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Predicting fluid properties with new PVT correlations based on Libyan crudes

Alkhaboli M*

Department of Petroleum Engineering, University of Tripoli, Libya

***Corresponding Author:** M Khazam, Department of Petroleum Engineering University of Tripoli, Tripoli, Libya. Tel.: +218 21-4627901; E-mail: mohsenkhazam@gmail.com

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Abstract

PVT properties are very important in reservoir and production engineering analyses such as material balance calculations, well testing, reserve estimation, inflow performance, production operations and design of surface facilities. New empirical PVT correlations have been developed for Libyan crudes with reliable degree of accuracy. These include; bubble point pressure (Pb), oil formation volume factor (Bo), gas solubility (Rs), stock tank oil molecular weight (Mwt), dead oil viscosity (μod), saturated oil viscosity (μob), under-saturated oil viscosity (μo), and oil compressibility (Co). Around 300 PVT samples collected exclusively from Libya, mainly Sirte, Ghadames and Murzuq basins, were used in our study to develop the above PVT correlations and covered wide range of API gravity (26 to 51°API) and reservoir temperature normally found in Libyan reservoirs. Minitab regression tool was extensively used in our study to develop the PVT correlations and to statistically appraise them against the industry published correlations. The new proposed PVT correlations have demonstrated much better performance compared to the industry published correlations when tested for Libyan crudes. Also, Artificial Neural Network (ANN) models have been developed for Libyan PVT properties predictions. The models show acceptable accuracy and generally are more accurate than the empirical correlations.

Introduction

The PVT properties are important parameters in reservoir engineering. However, these PVT properties are usually determined from laboratory studies, but in some cases where adequate samples cannot be obtained or during exploration phase, when only produced fluid properties are available from flowing tests, one can rely on the empirical PVT correlations for predicting the physical fluid properties. Such PVT correlations will help the reservoir and production engineers to obtain a preliminary estimate of the oil initially in place, calculation of the recovery efficiency, production capacity, variations in produced gas or oil ratios during reservoir's production life, etc. During the last 7 decades, several PVT correlations have been published. These empirical correlations are developed based on different data banks and different geographical regions. One of the early attempts for establishing PVT correlations was made by Standing. Graphical correlations were proposed for Pb, and Bo based on 105 experimentally measured data points which were collected from 22 hydrocarbon systems of California oil fields. In 1958, Lasater presented a Pb and Rs correlations based on 158 experimentally measured bubble-point pressures using 137 different crude oil systems from reservoirs in Canada, the U.S., and South America. The natural gases associated with these crudes were essentially free of non-hydrocarbons. Vazquez and Beggs presented a worldwide empirical correlation based on 5008 PVT measurements of 600 samples from all over the world using regression methods. They divided collected data into two groups based on API gravity, so that coefficients of developed correlation are different for these two groups. Also they introduced gas gravity at the reference separator pressure (γgs) and used this adjustment factor instead of gas gravity to improve performance of their correlations. In 1980, Glaso proposed empirical correlations for estimating Pb, FVF at saturation pressure, and two-phase FVF. His correlations were derived from the laboratory PVT analyses of North Sea oil which has paraffinicity characterization factor of 11.9, and they can be used for other types of oil/gas mixtures after corrected for the content of non-hydrocarbons in surface gas and paraffinincity. In 1988, Al- Marhoun developed correlations for estimating. These correlations were developed from a database of 69 bottom hole fluid samples and expressed as functions of reservoir temperature, gas gravity, solution gas-oil-ratio, and the stock tank oil gravity. Al-Marhoun used nonlinear regression methods to develop his correlations. In 1990, Petrosky developed empirical PVT correlations for Gulf of Mexico crude oils. His correlations included derived from a total of 128 laboratory analyses. In 1990, Labedi presented correlations for estimating oil FVF, oil density, and oil compressibility. His correlations are mainly function of measurable field data such as first-stage separator pressure and temperature, producing gas/oil ratio, stock-tank oil gravity, reservoir pressure, and reservoir temperature. More than 100 oil samples from three African countries, namely Libya (97 samples), Nigeria (27 samples), and Angola (4 samples) were used for developing his correlations. In 1994, Kartoatmodjo and Schmidt developed a new set of empirical correlations based on a large data collection from reservoirs all over the world.

Data Points and Statistical Indicators

All the data points used in this study are exclusively obtained from Libya, mostly for reservoirs from Sirte, Ghadames, Murzuq and offshore basins. On average basis, around 300 PVT sample data points were initially obtained for each property. The actual number of data points after excluding incompetent measurement and screening for unreasonable values are shown in Table 1 below. This table describes the range and number of experimental data points used in our study. Wider range of fluid properties is used in developing our PVT correlations making them much more representative for the crudes of Libya. In order to evaluate the predictions of the PVT correlations in terms of their accuracy, or their dispersion, or even their representation of the suggested model to the measured data. It should be pointed out that no individual statistical indicator should be thought upon as the ultimate gauge that can decide which correlation is better. Choosing the best correlation was assessed with many statistical indicators and was looked upon as an optimization process where each statistical indicator complements the others. Also scatter plots were constructed along with Pearson correlation in order to evaluate the relationships between variables to help in the process of formulations the new correlations. Residual plots, 3D plots and 45 degree plots were also constructed, beside the statistical indicators, in order to evaluate and visualize the suggested models compared to former studies.

Conclusions

New empirical PVT correlations have been developed for Libyan crudes with reliable degree of accuracy. These include; bubble point pressure, oil formation volume factor, gas solubility, stock tank oil molecular weight, dead oil viscosity, saturated oil viscosity, under-saturated oil viscosity, and oil compressibility. Around 300 PVT data point samples from Sirte, Muruzq, Ghadamis, and offshore basins were collected, screened and utilized for our study. These covered wide range of crude oils gravity ranges between them and reservoir temperature normally found in Libyan reservoirs. Minitab regression tool was extensively used in our study to develop the PVT correlations and to statistically appraise them against the industry published correlations. The new proposed PVT correlations have demonstrated better performance compared to the industry published correlations tested for Libyan crudes. Artificial Neural Network (ANN) models have been developed for Libyan PVT Property's predictions. The models show acceptable accuracy and are marginally accurate than the proposed empirical correlations.