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BUBBLE POINT PRESSURE CORRELATION FOR DEEP OFFSHORE REGION OF NIGERIA

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ABSTRACT: *Producing oil from deep offshore fields poses serious risk especially due to peculiar pressure and temperature regimes characterizing the fields. These variables affects the bubble point of the produced hydrocarbon in such fields. The significance of Bubble point pressure and gas solubility has led researchers to continually develop correlations to accurately predict these reservoir oil properties. In this work, measured bubble point pressure is first evaluated and a new correlation is established to estimate crude oil bubble point pressure for deep offshore region of West Africa. Nonlinear Multiple Regression analysis was utilized. The correlation applies to API crude oils ranging from 38 to 56. Comparison with other published ones of this new correlation indicates that it is much more precise than the others. The developed correlation's Average Absolute Percent Error (percentage) is 4.8 percent. The result is indicative of an agreement between the measured and estimated data.*

KEYWORDS- bubble point, pressure, correlation, deep offshore, Nigeria

INTRODUCTION

So many questions have been asked in other anticipate the volumetric and phase behavior of the hydrocarbon fluid produced from the reservoir. Questions of:
What kind of fluids will be produced?
Will the crude solidify at the bottom temperature? For offshore fields
Will the produced gas be reinjected, sold or flared?

This has been a concern for Reservoir and Production Engineers as to maximize hydrocarbon recovery cost effectively in the minimum amount of time

Laboratory analysis of reservoir oil sample is the best way to determine the reservoir's bubble point pressure. Reservoir pressure-volume-temperature (PVT) analysis is carried out experimentally in the PVT laboratory by simulating the hydrocarbon fluid flow from the reservoir to the surface. During this process, the bubble point pressure is measured. The bubble-point pressure (Pb) is defined as the highest pressure at which a bubble of gas is first liberated from the oil. Bubble point pressure is a vital reservoir fluid property. A bubble test designates important information to the geologist about the expected recovery of the oil in a well. If the oil that will be recovered is undersaturated (containing very little dissolved gas), only a small percentage of the oil is recoverable without the use of some advanced recovery method. Determination of this property is used to evaluate the hydrocarbon behavior and also the probable technology for improved hydrocarbon recovery.

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The experimentally obtained PVT properties can be time consuming, expensive and may not be accessible and readily available. Consequently, researchers have developed so many correlations to determine the bubble point pressure and other oil properties.

The aim of this study is to develop a bubble point pressure correlation for a deep-water offshore region using a nonlinear multiple regression analysis.

LITERATURE REVIEW

Several correlations for predicting bubble point pressure have been presented from different locations. Literature has revealed that the most commonly used empirical correlations are the Standing (1947), Lasata (1958), Glaso (1980), Vazques and Beggs (1980), and Al-Marhoun (1988) correlations for predicting bubble point pressure, dissolved gas and oil formation volume factor. The following correlations by a few researchers are summarized:

Standing (1947) developed correlations to determine the bubble point pressure and formation volume factor from solution gas oil ratio, oil density, gas relative density, and temperature. The correlation was developed from 105 data points of 22 HC mixtures from California Region.

$$\mathrm{Pb} = a1 * [\left(\frac{Rs}{\Upsilon g}\right)^{a2} * \frac{10^{a3*T}}{10^{a4*API}} - a5]$$

Where a1 = 18.2, a 2 = 0.83, a3 = 0.00091, a4 = 0.0125, a5 = 1.4

Lasata (1958) used standard physical-chemical equations of solutions to develop correlations of ϒg and Pb of 158 data points from Canada West Mid Continental U.S.A and South America.

$$\mathrm{Pb} = \frac{[(pf)(T+459.67)]}{\Upsilon g},$$

$$\Upsilon g = \frac{\frac{Rs}{a1}}{\frac{Rs}{a1}+\frac{a2}{Mo}}$$

Where $\mathrm{Mo} = \mathrm{a3} - \mathrm{a4} * \mathrm{API} + \mathrm{a5} * \mathrm{API}^2$

$\mathrm{pf} = \mathrm{a6} - \mathrm{a4} * \Upsilon g + \mathrm{a5} * \Upsilon g\mathrm{I}^2$

a1 = 379. 3, a2 = 350, a3 = 725.32143, a4 = 16.03333, a5 = 0.09524, a6 = 0.38418

a7 = 1.20081, a8 = 9.64868

Glaso (1980) Proposed a correlation for an empirical correlation for bubble point pressure from solution gas oil ratio values (Rs) as a function of pressure (P), temperature (T), specific gravity (ϒg) and oil gravity (ϒo). He developed correlation was obtained from 45 laboratory measurements from the North Sea region.

$$\mathrm{Pb} = 10^{\mathrm{a1}+\mathrm{a2}*\log(\mathrm{G})-\mathrm{a3}*(\log(\mathrm{G}))^2}$$

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Where $G = \left(\frac{Rs}{\Upsilon g}\right)^{a4} * T^{a5} * API^{a6}$

a1 = 1.7669, a2 = 1.7447, a3 = 0.30218, a4 = 0.816, a5 = 0.172, a6 = –0.989

Vasquez and Beggs(1980) carried out a Worldwide crude oil system study of 5008 data points.

$$Pb = \left[\left(a1 * \frac{Rs}{\Upsilon g}\right) * 10^{-a3 * \frac{API}{460+T}}\right]^{\frac{1}{a2}}$$

$$\Upsilon gs = \Upsilon g * (1 + 5.915 * 10^{-5} * Tsep * API * \log(\frac{Psep}{114.7})$$

If API<=30 => a 1 = 27.64, a2 = 1.0937, a3 = 11.172

If API >30 => a1 = 56.06, a2 = 1.187, a3 = 10.393

McCain (1991) also carried out a Worldwide crude oil system study of 100 pressure data points**.**

$$Pb = a1 * (Cpb - a2)$$

$$Cpb = \left(\frac{Rs}{\Upsilon g}\right)^{a3} * 10^{(a4*T - a5*API)}$$

Where a1=18.2, a2=1.4, a3=0.83, a4=0.00091, a5=0.0125

Al Marhoun (1988) developed a correlation for estimating bubble point pressure from the Middle Eastern crude oil system. The data was generated from 160 experimental pressure data. $Pb = a1 * Rs^{a2} * \Upsilon g^{a3} * \Upsilon o^{a4} * (T + 460)^{a5}$

Where a1 = 5.38088e-3, a2 = 0.715082, a3 = –1.877840, a4 = 3.143700, a5 = 1.326570

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$$Pb = a1 * (Cpb - a2)$$

$$Cpb = \left(\frac{Rs}{\Upsilon g}\right)^{a3} * 10^{(a4*T - a5*API)}$$

Where a1=18.2, a2=1.4, a3=0.83, a4=0.00091, a5=0.0125

Petrosky and Farshad (1993) carried out a PVT analysis on 81 laboratory data from Gulf of Mexico crude oil system. They developed a gas solubility correlation using a nonlinear regression software.

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$$Pb = a1 * [\left(\frac{Rs^{a2}}{\Upsilon g^{a3}}\right) * 10^{x} - a4]$$
$$x = a5 * T^{a6} - a7 * API^{a8}$$

a1 = 112.727, a2=0.5774, a3 = 0.8439, a4 = 12.340, a5 = 4.561e-5, a6=1.3911, a7= 7.916e-4

Al-Shammasi (1999) published a neural network model for oil formation volume factor consisting of two hidden layers, five nodes in the first layer and three in the second layer. The model used 1161 Worldwide data sets.

$$Pb = \Upsilon o^{a1} * \left(Exp(a2 * \Upsilon g * \Upsilon o)\right) * (Rs * T + 460) * \Upsilon g)^{a3}$$

Where a1=5.527215, a2=-1.841408, a3=0.783716

Ikiensikimama & Ogboja (2009) Performed a correlation on 250 data sets of a Niger Delta crude sample.

$$\Upsilon g = \frac{\frac{Rs}{a1}}{\frac{Rs}{a1} + (a2 * \frac{\Upsilon o}{S})} \qquad S = (a3 - a4 * API)^{a5}$$
$$Pb^{*} = a6 + a7 * Q + a8 * Q^{a9}$$

a1= 336.0064009, a2 = 6.7063984, a4 = 0.677706662, a3 = 47.57094772
a5= 1.530935619, a7 =-2.316548789, a6 = 0.243181338, a8= 10.60657909
a9 = 1.518030465, a10 = 635.4152349

Moradi (2010) Performed a multiple regression analysis of bubble point pressure on 1801 data sets from the Middle East.

$$Pb^{*} = a1 * LOG(API) * \left(\frac{141.5}{\Upsilon o} - 131.5\right)^{a1} * \left(\left(EXP(a3 * \Upsilon g * \Upsilon o)\right) * (Rs * (T + 460) * \Upsilon g)^{a4}$$
$$Pb = a5 * Pb^{*} + a6 * Pb^{*2} + a7 * Pb^{*3}$$

Moussa et al. (2017) Developed a model by utilizing a novel comprehensive approach using hybrid Self-adaptive Differential Evolution and Artificial Neural Network (SaDE- ANN) that could be used as a robust and effective model to predict Pb and Rs of crude oils based only on oil and gas gravities in addition to the reservoir temperature.

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Developing the Bubble Point Pressure Correlation

Data Analysis

For this work, a total of 176 data sets originated from a Deep-Offshore region were collected to confirm the accuracy of this work. The Data used consists of reservoir temperature, oil gravity, solution gas oil ratio, and average gas gravity for bubble point pressure. Microsoft Excel solver application was utilized for the regression equations.

Table 1: Data Range

PVT Parameter	Min.	Max.	Mean
BHP. (Psi)	4520.375	5358.965	6109.43
Rsi (scuft/Bbl)	1137.629	5540.787	15909.06
API	38.13	49.6183	55.85
T (°F)	159.038	193.35561	215.054
ϒg	0.5804026	1.98943	1.864004

The generalized relationship utilized for this empirical bubble point pressure correlation is developed by Standings

$$Pb = f(Rs, \overline{\Upsilon g}, \Upsilon o, T) \quad \text{Eq. 1}$$

The nonlinear multiple regression analysis was used to develop the following relation:

$$Pb = a1\ (\Upsilon o^{a2} * \Upsilon g^{a3} * T^{a4} * Rs^{a5}) \quad \text{Eq. 2}$$

Table 2: Bubble point pressure Coefficients

a1 = 67.3506	a2= 2.313833
a3 = 1.066621	a4 = 0.682024
a5 = 0.070147	ϒg= 1.864004

The Average Absolute Percent Error (AAPE) is measured as 4.8%. This indicates that there is a strong agreement between the experimental and estimated value.

$$E_a = \left(\frac{1}{n_d}\right) \sum_{i=1}^{n_d} |E_i| * 100$$

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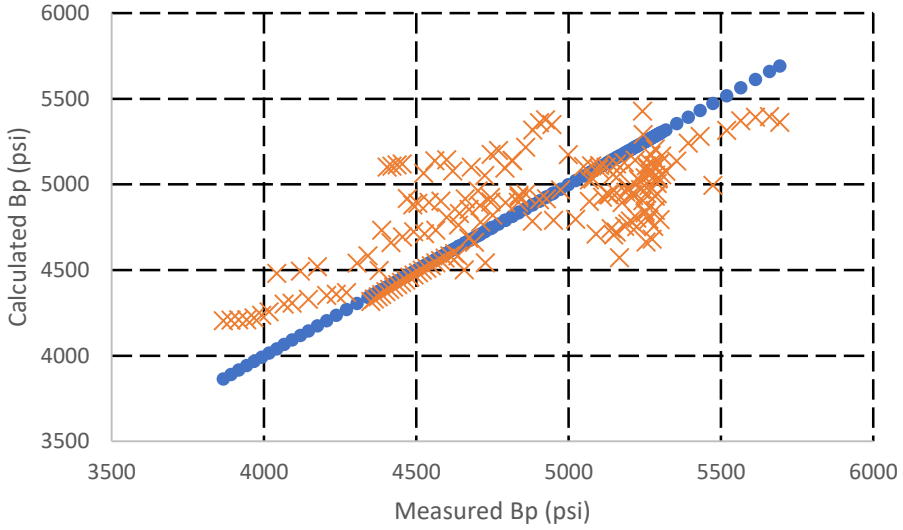

Figure 1: Cross plot of Bubble Point Pressure

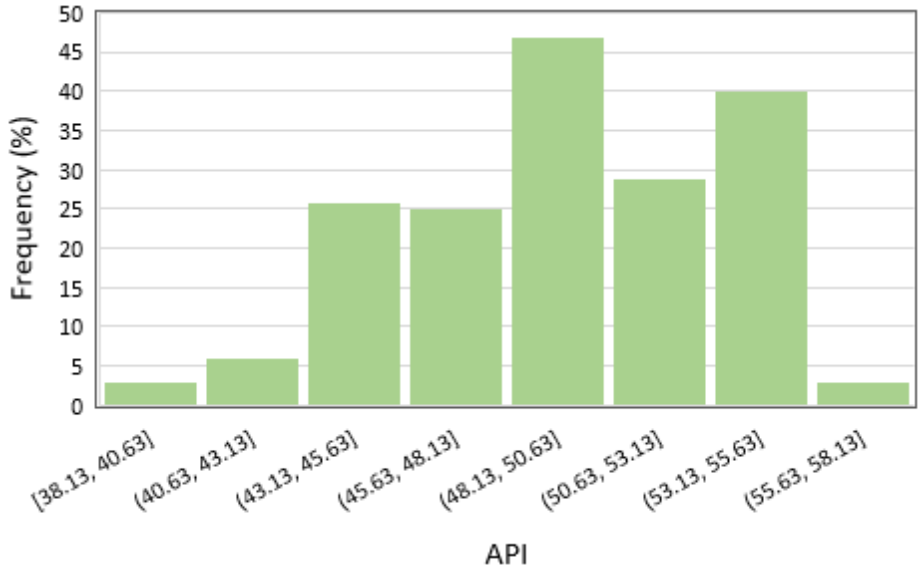

Figure 2: API Distribution Chart

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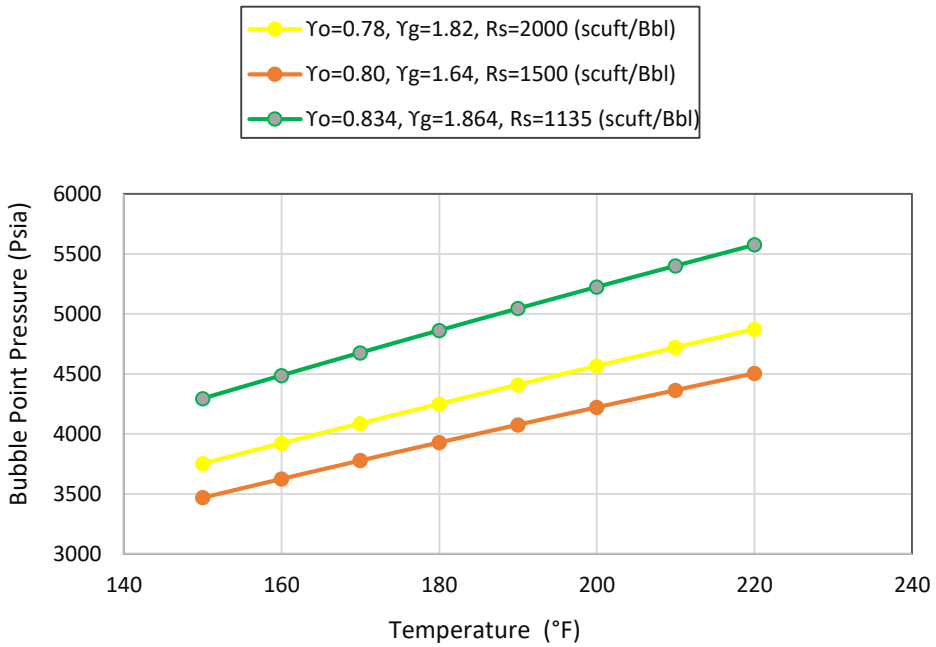

Figure 3: Effect of temperature on bubble point pressure at different Rs, gas and oil API gravity,

CONCLUSION

The accuracy of bubble point prediction is important to the petroleum engineers to characterize the oil reservoir and to account for oil in place. The result generated from this correlation was analyzed statistically and the Average Absolute Percent Error (AAPE) gotten is 4.8%. The correlation developed is an empirical correlation for Deep-Offshores region.

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