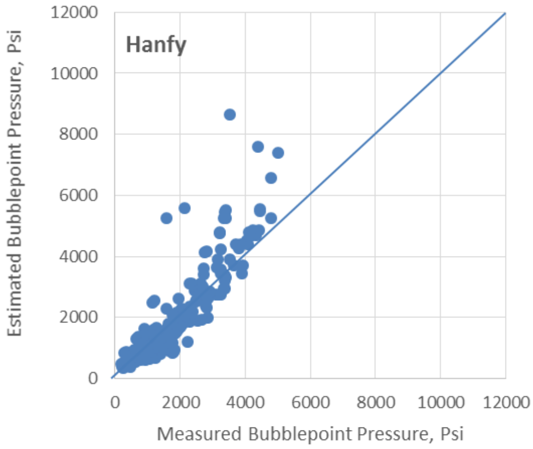












IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology
Vol. 2, Issue 12, December 2015

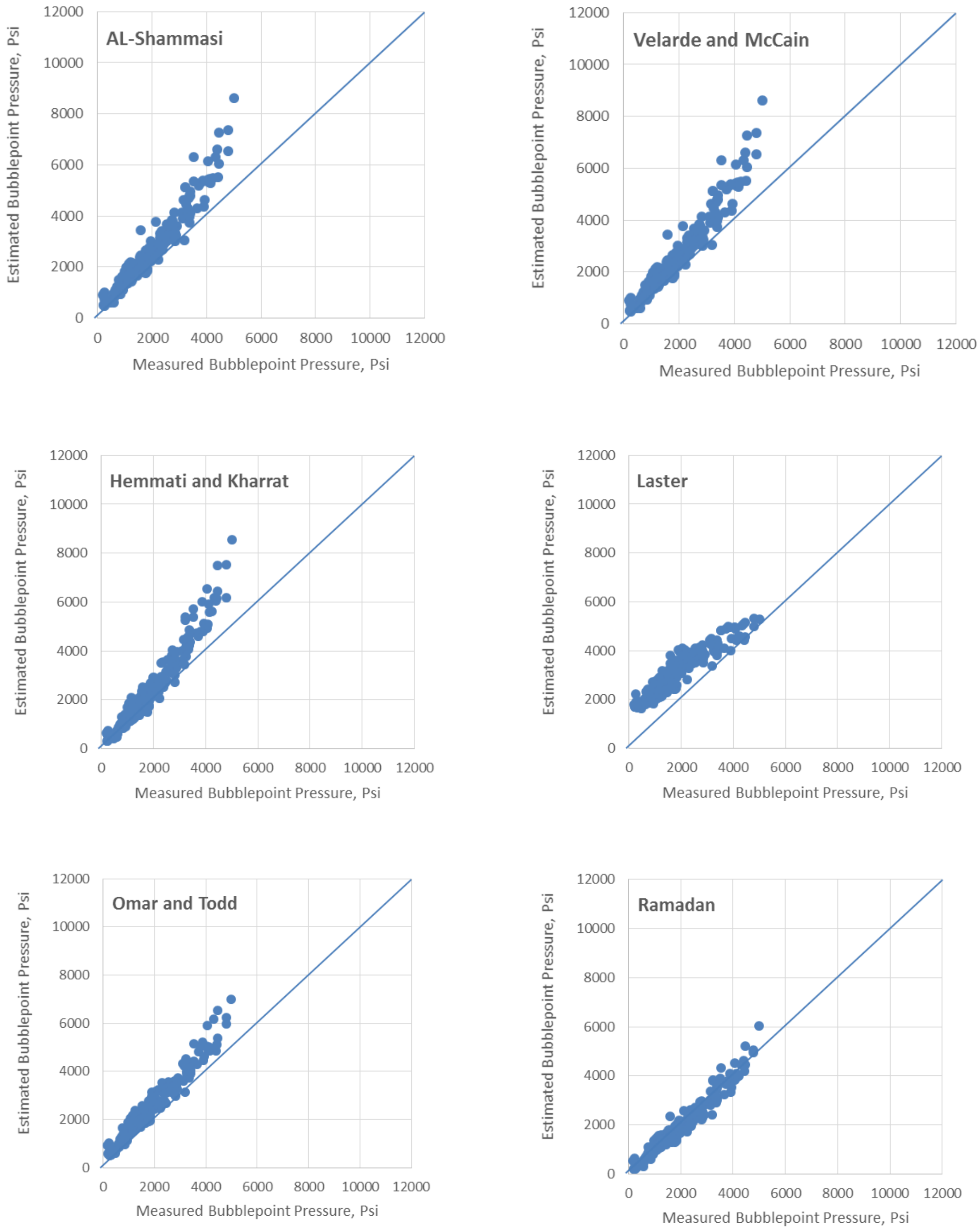


Fig 1: Cross Plot for the Evaluated Pb Correlation

DOI 10.17148/IARJSET.2015.21218

VI. CONCLUSION

New bubble-point pressure correlation was obtained for Egyptian crudes using nonlinear regression technique. This correlation was developed based on Standing's correlation. The new correlations gave better accuracy in estimating bubble-point pressure of Egyptian crudes as compared with other known correlations available in the literature. The new correlation was developed specifically for Egyptian crude oils but can be used for estimating the same bubble-point pressure for all types of oil and gas mixtures with properties falling within the range of the data used in this study. The bubble-point pressure correlations can be placed in the following order with respect to their accuracy: a) This study, Al-Mehaideb, Dokla and Osman, and Hanafy.

NOMENCLATURE:

E_i = Percent relative error
E_r = Average relative error
E_a = Average absolute relative error, %
n_d = Number of data points
P_b = Bubble point Pressure, psia
B_o= oil formation volume factor, bbl/STB
T= Temperature, oF
r = Coefficient of correlation
Rs = Solution gas-oil-ratio, scf/STB
x = Any physical quantity
$\bar{x}$ = Average value of X
γ_g = Gas specific gravity

SUBSCRIPTS:

b= bubble point
est =estimated from correlation
exp = experimental
g= gas
o= oil
s = solution

REFERENCES

1. Standing, M. B.:"A Pressure Volume Temperature Correlation for Mixture of California Oils and Gases," *Drill. & Prod. Prac, API*, Dallas (1947) 275-87.
2. Lasater, J. A.:" Bubble Point Pressure Correlation," SPE Paper 957-G, (MAY 1958).
3. Vasquez, M. and Beggs, H. D.: "Correlation for Fluid Physical Property Prediction," SPE 6719, (1980).
4. Glaso, O.:" Generalized Pressure-Volume Temperature Correlations," *JPT* (May 1980), pp 785-95.
5. Al-Marhoun, M. A.: "PVT Correlations for Middle East Crude Oils," *JPT* (MAY 1988) 650-66, Trans, 285, SPE Paper 13718.
6. Dokla, M. and Osman, M.: "Correlation of PVT Properties for UAE Crudes," *SPE Formation Evaluation* (March 1992) 41-46; Trans, 285, SPE Paper 21342
7. Macary, S. M. & El-Batanony, M. H.: "Derivation of PVT Correlations for the Gulf of Suez Crude Oils," EGPC 11th Pet. Exp. & Prod. Conf. (1992
8. Omar, M. I. and Todd, A. C.: "Development of New Modified Black oil Correlation for Malaysian Crudes," SPE 25338 (1993).
9. Petrosky, J. and Farshad, F.: "Pressure Volume Temperature Correlation for the Gulf of Mexico." 68th Soc. Pet. Eng. Anna. Tech. Con., Houston, TX, Oct 3-6 1993, SPE 26644.
10. Kartoatmodjo. Trijana and Schmidt, Zelimie: "Large data bank improves crude physical property correlations," *Oil and Gas Journa*l, July 4, 1994, pp 51-55.
11. Al-Mehaideb, R. A.: "Improved PVT Correlations for UAE Crude Oils," SPE 37691, SPE Middle East Oil Show CONF (Manamah, Bahrain, 3/15 –18/97) PROC V1, pp 109-120, 1997.
12. Hanafy. H.H. et al.:"A New Approach for Predicting the crude oil properties," paper SPE 37439 presented at the 1997 SPE Production Operations Symposium, Oklahoma, 9-11February.
13. Al-Shammasi A. A. "Bubble Point Pressure and Oil Formation Volume Factor Correlations", SPE 53185 (1999).
14. Velarde, J. et al.: "Correlation of Black Oil Properties at Pressure Below Bubble point Pressure" J. Cdn. Pet. Tech. Special Edition 1999, 38,93-97
15. Hemmati. M.N. and Kharrat. R."A Correlation Approach for Prediction of Crude-Oil PVT Properties" 15th SPE Middle East Oil & Gas Show and Conference held in Bahrain International Exhibition Centre. 11-14 March 2007.