# Impact of physical properties on material balance calculations: case study AL-Nasr oil field, Shabwah Governorate

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## Abstract

The accuracy of many petroleum engineering calculations (e.g., material balance calculations, reserve estimation, well test analysis, advanced production data analysis, nodal analysis, surface network modeling, surface separation, and numerical reservoir simulations) largely depends on the accuracy of the data on pressure, volume, and temperature (PVT). An approach to improve the material balance calculation method is presented in this study.

To achieve the objective, PVTP and MBAL Software programs were applied. PVT model was built by different methods. Software was implemented to calculate stock-tank oil, initially in place (STOIIP), using different approaches. Sensitive analysis was performed to investigate the effect of different parameters on material balance calculation. Illustration of the proposed approach was done on the data obtained from AL-Nasr oil field.

The Average absolute error of PVT properties such as bubble-point pressure, relative volume, oil formation volume factor,Solution gas oil ratio and oil density is used to compare between actual and calculated values. Results showed a good agreement. History production (cumulative oil production, cumulative gas production, cumulative water production) were also calculated to investigate the match between history parameters and calculated parameters. Results indicated that the impact of PVT errors on material balance calculations can be significant.

**Keywords:** material balance, PVT,modeling, Yemen,Shabwah Governorate.

## Introduction:

The material balance equation has long been regarded as one of the basic tools of reservoir engineers for interpreting and predicting reservoir performance. The material balance equation (MBE) can be used to estimate initial hydrocarbon volumes in place or to predict future reservoir performance and the ultimate hydrocarbon recovery under various types of primary driving mechanisms.

On the other hand, the classical material balance approach is very simple and it provides a valuable insight into the behavior of hydrocarbon reservoirs. It is necessary to accept that material balance is complementary to simulation.

The MBE calculations require production/injection data, pressure, PVT data, aquifer properties in order to quantify the original oil in place (OOIP or N) and drive mechanisms.

OOIP calculations, based on material balance calculations,are strongly affected by data uncertainty. Uncertainty, due to data errors,can be found in the above-mentioned data separately or together.

Usually, it is expected that the production data (oil or gas) are measured with confidence since the measurement equipment are highly technologic and can be trusted incomparison to the past Reservoir pressure which is more uncertain due to the lack of pressure measurements from wells in the field to find an average value of reservoir pressure.

PVT data can also be uncertain since, very often, PVT correlations which may be non-representative or incorrect pressure- volume- temperature (PVT) data are selected to be used in material balance calculations.

PVT data can include errors since it may not be possible to have a representative fluid sample of the reservoir. Laboratory measurements can also have errors.

The effect of data errors on reservoir engineering calculations, typically on material balance calculations, have been studied by several investigators [2,4,5,6,7,9,11,13,4,8].

Effect of PVT data error on material balance have been studied by many authors [1,7,11,13].However, it still not enough works on the effect of PVT errors on material balance calculation.

The aim of this study is to present an approach to improve the material balance calculation methods.

### The Effects of errors in PVT data on reserve estimation

The effect of data errors on reservoir engineering calculations typically on material balance calculations have been studied by several investigators [2,4,5,6,7,9,11,13,4,8].

Inaccurate estimation of PVT properties can lead to significant errors in calculation results. Trengove et al. [12] reported the effects of changing PVT data on simulation results in the case of a gas condensate reservoir. They used an equation of state (EOS) program to match the laboratory-measured PVT data and to produce modified black-oil (MBO) PVT functions for further use in reservoir simulation. They observed that variation in PVT data resulted in variation in MBO properties, leading to errors in recovery predictions from the simulator. Spivey and Pursell [10] studied the effects of errors in PVT data on well test analysis interpretation results. They showed that errors in fluid compressibility affect the interpreted distance to boundaries. Ambastha and van Kruysdijk [1] performed an error analysis study to quantify the effect of errors in the material balance equation for volumetric gas reservoirs. They concluded that errors in gas PVT data (z-factor and two-phase z-factor), in addition to errors in reservoir pressure, can produce significant errors in the calculated original gas-in-place (OGIP) volumes. They used Monte Carlo simulation techniques to generate many cases for the investigation of the upper and lower bounds for OGIP estimation errors expected from the errors in input data. The reported errors in OGIP reached 80% or more.

Baker et al. [2] studied the effect of PVT data errors on material balance equation results for oil reservoirs. They studied the use of PVT correlations to derive PVT data for material balance analysis. They concluded that deriving PVT data from correlations without tuning the correlation to match the solution gas oil ratio above the bubble point pressure could lead to significant errors in results of material balance analyses. They concluded that the impact of PVT errors on material balance results could be significant in two cases: if the decrease in reservoir pressure over the production history of the reservoir is small, or if the oil is highly volatile.

## Research Methodology:

To achieve the above-mentioned objectives, the following methodology is used.

The methodology is based on the application of PVTP and MBALSoftware programs. PVTP program is used for modeling PVT properties and performing matching and regression.In material balance calculations, the procedure STOIIP is calculatedusing PVT lab data as a base case. The calculation repeated using different correlations. After that, the calculation of OOIP is using matched correlations. Finally, the calculation of STOIIP is conducted,using improved PVT model.

The effect of different PVT parameterson material balance calculations and STOIIPis studiedbychanging properties, repeating calculation and comparing the results relative to the base case.

### Data Acquisition:

The data used for this study were obtained from a reservoir fluid study report (PVT) for Yemeni crude oil from AL-Nasr oil field, namely compositional analyses of sample,Constant Composition

Expansion, separator test, differential liberation test was used. The production history and reservoir data were also used.

## Results and Discussions:

In this section the, data obtained from PVT analysis were used for the purpose of simulation the different PVT tests by EOS model using PVTP software program after that the output data were entered into MBAL software to calculate the STOIIP. The effect of the error in fluid properties on the STOIIP was also studied. The results obtained are presented as follows.

### Modeling of PVT for AL-Nasr oil field

The proposed approach for improving material balance calculations is based on modeling PVT properties and is implemented according to the used methodology. Three approaches were followed to investigate the effect of PVT properties on the material balance calculations. A summary of these approaches is presented in Table(1).

**Table 1:**Different approaches used in this study

| | |
|---|---|
| Approach-1 | Simulation PVT data by using tuned EOS modeling |
| Approach-2 | PVT Simulation using EOS without tuning |
| Approach-3 | PVT Simulation data using correlations |

### Simulation Data by using EOS modeling

The PVT parameters and properties were calculated according to the first proposed approach and the results of the calculations were compared with the laboratory data. Results of modeling and calculating the bubble point pressure, using splitting and regression, are shown in Table.2.

**Table2:** Simulated and calculated bubble point pressure

| Bubble point pressure-splitting | | **AAE%** |
|---|---|---|
| Pb – Laboratory | 892 | |
| Pb – Calculated | 881.589 | **1%** |
| Bubble point pressure-regression | | |
| Pb – Calculated | 877.513 | **2%** |

As can be seen in table (2) there is good matching between the laboratory data and the simulated values.

A comparison of laboratory data calculated, using the equation of state for relative volume, oil formation volume factor, gas oil ratio, and density respectively for differential liberation at 135 $^{o}$F, is depicted in Figures1 to4, showing a good match between actual and simulated results with an average absolute error of less than 5%.

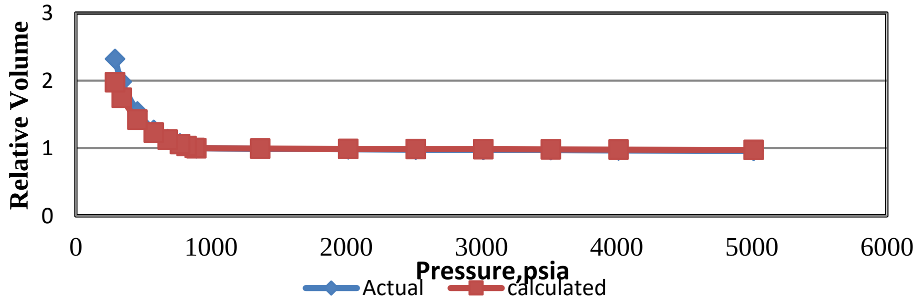

Figure 1: Comparison of calculated relative volume and actual value for constant composition expansion (approach 1)

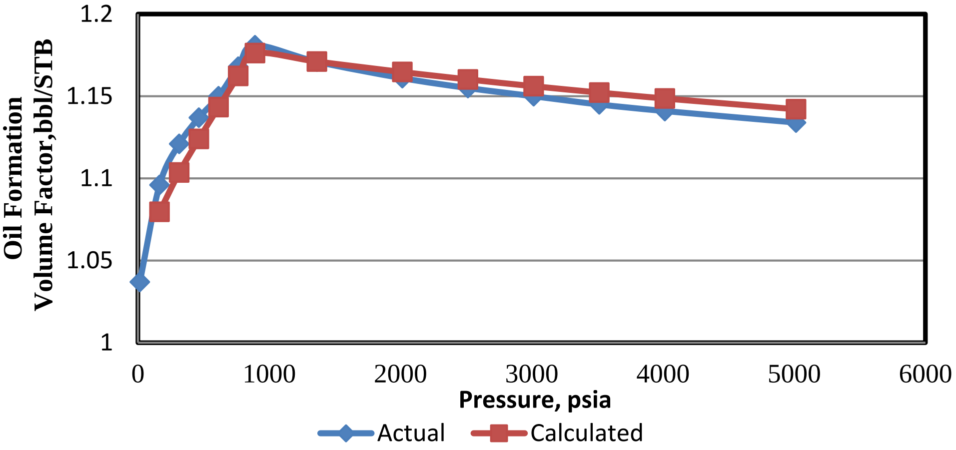

Figure 2: Comparison between calculated oil formation volume factor, using EOS and actual values for differential liberation (approach 1)

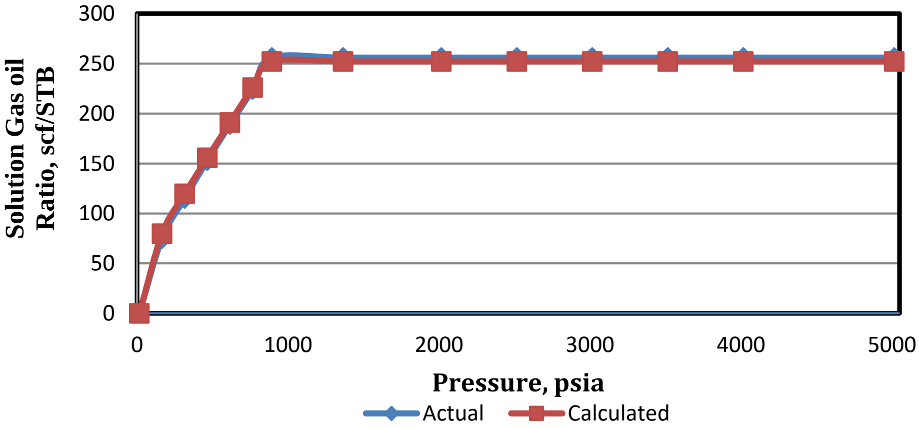

Figure 3: Comparison of calculated solution gas oil ratio, using EOS and actual value for differential liberation (approach 1)

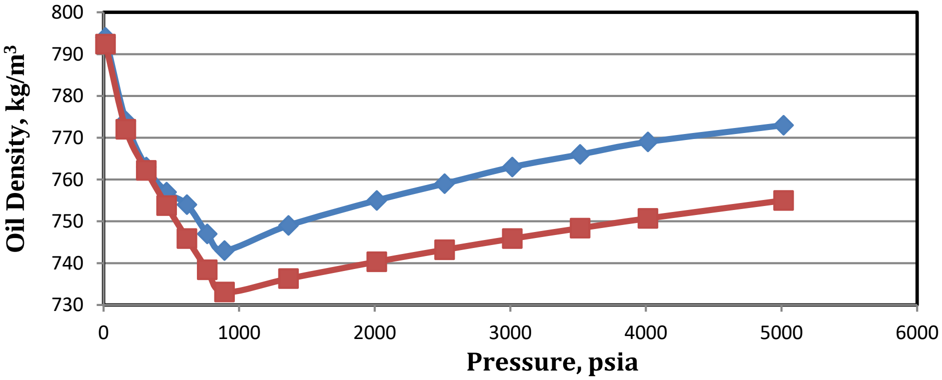

Figure 4: Comparison of calculated oil density using EOS and actual value for differential liberation (approach 1)

### PVT Simulation using EOS without tuning

The average error between the experimental values and the values obtained by modeling, using untuned equation of state,is represented in Figure 5.

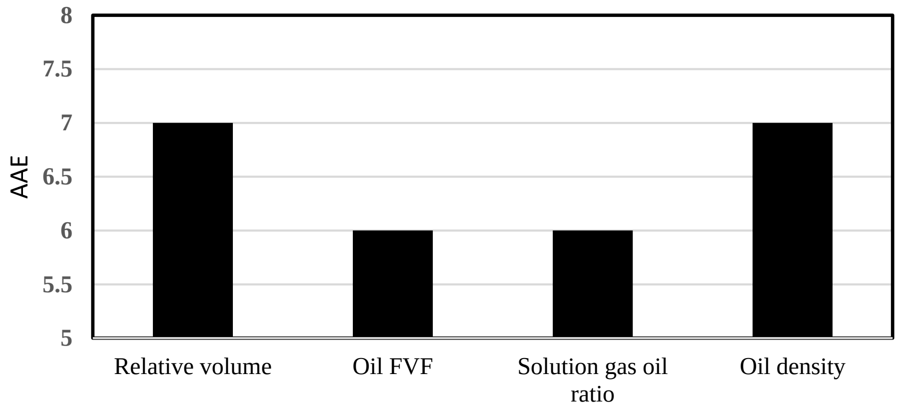

Figure 5: Comparison between calculated propeties, using EOS and actual values (approach 2)

Figure.6 presents comparisons between actual PVT properties and simulated by EOS for two approaches in term of AAE.

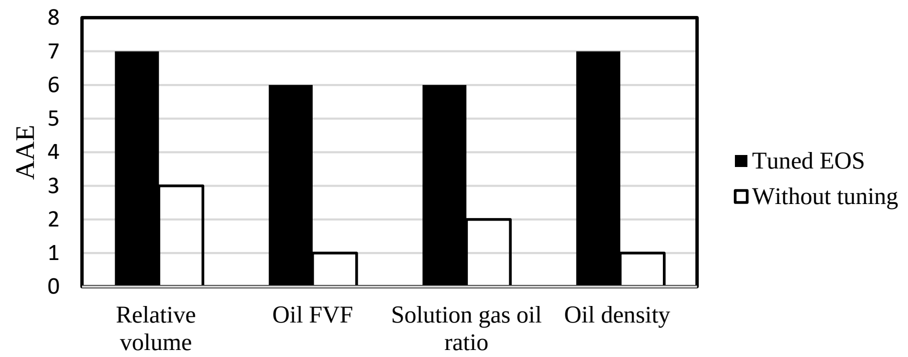

Figure 6: Average absolute error between actual and calculated PVT properties

Error analysis for two approaches indicate that compatibility between the measure data and the calculated ones, before matching is less. A comparison between the actual and calculated bubble point pressure, for different correlations in term of AAE,is presented in Figure.6.

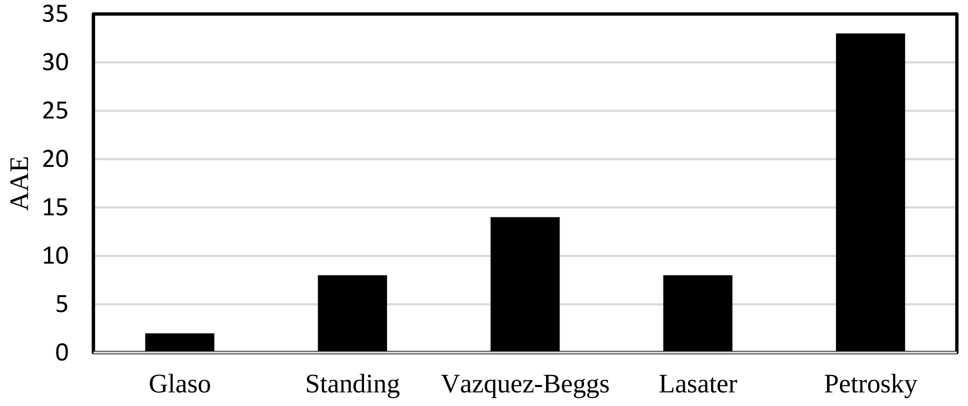

Figure 6: Error between calculated by correlations and actual saturation pressure

To find out the effect of properties calculated, using empirical correlations, the third approach was used. The result of the calculation, using the correlations and the average error between it and the experimental values,is shown in the Figures7 to 11.

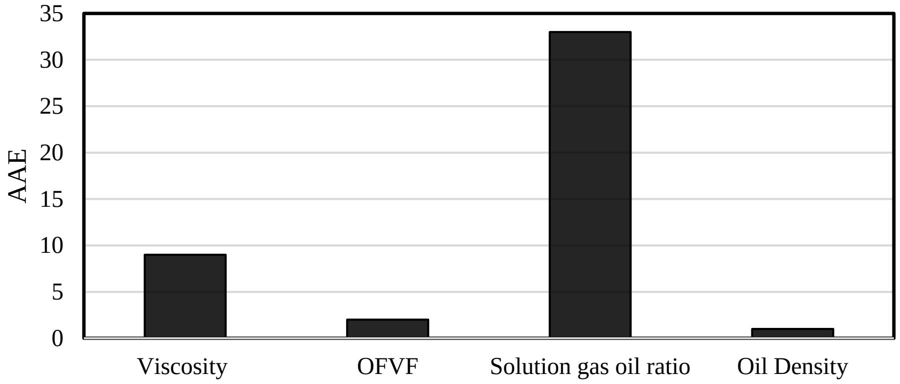

Figure 7: AAE of different properties calculated by Petrosky correlation

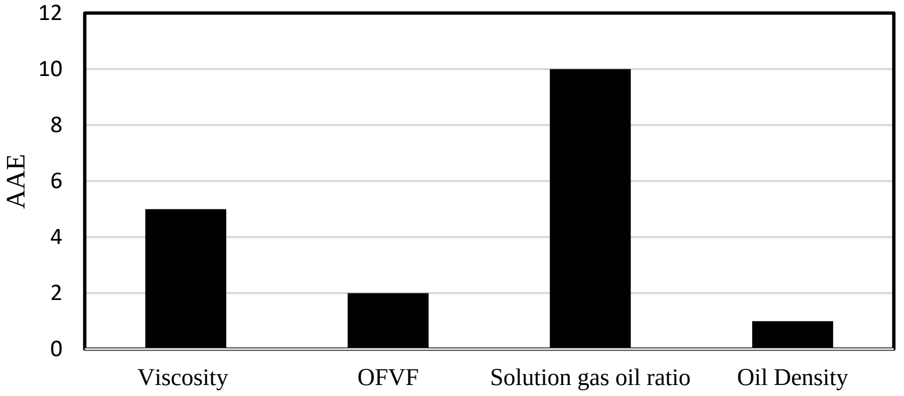

Figure 8: AAE of different properties calculated by Lasater correlation

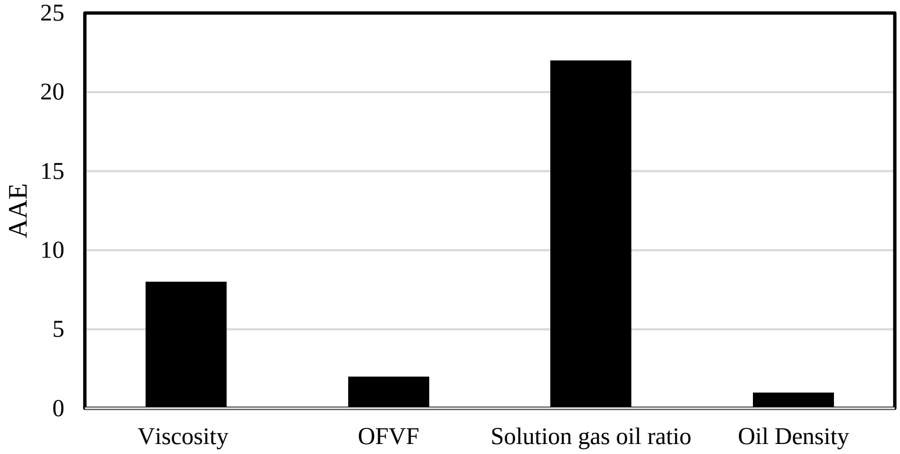

Figure 9: AAE of different properties calculated by Vazquez-Beggs correlation

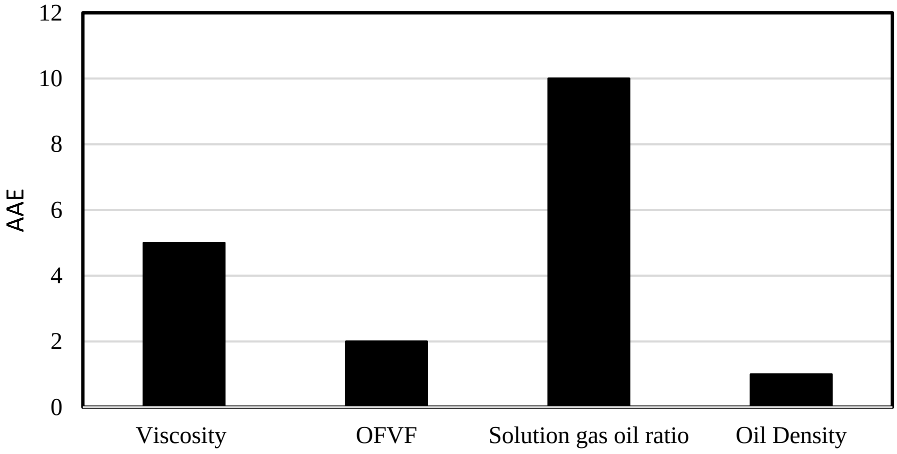

Figure 10: AAE of different properties calculated by Standing correlation

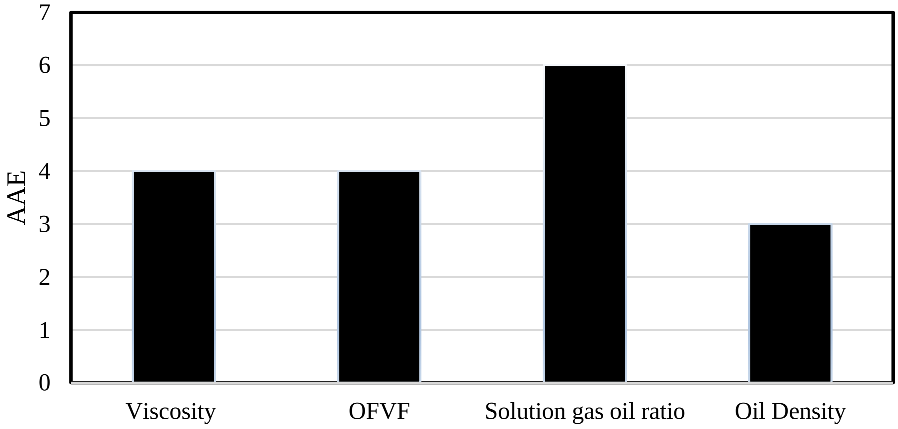

Figure 11: AAE of different properties calculated by Glaso correlation

As It is evident from the figures, the empirical relationships are ineffective in estimating properties. It gives a high average error, especially in estimating the PVT properties.

To study the effect of the PVT calculations obtained by different methods and approaches, these properties and variables were used in the balance calculations to generate cumulative oil, gas and water production. Investigation of matching between simulated and actual production history also done. Figures 12 to 15 represent result by using the first approach which give good match.

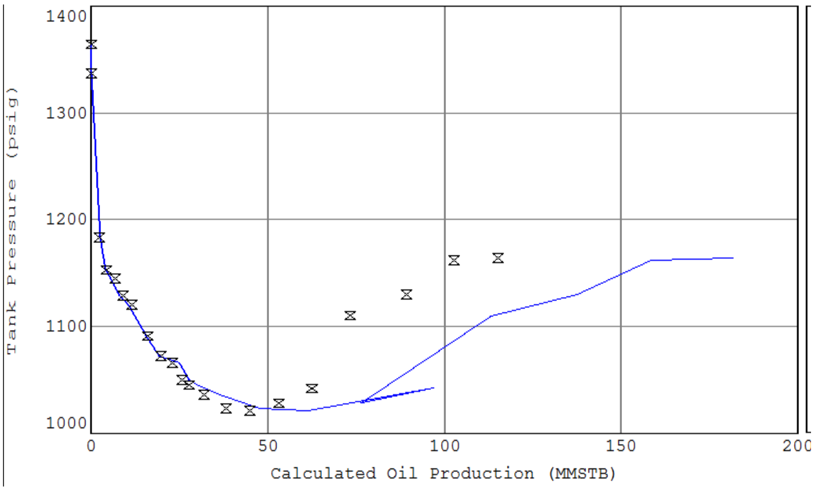

Figure 12: Calculated oil production vs tank pressure

It is observed that is a quite matching between the history production and calculated oil production. Figure 13 presents cumulative oil production between history production and simulation production.

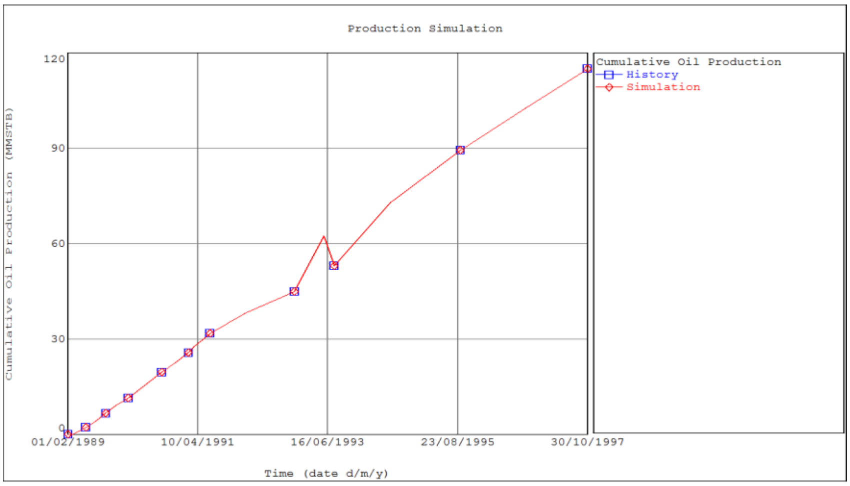

Figure13**:**Cumulative oil production vs time

It is shown that there is a good matching between history production and simulation production.

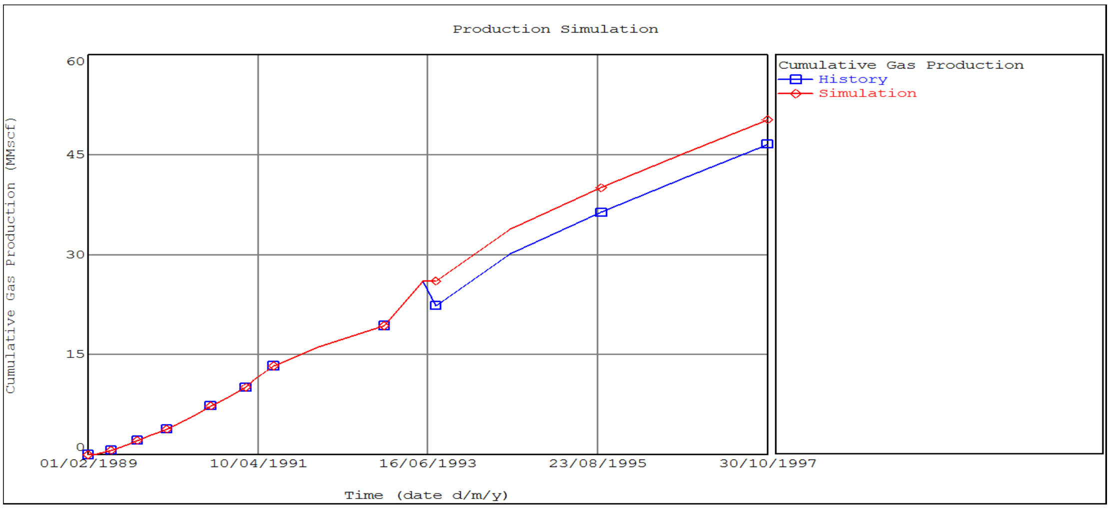

Figure14**:** Cumulative gas production

It is observed that there is a good matching between history production and simulation production is obtained.

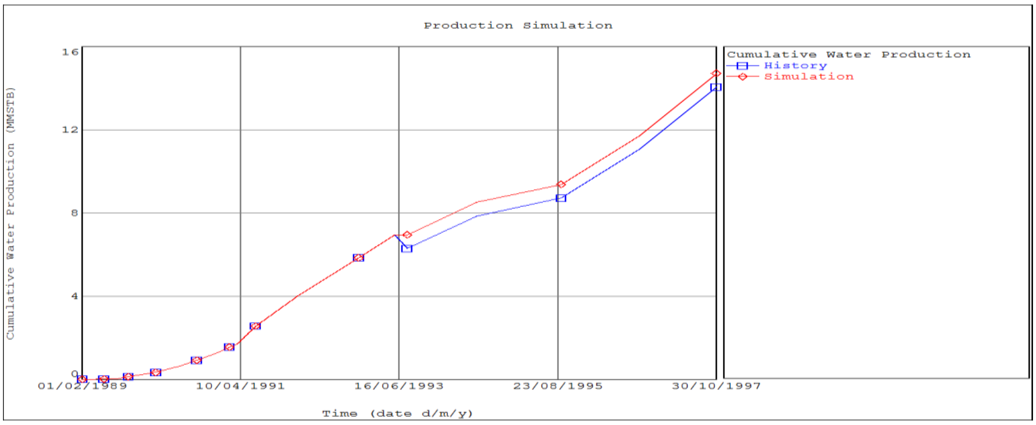

Figure 15:Cumulative water production

A good matching between actual production history was observed and simulation production history. Calculated tank pressure and oil production using analytical method is show the Figure.16.

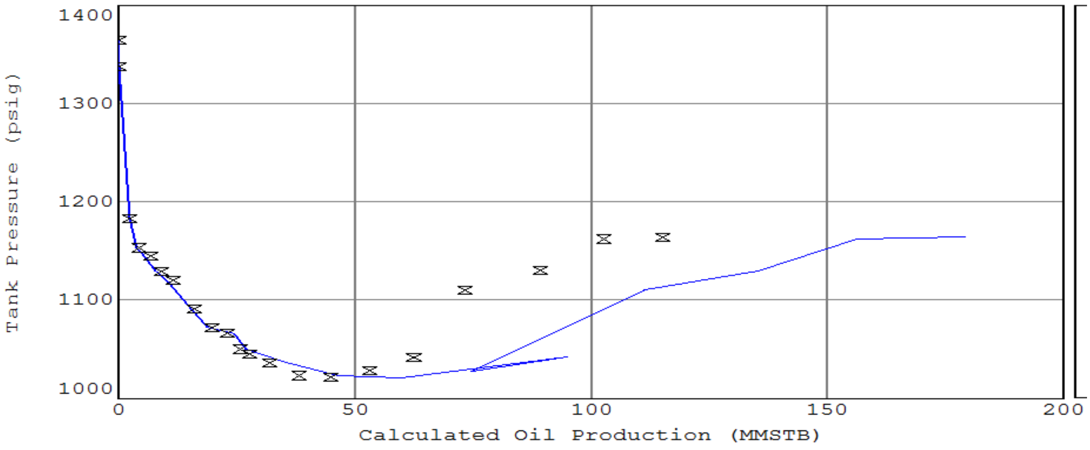

Figure16: Calculated oil production vs tank pressure (approach2)

It was observed that there is a quite matching between the history production and calculated oil production. Figure presents cumulative oil production between history production and simulation production.

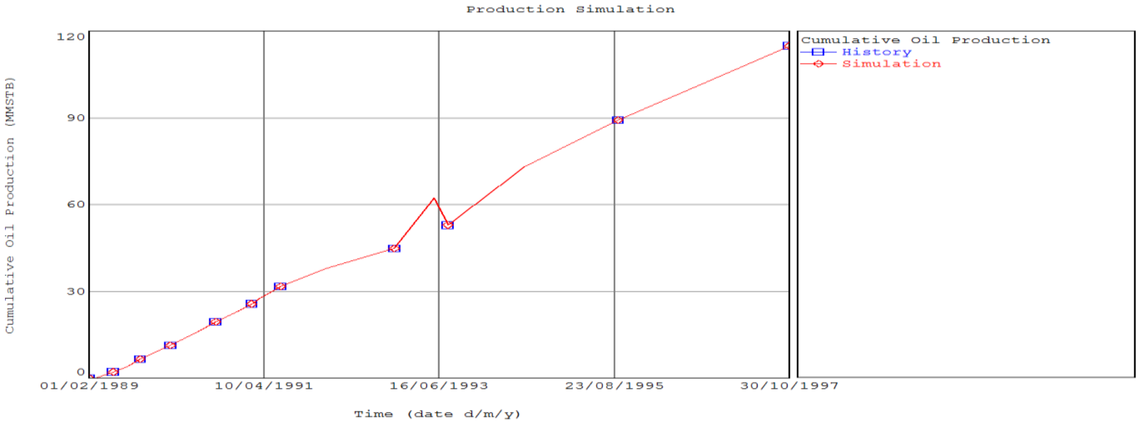

Figure 17: Cumulative oil production approach2

It is shown that there is a good matching between history production and simulation production.

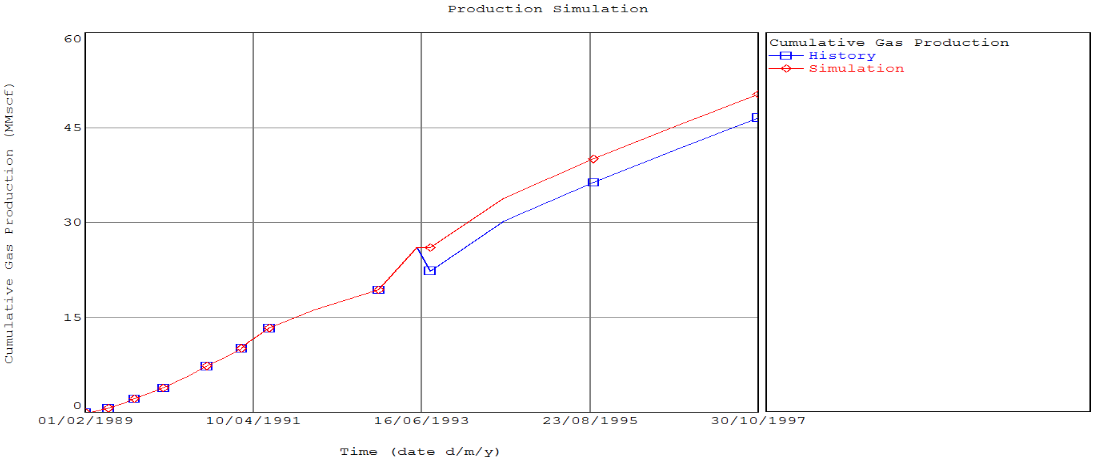

Figure 18:Cumulative gas production (approach2)

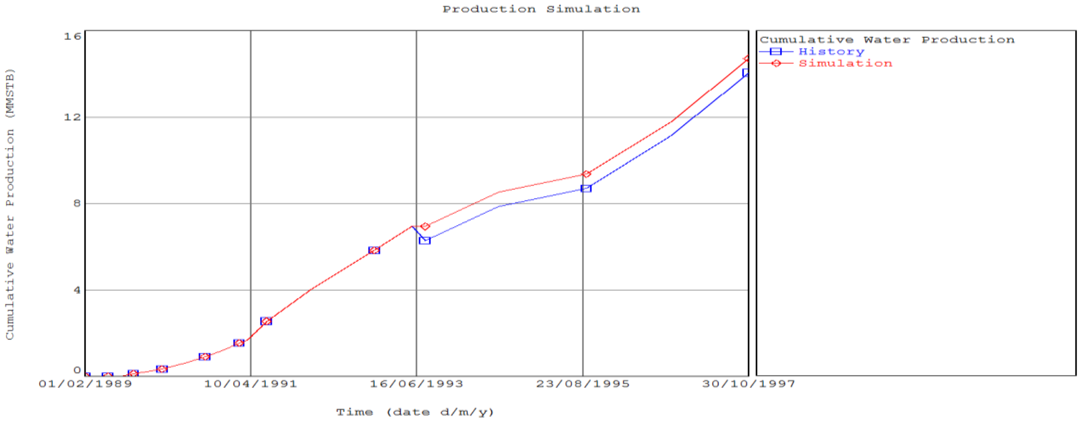

Figure19: Cumulative water production

In the same manner, the production history was recalculated, using mathematical relationships, and the results were compared with the laboratory data. Figures 20 through 23 show calculated oil production with pressure, cumulative oil, gas and water production respectively, generated according to third approach,in particular by using Petroskycorrelation.

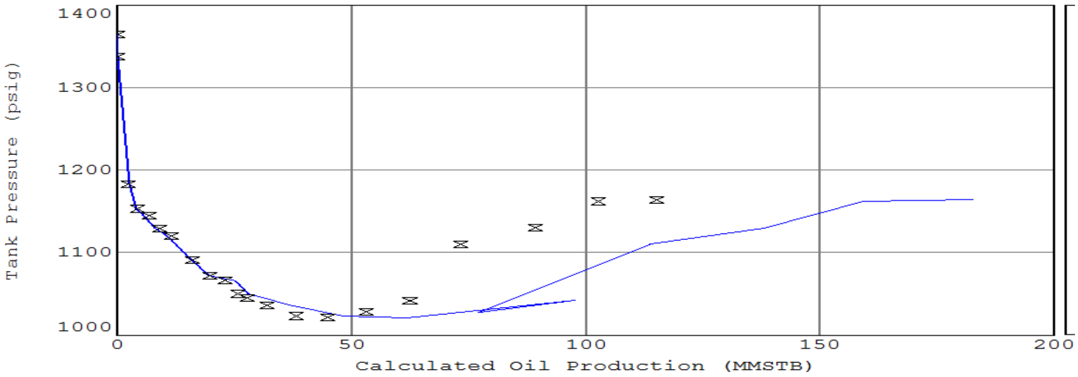

Figure20: Tank pressure vs oil production (approach 3)

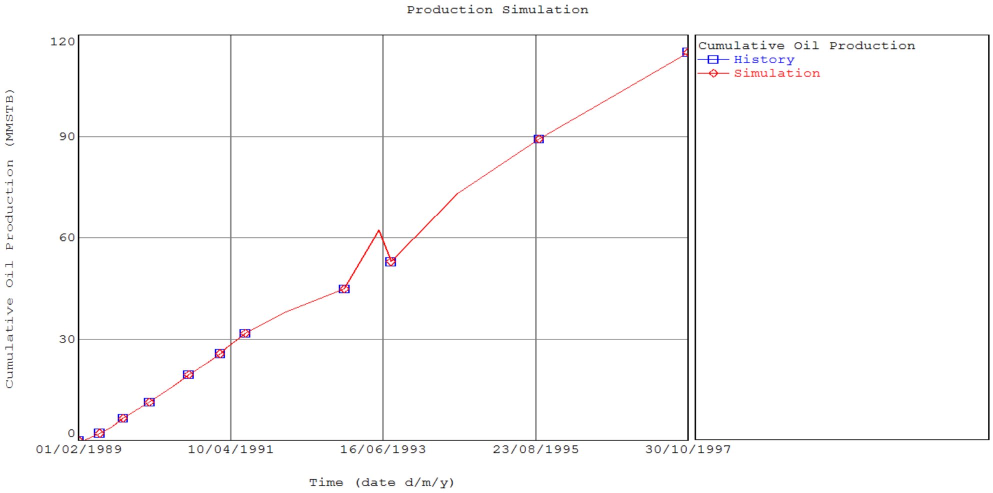

Figure21: Cumulative oil production (approach 3)

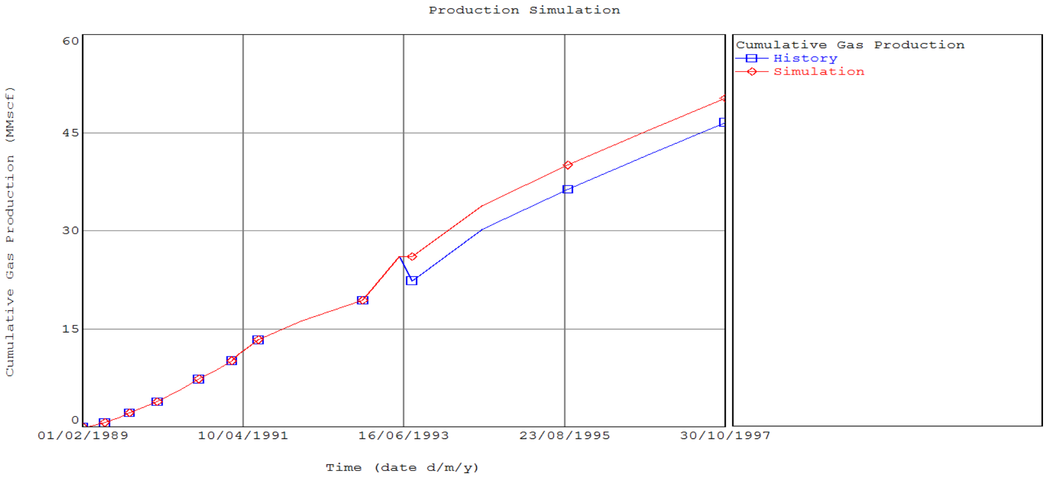

Figure22: Cumulative gas production (approach 3)

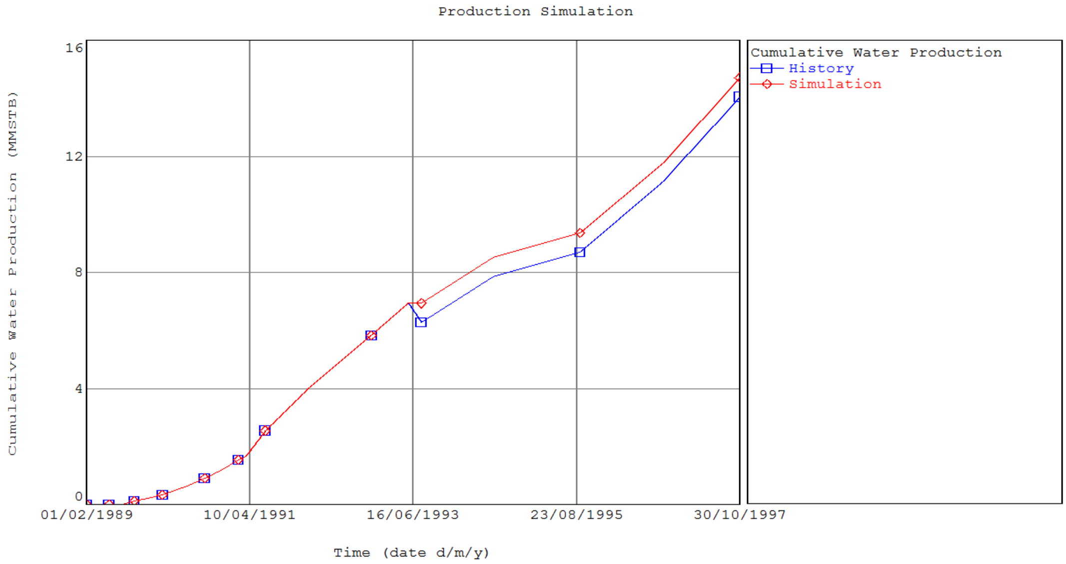

Figure 23:Cumulative water production

It is shown that application of PVT properties for material balance, using empirical correlations, have less accuracy than other approaches.

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# تأثير خصائص الضغط-الحجم-الحرارة على حساب توازن المواد

## دراسة حالة حقل النصر النفطي، محافظة شبوة

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## الملخص

تعتمد دقة العديد من حسابات هندسة البترول (على سبيل المثال، حسابات توازن المواد، تقدير الاحتياطي، تحليل اختبار البئر، تحليل بيانات الإنتاج المتقدم، التحليل العقدي، نمذجة الشبكة السطحية، الفصل السطحي، والمحاكاة العددية للمكمن) إلى حد كبير على دقة البيانات على الضغط والحجم ودرجة الحرارة (PVT)تم اقتراح نهج لتحسين طريقة حساب ميزان المواد في هذه الدراسة.

لتحقيق الهدف تم استخدام برامج PVTP وMBAL تم بناء نموذج PVT بطرق مختلفة. تم استخدام البرنامج لحساب زيت خزان المخزون اوليا (STOIIP) باستخدام طرق مختلفة. تم إجراء تحليل حساس لمعرفة تأثير العوامل المختلفة على حسابات توازن المادة. كما تم تصوير للنهج المقترح على البيانات التي تم الحصول عليها من حقل النصر النفطي .

خصائص PVT مثل ضغط نقطة الفقاعات، الحجم النسبي، معامل التكوين الحجمي للنفط، نسبة الغاز الذائب في النفط، كثافة الزيت. تم استخدام متوسط الخطأ المطلق للمقارنة بين القيم الفعلية والمحسوبة. أظهرت النتائج توافق جيد. تم حساب إنتاج التاريخ (الإنتاج التراكمي للنفط، والإنتاج التراكمي للغاز، والإنتاج التراكمي للماء) للتحقق من التطابق بين معلمات التاريخ والمعلمات المحسوبة. تشير النتائج إلى أن تأثير أخطاء PVT على حسابات توازن المادة يمكن أن يكون كبيرًا.

**الكلمات المفتاحية**: توازن المادة، تأثير بيانات الضغط-الحجم-الحرارة، اليمن، محافظة شبوة، نمذجة.