EVALUATION OF EMPIRICAL PVT CORRELATIONS AND EOS TUNING TO MODEL LIBYAN CRUDE OIL PROPERTIES USING PVTi SOFTWARE

Wahid R. Shtewi, Msc.*

Abstract: Understanding the PVT properties is very important to many kinds of petroleum determinations such as calculations of reservoir fluid properties, expect the future performance, selection of enhanced oil recovery methods, and production facilities design. Predict forcasting the reservoir fluid properties through imperical models have been increased during the last decade by knowing reservoir pressure and temperature, oil API gravity, and gas gravity. Correlations are used whenever experimentally derived PVT data are not available and data from local regions are expected to give better approximation to estimated PVT values.

In this paper, complete PVT lab experiments were done and then evaluate the most frequently used empirical black oil PVT correlations for application in the Middle East. Empirical PVT Correlations for Middle East crude oil have been compared as a function of commonly available PVT data. Correlations have been compared for: bubble point pressure; solution gas oil ratio, oil formation volume factor, and oil viscosity. After evaluates the Empirical correlations the crude sample was characterized using different EOS to arrive at one EOS model that accurately describes the PVT behavior of crude oil produced. The multi-sample characterization method is used to arrive at one consistent model for crude oil for the whole reservoir. The fluid sample is first analyzed for consistency to make sure that they are representative of oil produced, and then it is used to obtain parameters for EOS model. The tuning procedure for the EOS is done systematically by matching the volumetric and phase behavior results with laboratory results. Results showed some correlations gives good results and can be used with Libyan oil and some gives high percentage of error. For EOS all of them need tuning because mismatching with lab data but after regression a very good match of PVT properties predicted are getting.

Keywords: PVT proerties, Bubble point pressure, Solution gas oil ratio, Oil formation volume factor, Oil viscosity, Emperical correlations, EOS.

INTRODUCTION

The PVT studies or analysis is very important in petroleum engineering, it is considered as the main part for petroleum reservoir studies, the selection of enhanced oil recovery techniques, production equipments design and the evaluation of the recovery efficiency of oil fields. In the lack of PVT data for any reason; correlations are used to get the physical properties of reservoir hydrocarbons (Hemmati and Kharrat, 2007).

A reservoir PVT behavior can be very complicated especially when the composition and PVT properties vary with depth, or when different geological formations produce significantly different fluids from the same field. The PVT behavior cannot be described properly by a single set of PVT properties, where composition, saturation pressure, API oil gravity, producing GOR and reservoir temperature may vary (Danesh, 1998). As a result the PVT data are considered to be essential and need to be updated continuously. Thus, understanding, handling and using the resulting data from traditional PVT reports is of great importance to the petroleum engineers. It is worth mentioning that PVT data to be feed into the black-oil or compositional simulator can be obtained from empirical correlations, laboratory measurement, and EOS fluid characterization (McCain, 1990).

In reservoir performance estimations the Empirical PVT correlations which are generally used in petroleum engineering are very vital tools. The PVT parameters usually obtained from lab experiments by using representative samples. But, reservoir fluid properties must be calculated when detailed laboratory PVT data are not available. Because the chemical

*Petroleum Engineering, Specialist in Reservoir Fluid section (PVT lab) Libyan Petroleum Institute Tripoli/Libya Email: w.shtewi@lpilibya.com

composition of crude oil differs from region to region, the geological conditions must be considered for modified or developing correlations.

Equations of State E.O.S are increasingly being used to model fluid properties of crude oil and gas reservoirs. This technique offers the advantage of an improved fluid property prediction over conventional black oil models. Once the crude oil or condensate fluid system has been probably characterized, its PVT behavior under a variety of conditions can easily be studied. This description is then used, within a compositional simulator, to study and choose among different scenarios for EOR schemes, such as miscible gas injection for oil reservoirs or liquid recovery under lean gas injection for condensate reservoirs (PVTi Refernce Manual, 2014).

GETTING PVT PROPERTIES TECHNIQES

Labortary Experiments

Typical tests are performed on bottom hole or surface samples to characterize the hydrocarbon fluids. They involve differential test, constant mass expansion, constant volume depletion, and flash separation tests and the measurement of the fluid composition, molecular weight, specific gravity, viscosity, compressibility, saturation pressure, formation volume factor, solubility. These tests are designed to simulate to the thermodynamic reservoir processes. Although some assumptions where applied, and some other real factors were not considered (such as the presence of porous media and water phase) testing results are considered to be an important source of data in reservoir engineering calculations (Ahmed, 1989; Bradley, 1987). The three main application areas of the PVT data are:

- To provide data for reservoir calculations.
- To provide physical property data for fluid flow calculations.
- For designing surface production facilities.

Oil System Correlations

The knowledge of physical properties for reservoir fluids are very important to petroleum engineers for both reservoir and production estimations. For reservoir performance studies these properties should be calculated at reservoir temperature and various pressures, and for wellbore hydraulics determinations at conditions of both changing temperature and pressure.

If reservoir fluid samples are available, the fluid properties of interest can be measured with a pressure-volume-temperature (PVT) analysis. However, these analyses usually are conducted at reservoir temperature only and the variation of the properties with temperature is not available for production system calculations. Also, in many cases a PVT analysis may not be available at the beginning of the reservoir life or may never be available because of economic reasons. To overcome these obstacles, empirical correlations have been developed for predicting various fluid physical properties from limited data. The main purpose of correlations is for estimating properties of reservoir fluids such as:

- Bubble Point Pressure (Al-Marhun,1988; Khazame, 2016; Dokla and Osman, 1992; Vasquez & Beggs, 1980; Petrosky and Farshad, 1990; Glaso, 1980).
- Oil Formation Volume Factor (Vasquez & Beggs, 1980; Al-Marhun,1988; Petrosky and Farshad, 1990; Glaso, 1980).
- Gas Oil Ratio. (Vasquez & Beggs, 1980 ; Al-Marhun, 2002; Petrosky and Farshad, 1990; Glaso, 1980).
- Crude Oil Viscosity (Chew and Connally, 1959; Beggs and Robinson,1975; Glaso, 1980).

Equation of State Simulation

"Equation of State" is defined as an analytic expression relating pressure to temperature and volume.

Because of relatively high cost of performing the experimental PVT tests and the uncertainties in the accuracy of such laboratory measurements, equation of stat offer an attractive approach for generating these necessary data.

The major goal of reservoir simulation is to predict future performance of the reservoir and find ways and means of optimizing the recovery of some of the hydrocarbons under various operating conditions.

CONDUCTED WORK & RESULTS

Part One: Evaluation of PVT Correlations

Complete PVT analysis including direct flash, constant composition expansion (flash liberation process), differential liberation process, and oil viscosity tests were conducted for reservoir oil sample from one of Libyan oil fields.

In this part, all the PVT experiments were conducted in the PVT lab of the Libyan Petroleum Institute then the results of experiments were compared with the results from the Empirical correlations. All tests at reservoir temperature 204 °F:

- **Bubble Point Pressure, P_b:**
  The Experimental P_b = 660Psia
- **Oil Formation Volume Factor, B_{oi}:**
  The Experimental B_o = 1.0965 bbl/STB
- **Gas Oil Ratio, R_{si}:**
  The Experimental R_s = 93 Scf/STB
- **Oil Viscosity:**

Experimental dead oil viscosity =5.705cp
Experimental bubble point (saturated) oil viscosity = 4.915 cp
Experimental under saturated oil viscosity at reservoir P=2686 psia & T =204 F° =5.184cp
To evaluate the Empirical correlations for estimating the oil viscosity, the viscosity by correlations in three faces have to be determined at dead oil, saturated oil, and under saturated oil viscosity and compare them with the lab results.

Part Two: Equation of State Model
Simulation of PVT lab data by E.O.S (PVTi software)

In this part, the PVTi software was used to simulate the Laboratory PVT data by using the scenario of entered the reservoir component up to C7+(with impurities N_2, CO_2, H_2S) and tuning by changing these parameters, binary interaction parameter (BIP), omega a parameter (Ω_a), acentric factor parameter (ω), and Zc for oil viscosity. All results of comparison and model are illustrated in tables 1-8 and figures 1-3

CONCLUSIONS

The followings are the main conclusions that can be withdrawn from this study:

1- Complete PVT lab studies have been done for Libyan oil samples to compare the properties with the empirical correlations for Middle East crude oil and the results show that there is a clear difference.
2- The results of evaluation show that some of correlations are reliable to use with Libyan crude oil and others give high percentage of error.
3- Average absolute relative error is an important indicator of the accuracy of an empirical model; it is used in this study as a comparative criterion for testing the accuracy of correlations.
4- The oil formation volume factor correlation provided the best accuracy of the correlations evaluated.
5- Characterization the experimental data by PVTi software show that when we use the original Equation of State to predict the previous PVT properties, we have got unsatisfactory results and all the E.O.S needs tuning.
6- After regression we found that:
   - There are a good match with lab results.
   - The bubble point pressure is very sensitive to the omega A and Tc.
   - The best EOS are 3parameter Peng_Robinson (PR3) and 3parameter Soave_Redlich_Kwong (SRK3), while Radlich_Kowng (RK) proved to be the worst one.
   - For oil viscosity the ZJ correlation gives high percentage of error so it's not advised to use.
   - The best regression for oil viscosity by change Zc parameter.

Table 1: Experimental and Calculated Pb, Psia.

Correlation	Experimental P_b	Calculated P_b	Abs. Error %
Standing	660	615	6.8
Glaso	660	596	10.7
Vesquez	660	609	7.7
Marhoun	660	746	11.5
Petrosky	660	632	4.4
Dokla	660	539	18.3
Mohsen Khazam	660	797	20.8
Valko & Mccain	660	631	4.4
Omar &Todd	660	702	6.3
Al-shammasi	660	667	1.1
Macary & Elbatanoney	660	806	22
Mehran	660	652	1.2

Table 2: Experimental and Calculated Bo, bbl/STB.

Correlation	Experimental B_o	Calculated B_o	Abs. Error %
Standing	1.0965	1.1091	1.15
Glaso	1.0965	1.0802	1.5
Vesquez	1.0965	1.1189	2
Marhon	1.0965	1.1303	3
Petrosky	1.0965	1.0961	0.03
Material Balance	1.0965	1.0190	7
Schmidt	1.0965	1.1273	2.8
Arps	1.0965	1.0965	0

Table 3: Experimental and Calculated Rs, Scf/STB

Correlation	Experimental R_s	Calculated R_s	Abs. Error %
Standing	93	529	469
Glaso	93	442	375
Vesquez	93	471	407
Marhon	93	558	500
Petrosky	93	475	411
Velarde	93	553	495
Hanafy	93	789	748
De Ghetto	93	213	129

RECOMMENDATIONS

From this study, it is recommended that before using the Empirical correlations in reservoir calculations, make sure that they can be used for estimating the same PVT parameters for all types of oil and gas mixture with properties falling within the range of data for each correlation. With Libyan crude oil we advice to modify a new correlations that special for Libyan oil. When we use any simulator we should to choose the right parameter for tuning to get good match model.

Table 4: Experimental and Calculated oil viscosity

Dead Oil Viscosity			
Correlation	Experimental μ_{od}	Calculated μ_{od}	Abs. Error %
Beal's	5.705	3.334	41.5
Beggs	5.705	3.291	42.3
Glaso	5.705	3.793	33.5
Saturated Oil Viscosity			
Correlation	Experimental μ_{ob}	Calculated μ_{ob}	Abs. Error %
Chew	4.915	4.059	17.4
Beggs	4.915	3.129	36.3
Under-Saturated Oil Viscosity			
Correlation	Experimental μ_o	Calculated μ_o	Abs. Error %
Beggs	5.184	6.885	32.8

Table 5: Experimental and simulated Pb

Equation	P_b lab	Pb before tuning	ADD%	Pb After tuning	ADD%
PR3	660	403	39	660	0
SRK3	660	395	40	660.18	0.02
RK	660	267	59.5	478	27.5
ZJ	660	398	39.6	660.3	0.04

Table 6: Experimental and Simulated Bo

Equation	B_o lab	Bo before tuning	ADD%	Bo After tuning	ADD%
PR3	1.0965	1.1151	1.7	1.1112	1.3
SRK3	1.0965	1.1223	2.3	1.0781	1.68
RK	1.0965	1.1791	7.5	1.0965	0
ZJ	1.0965	1.1474	4.6	1.1096	1.2

Table 7: Experimental and Simulated Rs

Equation	R_s lab	Rs before tuning	ADD%	Rs After tuning	ADD%
PR3	93	81.9	12	89.3	4
SRK3	93	84.4	9.2	76	18
RK	93	74.3	20	75.5	19
ZJ	93	85.6	7.9	87.9	5.5

Table 8: Experimental and Simulated oil viscosity

Dead Oil Viscosity					
Equation	μ_{od} lab	Before tuning	ADD%	After tuning	ADD%
PR3	5.705	4.121	27.7	6.764	18.5
SRK3	5.705	3.834	32.7	5.022	11.9
RK	5.705	1.084	80.9	2.458	56.9
ZJ	5.705	3.420	40	13.219	132
Saturated Oil Viscosity					
Equation	μ_{ob} lab	Before tuning	ADD%	After tuning	ADD%
PR3	4.915	3.674	25.3	4.774	2.868
SRK3	4.915	3.463	29.5	4.815	2
RK	4.915	1.072	78.2	2.382	51.5
ZJ	4.915	3.111	36.7	11.893	142
Under-Saturated Viscosity					
Equation	μ_o lab	Before tuning	ADD%	After tuning	ADD%
PR3	5.184	4.583	11.6	5.773	11.3
SRK3	5.184	4.617	10.9	5.742	10.7
RK	5.184	1.326	74.4	2.959	42.9
ZJ	5.184	3.827	26.2	14.289	175

NOMENCLATURES

PVT pressure-volume-temperature
B_o oil formation volume factor, bbl/STB
API stock-tank oil gravity, APIo
GOR gas oil ratio
OFVF oil formation volume factor
P_b bubble point pressure, psia
Rs solution gas-oil-ratio, SCF/STB
SCF standard cubic feet
STB stock tank barrel
Y_g gas specific gravity (air = 1)
Y_o oil specific gravity (water = 1)
T reservoir temperature, °R
μ_o viscosity of under-saturated oil, cp
μ_{ob} viscosity of saturated oil, cp
μ_{od} viscosity of the dead oil as measured at 14.7 psia and reservoir temperature, cp
EOS equation of state
SCF standard cubic feet
STB stock tank barrel
SW schmidt-wenzel E.O.S
PR peng-robinson E.O.S
RK redlick-kwong E.O.S
SRK soave-redlick-kwong E.O.S

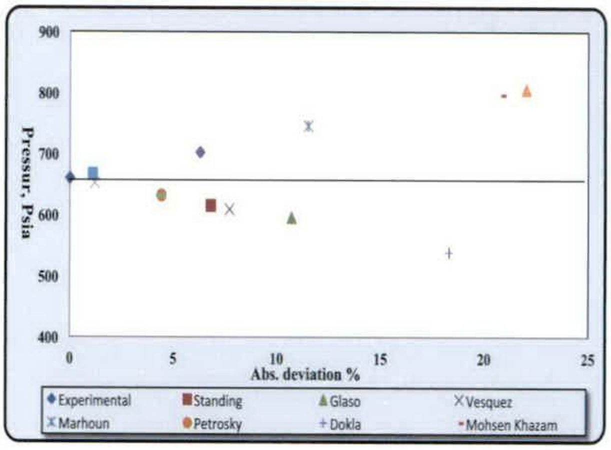

Fig. 1. Experimental and Calculated Pb

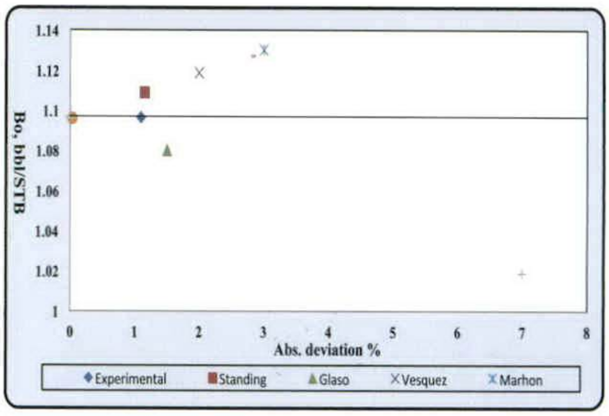

Fig. 2. Experimental and Calculated Bo

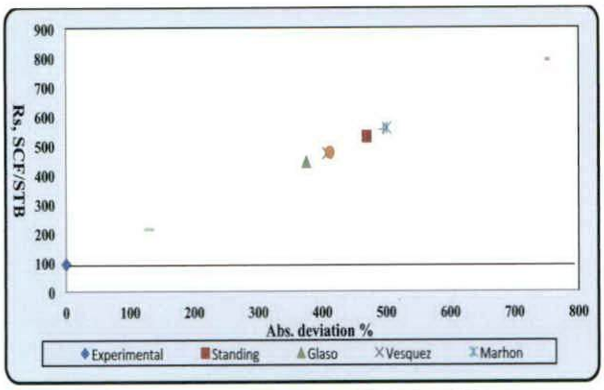

Fig. 3. Experimental and Calculated Rs

REFERENCES

Ahmed, T. (1989). Hydrocarbon Phase Behavior. *Gulf Publishing Company*, Houston, Texas, ***V.*** *7*: 136-244.

AL-Marhoun, M. A. (1988). PVT Correlations for Middle East Crude Oils, *JPT*, ***V. 40(5)***: 650-666.

AL-Marhoun, M. A. (2002). Reservoir Fluid Properties–State of the Art and Outlook for Future Development. *Distinguished Lecturer Program SPE*: 2001-2002.

Beggs, H. D. & Robinson, J. R. (1975). Estimating the Viscosity of Crude Oil Systems. *JPT*, P.P 1140-1141.

Bradley, H. B. (1987). Petroleum Engineering Handbook, *Third Edition*, USA, *Society of Petroleum Engineers*: 680.

Chew, J. and Connally, C. A. (1959). A Viscosity Correlation for Gas-Saturated Crude Oils. *Trans. AIME*, ***V. 216***: 23-25.

Danesh, A. (1998). PVT and Phase Behavior of Petroleum Reservoir Fluids, *First Edition*, Amsterdam, Elsevier Science B.V. 403.

Dokla, M. F. and Osman, M. E. (1992). Correlation of PVT Properties for UAE Cruds. *SPE*: 80-81.

Glaso, O. (1980). Generalized Pressure-Volume-Temperature Correlations, *JPT:* 785-795.

Hemmati, M. N. and Kharrat, R. (2007). Evaluation of Empirically Derived PVT Properties for Middle East Crude Oils. *Scientia Iranica*, ***V. 14(4)***: 358-368.

Khazame, M. (2016). New PVT Correlations Based on Libyan Crudes for Predicting Fluid Physical Properties, *Oil and Gas Reaserch*, ***2016***:1-9.

McCain, W. D. (1990). The Properties of Petroleum Fluids, *Second Edition*, Tulsa, OK, USA: Pennwell Books: 584.

McCain, W. D. (1991). Reservoir-Fluid Property Correlations–State of the Art. *SPE*: 266-272.

Petrosky, G. E. & Farshad F. F. (1990). Pressure-Volume-Temperature Correlations For Gulf of Mexico Crud Oils, *SPE Paper No.26644*.

PVTi Software Technical Description file (2014). Schlumberger Refernce Manual.

Vasquez, M. and Beggs, D. (1980). Correlations for Fluid Physical Properties Prediction. *JPT*: 968-970.