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Varying GOR Effect on Oil Production for Nubian SANDSTONE using PIPESIM Software

K. Rahuma*[a], Sh. Alshakah[b], A. Eswayah[c]

[a] Department of Petroleum Engineering, Faculty of Engineering, University of Tripoli, Libya
[b] Al Waha Company, Tripoli, Libya
[c] Alfa Company, Tripoli, Libya

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ABSTRACT

Evaluating the Gas-Oil Ratio (GOR) is crucial for optimizing oil recovery strategies, minimizing environmental impact, and ensuring economic viability. GOR represents a critical parameter in the oil and gas industry, as it deeply influences the complex relationships governing well production performance. A comprehensive evaluation of production system dynamics provides a data-driven framework to assess reservoir heterogeneity while analyzing and optimizing oil production relative to GOR. This study builds upon existing knowledge by evaluating the impact of varying GOR levels across four wells. A Black Oil model was developed and subsequently converted—using PVT data—into a Compositional Model to better understand fluid behavior, evaluate performance, improve production rates, and validate results against well-testing data. Comparative analysis between the Black Oil and Compositional models yielded additional insights into production enhancement strategies. Reservoirs with high GOR typically exhibit a gas cap that affects pressure distribution and fluid displacement, whereas low-GOR reservoirs present challenges related to fluid mobility and sweep efficiency due to the dominance of viscous forces. Results from Wells X1, X3, and X4 demonstrated a positive correlation between increases in tubing size, productivity index, and overall oil output. Upsizing the production tubing diameter significantly reduced flowing friction losses, thereby enabling higher volumetric flow rates, improving well deliverability, and maximizing potential oil production. Furthermore, adjusting the wellhead choke size proved pivotal in optimizing output; careful choke selection managed downhole pressure drops to maintain optimal conditions for enhanced fluid flow, where well X2 improved oil production rate by doubling when they applied a workover and increased the tubing size.

أثر تباين نسبة الغاز إلى النفط (GOR) على إنتاجية النفط من تكوين الحجر الرملي النوبي (Nubian Sandstone) باستخدام برنامج *PIPESIM*

خلود رحومة[a]*، شريفه السكاصى[b]، افنان السايح[C]

[a] قسم هندسة النفط، كلية الهندسة ، جامعة طرابلس، ليبيا
[b] شركة الواحة ، طرابلس ، ليبيا
[c] شركةالفا، طرابلس، ليبيا

الكلمات المفتاحية:
انتاج النفط
النمذجة
خواص المكمن
معامل الانتاجية
نسبة النفط للغاز

الملخص

يُعد تأثير نسبة الغاز إلى النفط عاملاً حاسماً في تحسين استراتيجيات الاستخراج، وتقليل الأثر البيئي، وضمان الجدوى الاقتصادية. تعد نسبة الغاز إلى النفط أحد العوامل المهمة في الصناعة النفطية، حيث إنها تسلط الضوء بشكل كبير على العلاقة المعقدة بين أداء إنتاج آبار النفط. ان التقييم الديناميكي الشامل لنظام الإنتاج يعتمد على تحليل البيانات التي نؤثر على تباين نسبة النفط والغاز. أُجريت هذه الدراسة لتعزيز المعرفة حول تأثير نسب الغاز إلى النفط المختلفة على سلوك الخزان في حالات النسب العالية والمنخفضة. وتستخدم الدراسة تقنيات متقدمة لدراسة الخزانات باستخدام نموذج تركيبي لبيانات الضغط والحجم والحرارة(PVT) ، مما يوفر فهمًا أفضل لسلوك الغاز ويتتبع سلوك كل مكون على حدة باستخدام برنامجPIPESIM ، بهدف التركيز على تحديد الفرص لزيادة الإنتاج وخفض تكاليف التشغيل لتحقيق الربحية المثلى .الهدف من هذه الدراسة هو

*Corresponding author:
E-mail addresses: K.rahuma@uot.edu.ly ,(Sh. Alshakah)sharitaalshakahi@gmail.com ,(A .Eswayah)afnaneswayah@gmail.com
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إنشاء نموذج للنفط الأسود لأربعة آبار وتحويل بيانات PVT إلى نموذج تركيبي من أجل الحصول على فهم أفضل لسلوك النفط والغاز وأدائهما، وتحسين معدل الإنتاج، ثم التحقق من صحة البيانات باستخدام نتائج اختبارات الآبار.

Introduction

The Gas-to-Oil Ratio (GOR) is a critical parameter to impact the production and performance of oil wells. Researchers have extensively studied the relationship between GOR, oil production from reservoir dynamics, and potential recovery, which has provided valuable insights [3]. The composition of the reservoir fluid is a foundation for understanding the interplay between the relative proportions of oil, gas, and water can affect the way GOR influences oil production. The presence of impurities or the viscosity of the oil can modify the relationship between GOR and oil production; while increasing the GOR may sometimes lead to higher oil production, the associated costs of handling and processing the additional gas may outweigh the benefits, making it economically unfeasible to maximize GOR [2].

Nodal analysis provides a comprehensive framework to analyze the interrelated elements of the production system and to determine the optimal operating conditions within various methods employed, with the most common and widely used approach for production optimization.

In this study, an investigation was performed on the GOR variability effect to increase achieving optimal profitability from the well.

Literature Review

Researchers have extensively studied the relationship between GOR and oil production, which provided valuable insights [3]. One of the pioneering studies on the effect of GOR was conducted by Vasquez and Beggs (1980), who developed empirical correlations to predict the physical properties of reservoir fluids, including GOR, which influence factors such as oil viscosity, which in turn affects the flow behavior and production potential of the well.

Beliveau (2004) explained that there are three major factors that have an impact on gas-oil ratio (GOR) performance, such as gas-oil relative permeability curve, the presence of an initial gas cap and the strength of any associated aquifer. Generally, once producing GOR occurs, the impact is direct on production rate to push fluids up to the surface, as Slider (1983) pointed out in his work that when gas begins to flow from reservoir to the well, the production rate will increase during the initial phase as a result of an increase in fluid viscosities in the reservoir.

Shadizadeh and Zoveidavianpoor (2009) state that large tubing is good for higher flow rates, low pressure loss and lower fluid velocity desirable during the early life of a well; however, as reservoir pressure and flow rate decline, large tubing may become less advantageous as liquid hold up problem encountered, thus smaller tubing size maybe necessary.

Sinha et al. (2014) developed a numerical model to simulate the effect of GOR on the performance of multiphase flow in horizontal wells. Their findings suggest that the optimal GOR for oil production can vary depending on factors such as the well configuration, reservoir characteristics, and production conditions.

However, Chukwueke et al. (1998) and Ivanov et al. (2016) argue that GOR can suspend the production of the well. In reservoirs with a thin oil rim below a gas cap, oil production can be severely hampered by gas coning problems, especially in horizontal wells, as gas coning and early gas breakthrough in producers can lead to a significant reduction in oil recovery and the resulting early suspension of wells due to high GOR. When producing GOR is too high, equal or greater than solution GOR can cause problems such as pressure loss or liquid loading along the well, which is caused by the bubbling of gas. Tubing size selection plays an essential role in production phase in order to flow fluids from the bottom of the well up to the surface.

Elshahawi et al. (2016) investigated the impact of GOR on the productivity of mature oil fields. They observed that in some cases, reducing the GOR through gas injection or other methods can lead to improved oil recovery, particularly in reservoirs with high initial GOR.

Guo et al. (2017) studied the effect of GOR on the performance of horizontal wells in unconventional reservoirs. They found that as GOR increases, the oil production rate may initially increase due to the enhanced flow of gas, but a further increase in GOR can lead to a decline in oil production due to factors such as gas breakthrough and reduced oil mobility [5].

There are several empirical methods that are used to generate current and future IPR: Vogel; Fetkovich; Jones et al.; Richardson and Shaw; Wiggins; Klins and Majcher; Sukarno and Wisnogroho (Daoud et al., 2017).

In a two-phase flow reservoir, solution gas drive reservoir, the straight-line method is known to have limitations in such a reservoir; thus, Vogel (1968) introduced an equation of a curve that gives a reasonable empirical:

$$\frac{Q_o}{Q_{max}} = 1 - 0.2 * \left(\frac{P_{wf}}{P_r}\right) - 0.8 * \left(\frac{P_{wf}}{P_r}\right)^2 \quad [1]$$

Dashtian et al. (2020) investigated the effect of GOR on oil production in heterogeneous reservoirs. They observed that in reservoirs with high permeability contrasts, the impact of GOR on oil production can be more pronounced and complex. The authors highlighted the importance of considering reservoir heterogeneity when analyzing the relationship between GOR and oil production [4]

Nodal analysis is a systems analysis, involves estimating the entire production system of oil or gas wells and optimize the system components to achieve the desired flow rate efficiently [9]. The inflow Performance Relationship (IPR) curve represents reservoir inflow, while the Vertical Lift Performance (VLP) curve represents wellbore lift capacity. By intersecting these curves on a pressure vs. rate plot, we can estimate how much oil, water, and gas the well can produce [9]. The intersection of the PI plot with the x-axis is the flow rate corresponding to a P_{wf} equal to zero. This point in the IPR plot is known as the Absolute Open Flow (AOF) potential of the well. [11]

Methodology

This study uses PIPESIM software for four well data sets (two with high GOR, and the others with low GOR). Building well models using PIPESIM with a black oil system.

- Validating Wells Models using well test data.
- Identify bottleneck issues and try to solve it.
- Analyze model results for each well.
- Convert the model to a compositional model.
- Compare the results of black oil and compositional models.
- Identify the operation tubing size.
- Run sensitivity
- reservoir pressure, Productivity Index

Optimization and improve oil production rate.

PIPESIM Software

Tool developed by Schlumberger, and the primary purpose of PIPESIM is to help engineers design, optimize, and troubleshoot various components and processes in oil and gas production, such as wellbore flow, surface facilities, pipelines, and gathering systems. It provides a comprehensive set of modeling capabilities and features that allow engineers to simulate complex flow scenarios and evaluate system performance under different operating conditions (Figure 1).

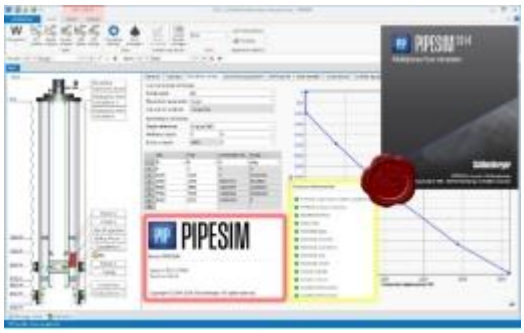


Figure 1: PIPESIM layout

PIPESIM also supports integration with other software tools and data

sources, enabling engineers to incorporate real-time data, perform sensitivity analyses, and interface with reservoir simulators, production databases, and optimization algorithms.

In summary, PIPESIM is a powerful software tool used in the oil and gas industry for the simulation, analysis, and optimization of production systems. It helps engineers make informed decisions, improve system performance, and enhance operational efficiency in oil and gas production.

Results and discussion

Using software to build a representation of the production system for each well, including constructing the wellbore model figure [2].

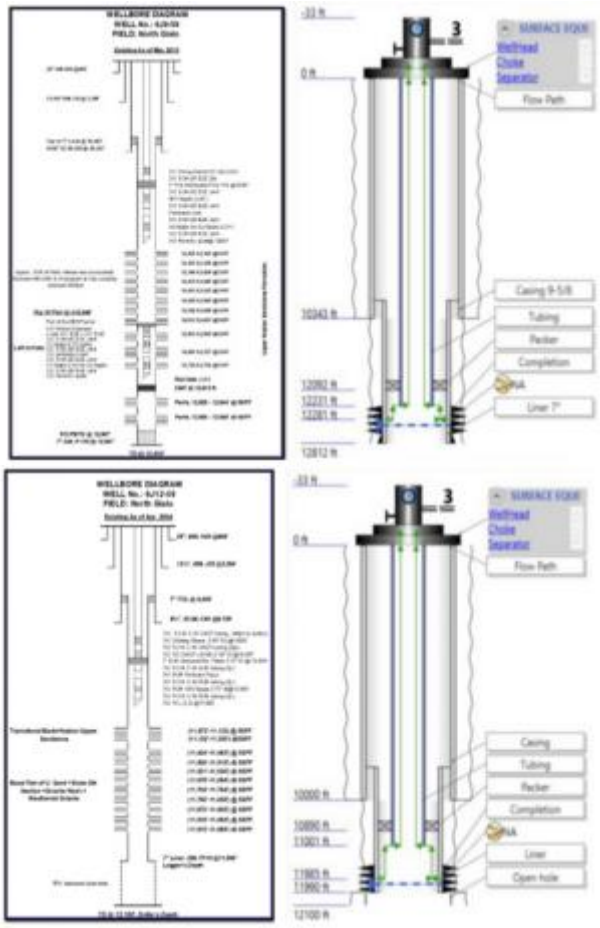


Figure 2: Completion design of wells and its construction in Pipesim

Well pipeline elevation

As shown in Figure 3, the cross point between the inflow performance relationship IPR curve and vertical lift performance (VLP) curve for the operating point matches the value measured from the well testing. Also, this model shows that the well is operating within the envelope limits.

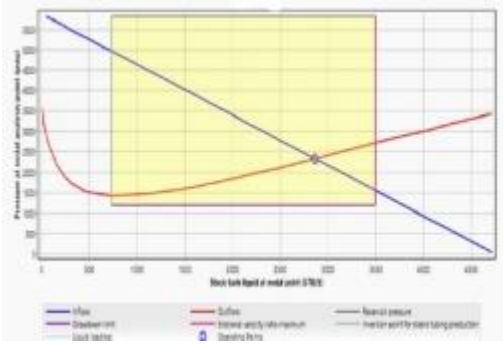


Figure 3: PVT envelope in PIPESIM

Comparison of black model to compositional model for well X1.

As shown in Table 1, there is a significant improvement in the results with the compositional model compared to actual results obtained from well test data. However, further investigation was performed in terms of Productivity Index (PI), which can improve the well production rate with workover. Based on previous stimulation performed for this reservoir, the oil production rate could be increased by 10 times; Therefore, this task was done for this well, and the production could be improved to reach about 6000 STB/Day. On the other hand, choke size can improve the oil production rate by about 300 STB/day.

Table1: Comparison of black oil Model to composition model.

Parameter	GOR	Oil Rate	Gas Rate	Productivity Index
Unit	SCF/BBL	STB/D	MMSCF/D	STB/d/psi
XX	3143-3774	2631-6997-	9.206-8268	
Black Oil	1280-3211	2403.35 - 4301.13	4.42881-8.84388	1.029-1.58
Compositional	1259.73-3657.86	2564.42 - 4212.75	4.50632-11.06216	1.029-1.58
Coke size (0.55-0.75)	1259.73-3657.86	2398.2-5679.6	4.55777-7.16822	1.029-4.516

Sensitivity Analysis:

The results obtained from the sensitivity analysis are presented as follows:

Sensitivity on PI

The production of the four wells could be capable of improving the flow rate to (2690, 6000, 7220, 6000) STB/day, if the wells are subjected to workover and stimulation such as hydraulic fracturing. The effect on different t productivity indices is shown in Figure 4.

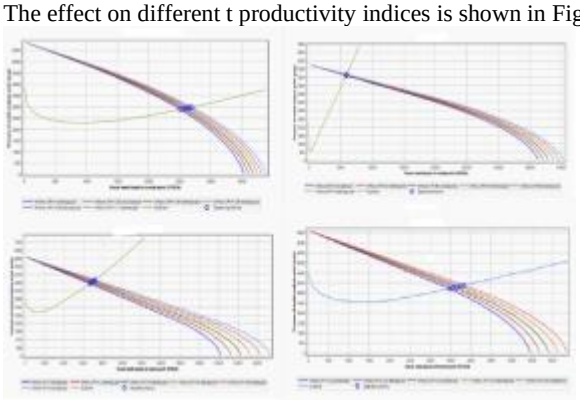


Figure 4: Effect of different productivity indices.

Sensitivity to Reservoir Pressure:

As production continues, the well pressure will decrease, and more gas will be released from the oil, which causes a drop in oil production rate with a drop in well bottom-hole pressure Figure 5.

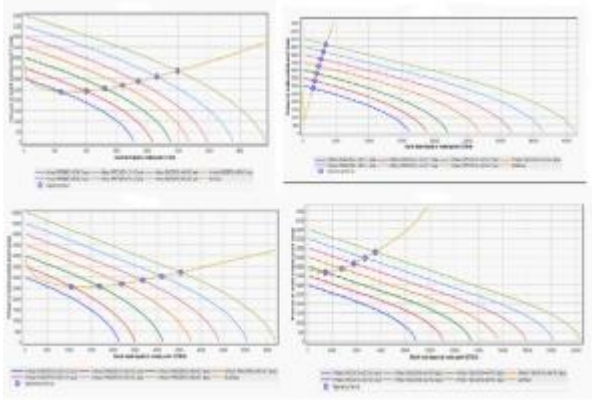


Figure 5: Sensitivity on reservoir pressure for wells

Conclusion

The analysis of GOR trends to assessment of different tubing sizes has yielded important insights that can be applied to enhance oil production and overall field operations. The comprehensive evaluation of the production system dynamics has provided a data-driven framework to support critical decision-making throughout the life of the asset. The importance of this study is using a compositional model for the PVT data, which provides a better understanding of the

gas behavior and tracks each component's phase behavior separately.

Increasing the productivity index of the wells had a direct and favorable effect on oil production, where well X2 improved oil production rate by doubling when they applied a workover and increased the tubing size.

Wells X1, X3, and X4 demonstrated a positive correlation between increases in the productivity index and tubing size, leading to increased oil production. Upsizing the production tubing diameter in wells contributed to the observed increase in oil production. Larger tubing sizes reduced flowing friction losses, allowing for higher volumetric flow rates of the produced fluids, effectively increasing the well's deliverability and maximizing potential oil production.

Adjusting the choke size, which controls the flow restriction at the wellhead, played a key role in optimizing the oil production from these wells. By carefully selecting an appropriate choke size, the pressure drops across the choke could be managed to maintain optimal downhole conditions for enhanced oil flow. Increasing the choke size allowed for higher flow rates and improved oil production.

Recommendation:

By following these steps, you can effectively use the PIPESIM software to analyze the impact of GOR on oil production and develop strategies to optimize hydrocarbon recovery (Build an Accurate PIPESIM Model, Sensitivity Analysis on GOR, Identify Optimal GOR, Develop GOR Management Strategies, Validate and Refine the Model)

. This will ensure the model accurately reflects the reservoir dynamics and provides reliable guidance for future decision-making.

Nomenclatures

OOIP Original Oil in Place
GOR = Gas-oil ratio
GLR = Gas-liquid ratio
PVT= pressure volume temperature
OIIP = Oil Initial in Place
OTS = Oilfield Technical Services
IPR = Inflow Performance Relationship
VLP = Vertical Lift Performance
PWF = Bottom Hole Flowing Pressure
PI = Productivity Index
AOF = Absolute Open Flow
Pb = Bubble Point Pressure
WOR = Water-Oil Ratio
BOPD = Barrels of Oil Per Day
UNS = Upper Nubian Sand
NMS = Nubian Middle Shale
LNS = Lower Nubian Sand
LNBS = Lower Nubian Basal Sand
WTF = Wireline Formation Tester
WSW = Water Source well
Qg = Gas Rate
Qo = Oil Rate
Q max = Maximum oil flow rate, i.e., AOF
Pwf = Pressure flowing well, psig
MSTBPD = hundred stock tank barrels per day
MMSCFPD = thousand standard cubic feet per day
PLT = Production Logging Tools
WHT = Well Head Temperature
WHP = Well Head Pressure
BHFP = Bottom Hole Flowing Pressure
FLP = Flow Line Pressure
S.G = Specific gravity
TD = Total Depth
TS = Surface Temperature

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