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Pressure Prediction Using Material Balance Equation/ Case History/ Ghani Field/Libya

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ABSTRACT

This study examines the material balance equation (MBE) for predicting future reservoir pressure in the Ghani field / farrud reservoir. The reservoir's complexity made material balance calculations challenging. Relevant properties were extracted, and composite PVT set and relative permeability curves were obtained from PVT and SCAL data. Cumulative production and injection data from 1980-2024 were screened and optimized. The material balance calculations were executed for the historical production/injection period up to the end of 2024, employing various aquifer models. To match average pressure behavior, an aquifer influx was superimposed on the model. The MBAL software revealed energy contributions, indicating aquifer influence, leading to the successful application of the Carter-Tracy aquifer model and demonstrating good consistency with observed data. Ultimately, the Carter-Tracy model was used for water influx calculations. The energy plot indicated that water injection and influx were the primary contributors to production over time, while fluid expansion and PV compressibility played a minor role. A notable discrepancy in the history match post-2002 was attributed to the diminishing effects of the water influx model and the increasing influence of the water injection system, which accounted for approximately 94% of total reservoir energy.

توقع الضغط باستخدام معادلة توازن المادة

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الكلمات المفتاحية:

معادلة التوازن المادي (MBE)
الضغط
التنبؤ

الملخص

هذا الدراسة استخدمت معادلة التوازن المادي (MBE) لتوقع الضغط المستقبلي في خزان فارد حقل غاني. يستعرض تعريفات وأهداف وقيود وافتراسات وتطبيقات معادلة توازن المواد (MBE)، ويفحص نماذج تدفق المياه وآليات إزاحة الخزان. يتم إجراء التحليل على خزان كربونات النفط في ليبيا. تعقيد المكنن جعل حسابات توازن المواد تحديًا. تم استخراج الخصائص ذات الصلة، وتم الحصول على مجموعة PVT المركبة ومنحنيات النفاذية النسبية من بيانات PVT و SCAL. تم تحليل بيانات الإنتاج والت injection التراكمية من 1980-2024. تم تنفيذ حسابات توازن المواد لفترة الإنتاج/الحقن التاريخية حتى نهاية عام 2024، باستخدام نماذج مختلفة للمياه الجوفية. لمطابقة سلوك الضغط المتوسط، تم تراكب تدفق المياه الجوفية على بيانات الإنتاج. كشف برنامج MBAL عن مساهمات الطاقة، مما يشير إلى تأثير الخزان الجوفي، مما أدى إلى التطبيق الناجح لنموذج الخزان الجوفي كارتر-ترايسي وأظهر توافقًا جيدًا مع البيانات الملاحظة. في النهاية، تم استخدام نموذج كارتر. أشار مخطط الطاقة إلى أن حقن المياه وتدقيقها كانا المساهمين الرئيسيين في الإنتاج مع مرور الوقت، بينما لعبت تمدد السوائل وضغطة الحجم دورًا ثانويًا. كان الاختلاف الملحوظ في مطابقة التاريخ بعد عام 2002 يُعزى إلى التأثيرات المتناقصة لنموذج تدفق المياه والتأثير المتزايد لنظام حقن المياه، الذي كان يمثل حوالي 94% من إجمالي طاقة الخزان.

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1. Introduction

The present study is concerned with improving oil reservoir management by predicting reservoir pressure using the Material Balance Equation (MBE).

Traditional material balance is a convenient method for evaluating dynamic reserves. MBAL (1) is a commonly used software to carry over material balance equation calculations utilizing different options. The model incorporates initial hydrocarbon volumes, production and injection history data, and water influx dynamics. If a good history match is obtained, then the results will provide insights into future reservoir performance, enabling better decision-making and resource management in hydrocarbon extraction. MBE Application is used as a voidage replacement" tool. It helps determine if water injection volumes are sufficient to replace produced volumes and maintain reservoir pressure. Engineers use the MBE to predict whether reservoir pressure will be maintained, rise, or fall. This is crucial for reservoir management [1, 2]. Production data analysis (PDA) uses flowing bottom-hole pressures instead of shut-in pressures, allowing for continuous pressure prediction without the need for expensive shut-in surveys [3, 4]. The pressure predictions from the MBE are used to validate and history-match more complex, multi-cell numerical simulation models, which provide a more granular, spatially aware pressure forecast [5]. Numerical simulations are common methods used to analyze the dynamic characteristics [7, 8]., The MBE remains an indispensable first-step tool for reservoir engineers to predict reservoir pressure, estimate reserves, and forecast the future performance of both oil and gas fields. Its simplicity, grounded in the fundamental law of conservation of mass, ensures its continued relevance in the industry. The first objective of this study is to predict future reservoir pressure of an oil reservoir called Farrud/Ghani, which is located in the Sirte Basin/Libya. The Ghani reservoir is a carbonate oil reservoir that contains 31 producers and 20 injectors and covers 7,200 acres.

2. GENERAL

2.1 Geological Overview

2.1.1 Stratigraphical Column Description

Figure.1 shows the Chrono-Stratigraphic subdivision of geological time. The oldest formation is the Hagfa, followed by the Beda formation, which was formed around 60 million years ago. The youngest is the Zelten formation, which crosses the boundary into the younger Eocene Epoch. The Beda formation is divided into Thalith, Beda C, and Mabruk members, with the youngest subdivided into Mabruk A and B. These formations are oil-producing reservoirs.

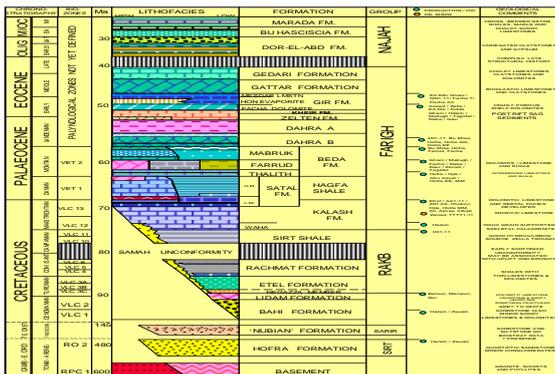


Fig. 1: The Chrono-Stratigraphic Sub-Division of Geological Time

2.2 Tank Model Set Up

The interface uses a single tank model with oil as the main fluid to provide a cumulative reservoir production history. It uses black oil correlations to define fluid properties and matches them with laboratory measurements as shown in figure 2. Formation rock compressibility is used to determine energy contribution due to hydrocarbon pore volume reduction.

Pressure	Gas Oil Ratio	Oil Viscosity	Gas Viscosity
1 5000	668	1.3663	0.464
2 4750	668	1.3659	0.458
3 4372	668	1.3754	0.448
4 4042	668	1.3809	0.439
5 3729	668	1.3863	0.431
6 3435	668	1.3909	0.423
7 3052	668	1.3982	0.413
8 2747	668	1.4007	0.404
9 2305	668	1.4128	0.391
10 2020	668	1.4192	0.382
11 1900	668	1.421	0.378
12 1647	586	1.3836	0.404
13 1347	490	1.3371	0.436

Fig.2: PVT data

The reservoir is an undersaturated oil reservoir, with current pressure above 1900 psia. The reservoir was subjected to water injection. Figure 3 shows part of pressure history and production history as an input to MBAL model.

It is expected that the reservoir was partially subjected to aquifer support. It is important to include in the model the most representative influx model that lead to best history match..

Time	Reservoir Pressure	Cum Oil Produced	Cum Gas Produced	Cum Wat Produced	Cum Gas Injected	Cum Wat Injected
01/09/1980	2334.7	0	0	0	0	0
01/12/1981	2076.7	8.9	634.6	0	0	0
01/12/1982	2039.7	15.4	634.7	0	0	0
01/12/1985	1908.7	25.5	722.098	0.2	0	0
01/12/1986	1893.7	28.1	733.9	0.4	0.187	0
01/12/1987	1880.7	29.6	740.639	0.4	1.448	0
01/12/1988	1859.7	33.1	737.299	0.4	2.253	0
01/12/1989	1915.7	35.6	735.399	0.4	5.835	0
01/12/1990	1936.7	38.4	729.699	0.5	10.682	0
01/12/1991	1951.7	41.8	726.299	0.6	15.866	0
01/12/1992	1949.7	45.4	723	0.9	21.057	0
01/12/1993	1931.7	49.9	721.391	1.1	26.252	0
01/04/1994	1897.7	50.1	722.299	1.1	29.983	0
01/10/1994	1939.7	52.4	727.3	1.2	37.113	0
01/02/1995	1976.7	56.5	725.2	1.7	47.864	0
01/03/1996	2039.7	60.1	734.601	2.2	58.341	0

Fig 3: Pressure and production data

3. Adjustment of input data

The methods for model development and pressure performance forecasting, covering system options, PVT fluid properties, and the adjustment of differential liberation data to separator conditions.

$$B_0 = (B_{ofb})(S_{od}), \quad S_{od} = \left(\frac{B_{od}}{B_{0db}}\right)$$

Where;

B₀/S_{0d}: Oil shrinkage & gas evolution

B₀/B_{0fb}: Reserve calculation & production in Figures 4 & 5.

$$R_s = R_{sfb} - (R_{sdb} - R_s) \left(\frac{B_{od}}{B_{0db}}\right)$$

Where;

R_s: Gas solubility, (SCF/STB),

R_{sfb}: Bubble-point solution gas-oil ratio from the separator test, (SCF/STB),

R_{sdb}: Solution gas-oil at the bubble-point pressure as measured by the differential liberation test, (SCF/STB),

R_{sd}: Solution gas-oil ratio at various pressure levels as measured by the differential liberation test, (SCF/STB).

Fig.4: Black oil - matching

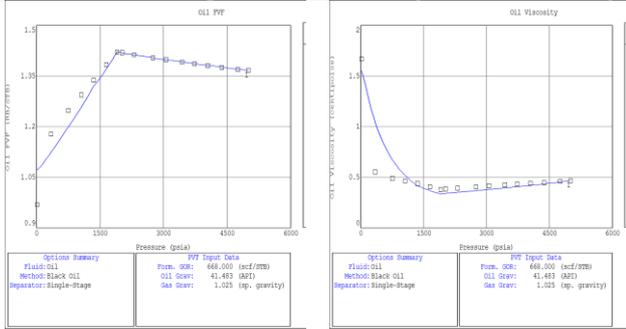


Fig.5: Observed versus simulation data – oil fluid properties

3.1.2 Tank Input Data

3.2 Model verification and History Matching

To improve the history match, regression analysis can be performed on least uncertainty parameters. These parameters include, original oil in place (OOIP), water influx rates, ...etc. After many runs, it was found that the most effective parameters are OOIP and Water influx. Fig 7 shows the history match without any regression on OOIP and Aquifer data.

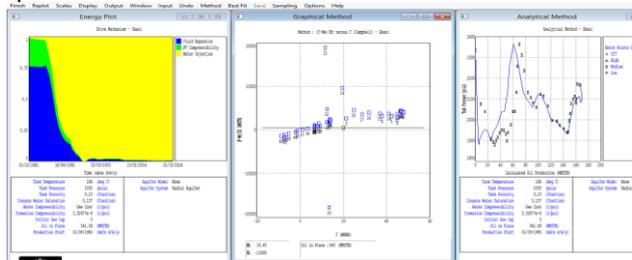


Fig.7: History match without regression

3.3 History Match with Regression Analysis on OOIP

Many history match runs were conducted using MBAL to match the historical data. After many attempts a reasonable match has been obtained at early stages as shown in Fig 8 and Fig 9. The results indicated overall improvement in history matching with OOIP regression. The model shows high differences in pressure data which indicates the importance of including water influx schemes.

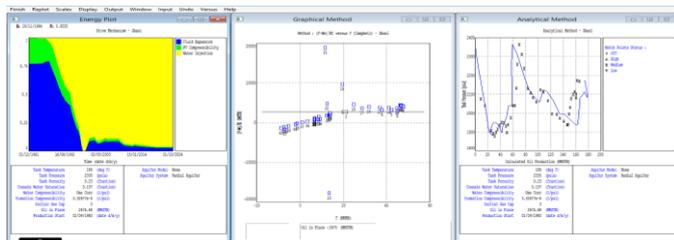


Fig.8: History matching with OOIP regression



Fig.9: Pressure History Match with OOIP regression

3.4 History Match with Regression Analysis on OOIP and Water Influx Models.

Water influx models, like the Fetkovich Steady State Model, Carter-Tracy models are crucial in reservoir engineering for estimating water encroachment (2). Fig 10 shows the differences in history matching between water influx and without it. Including Water influx model of Fetkovich in the calculations has improved the overall history.

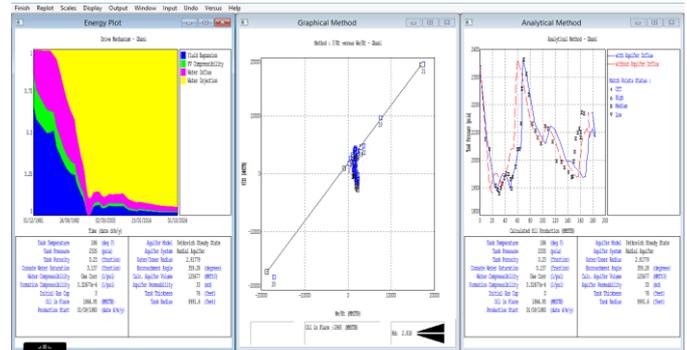


Fig.10 History matching with aquifer parameters & OOIP regression

4. Prediction of Reservoir Pressure

Following a reasonable history match, many prediction runs were performed to forecast future reservoir pressure. Two cases were run. Fig 11 shows the case I represents the future performance without water influx calculations while case II with water influx in Fig 12. The results indicated that reservoir pressure will continue to decline if no active aquifer is present. It is important to keep water injection scheme on operation in order to keep the reservoir pressure above the bubble point pressure.

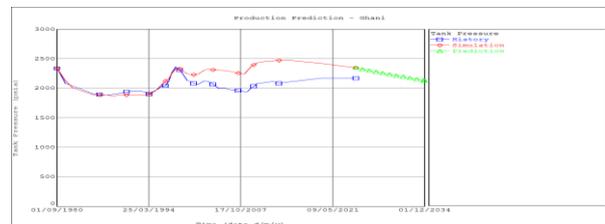


Fig.11 Pressure prediction run – Case I



Fig.12 Pressure prediction run – Case II

4. Conclusions

Using MBAL to history match pressure and production data were unsatisfactory when applied on Farrud/Ghani reservoir due to inconsistencies in reservoir pressure data, likely linked to lateral heterogeneities and compartmentalization.

An analysis of the dominant drive mechanism was made and led to the following conclusions:

- The expansion of reservoir fluid is the primary drive mechanism, accounting for over 48% of pressure support before water injection. Rock volume compressibility is less important, representing 18% at production.
- Aquifer water influx represents 20-40% of driving mechanisms, with water injection not significantly altering aquifer influx support from 1981 to 1988.
- Water injection is needed to support reservoir pressure

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