

Gas lift Optimization based on injection rate, gas gravity, and water cut effects: A Field Case Study Using PROSPER Simulator

Ibrahim Al-dukali ^{*1}, Entesar Haman², Hamad Abu Azoum³, Yassin nouraldin⁴, Omar Quwaidi⁵,
Abdul Mohsen Hassan⁶

^{1,3,4,5,6} Petroleum and gas Engineering Department, Faculty of engineering, Sheba University, Libya

² Petroleum Engineering Department, Zawia University, Libya

*ibr.aldukali@sebhau.edu.ly

Abstract

Gas lift optimization has become increasingly important in mature oil fields where natural reservoir energy is insufficient to sustain economic production rates. In this study, a continuous gas lift oil well (X001) located in the Sirte Basin, Libya, was modelled and optimized using the PROSPER production modelling software based on actual field data. The well model was developed, using reservoir properties, PVT data, inflow performance relationship (IPR), and completion details, and was calibrated against measured production data to ensure model reliability. Sensitivity analyses were conducted to evaluate the effects of gas injection rate, injection gas gravity, and water cut on oil production performance. The results show that oil production increases with gas injection rate up to an optimum value, beyond which further gas injection becomes inefficient. The optimum gas injection rate, identified at approximately 0.4 MMscf/day, yielding a maximum oil production rate of about 1201 STB/day. In addition, lighter injection gas resulted in improved lifting efficiency and higher oil production, while increasing water cut significantly reduced production performance. The applied methodology demonstrates the effectiveness of production modelling and sensitivity analysis as decision-support tools for optimizing gas lift systems in mature oil fields.

Keywords: Gas lift optimization, Continuous gas lift, mature oil fields, PROSPER simulator, Sirte Basin.

المخلص

أصبح تحسين عملية الرفع بالغاز ذا أهمية متزايدة في حقول النفط الناضجة حيث لا تكفي طاقة المكن الطبيعية للحفاظ على معدلات إنتاج اقتصادية. في هذه الدراسة، تم تصميم نموذج لبئر نفط يعمل بتقنية الرفع المستمر بالغاز (X001) في حوض سرت، ليبيا، وتحسينه باستخدام برنامج PROSPER لنمذجة الإنتاج، وذلك بالاعتماد على بيانات حقلية فعلية. تم تطوير نموذج البئر باستخدام خصائص المكن، وبيانات PVT، وعلاقة أداء التدفق الداخل (IPR)، وتفاصيل الإكمال، وتمت معايرته باستخدام بيانات الإنتاج المقاسة لضمان موثوقية النموذج. أجريت تحليلات حساسية لتقييم تأثير معدل حقن الغاز، وكثافة غاز الحقن، ونسبة الماء على أداء إنتاج النفط. تُظهر النتائج أن إنتاج النفط يزداد مع زيادة معدل حقن الغاز حتى قيمة مثلى، وبعدها يصبح حقن الغاز غير فعال. تم تحديد معدل حقن الغاز الأمثل عند حوالي 0.4 مليون قدم مكعب قياسي في اليوم، مما ينتج عنه معدل إنتاج أقصى للنفط يبلغ حوالي 1201 برميل قياسي في اليوم. بالإضافة إلى ذلك، أدى حقن غاز أخف إلى تحسين كفاءة الرفع وزيادة إنتاج النفط، بينما أدت زيادة نسبة الماء إلى انخفاض كبير في أداء الإنتاج. تُظهر المنهجية المطبقة فعالية نمذجة الإنتاج وتحليل الحساسية كأدوات لدعم اتخاذ القرار في تحسين أنظمة الرفع بالغاز في حقول النفط الناضجة.

الكلمات المفتاحية: تحسين الرفع بالغاز، الرفع المستمر بالغاز، حقول النفط الناضجة، برنامج محاكاة PROSPER، حوض سرت.

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1. Introduction

Artificial lift systems play a critical role in sustaining oil production from mature reservoirs where natural reservoir energy is no longer sufficient to maintain economic flow rates. Among the various artificial lift techniques, gas lift remains one of the most widely applied methods due to its operational flexibility, ability to handle high water cuts and sand production, and suitability for deviated and offshore wells [Takács, 2018;

Brown, 2019]. However, inefficient gas lift operation, can lead to excessive gas consumption, unstable production, and increased operating costs, emphasizing the need for systematic optimization. Recent studies have highlighted that gas lift performance is highly sensitive to operating parameters such as gas injection rate, injection gas properties, and produced fluid characteristics. Several researchers have demonstrated that increasing gas injection rate improves oil production only up to an optimum point, beyond which further injection results in gas slippage and reduced lifting efficiency [Alarcón et al., 2020, Hasan & Kabir, 2021]. Other studies emphasized the influence of injection gas gravity, reporting that lighter gases provide better lifting performance due to improved gas expansion and reduced hydrostatic pressure [Guo et al., 2019, Ahmed et al., 2022]. In addition, increasing water cut has been consistently reported as a major factor that degrades gas lift efficiency by increasing mixture density and frictional losses in the tubing [Mohammed et al., 2020; SPE, 2023]. With the advancement of integrated production modeling tools, such as PROSPER, several recent investigations have adopted, nodal analysis and sensitivity studies to optimize gas lift systems under varying reservoir and operational conditions [Petroleum Experts, 2021; Al-Saeedi et al., 2022]. These studies confirm that reliable well models calibrated with field data are essential for identifying optimum operating conditions and supporting production optimization decisions. Despite the extensive literature on gas lift optimization, limited studies have focused on the combined effect of gas injection rate, injection gas gravity, and water cut for wells operating in mature fields under real field constraints. Therefore, the objective of this study is to evaluate and optimize gas lift performance for a producing oil well using production modeling and sensitivity analysis. By systematically analyzing key controlling parameters, this research aims to identify optimum operating conditions that maximize oil production while minimizing gas consumption, thereby contributing to more efficient and economical gas lift operations.

1.1 Problem Statement

Gas lift is widely used in mature oil fields to sustain production; however, its performance is often limit by non-optimal operating conditions. In many wells, gas injection parameters are select based on fixed design assumptions or operational experience, without systematic re-optimization as reservoir and fluid properties change over time. This frequently leads to inefficient gas utilization, increased operating costs, and suboptimal oil production. Moreover, gas lift performance is strongly influence by interacting parameters such as gas injection rate, injection gas gravity, and water cut. While these factors have been study individually, their combined effect under real field conditions has not been adequately evaluated using calibrated production models. Consequently, an integrated and field-based optimization approach is required to identify optimum gas lift operating conditions.

1.2. Research Objectives

- 1- To develop and calibrate a reliable production model for a gas-lifted oil well using actual field data and the PROSPER simulator.
- 2- To evaluate the effect of gas injection rate on oil production performance and identify the optimum injection rate that maximizes oil production with efficient gas utilization.
- 3- To investigate the influence of injection gas gravity on gas lift efficiency and oil production rate under stable operating conditions.
- 4- To assess the impact of increasing water cut on gas lift performance and oil production behavior.
- 5- To apply sensitivity analysis to determine the key parameters controlling gas lift optimization in mature oil wells.
- 6- To establish practical guidelines for optimizing gas lift operations that can be applied to similar wells under comparable reservoir and operational conditions.

2. Data and Methodology.

2.1 Well and Reservoir Data

Table (1) PVT data of the Reservoir fluid

Parameter	Quantity	Unit
GOR	509	SCF/STB
Oil Gravity	35	API
Gas Gravity	0.79	
Water Salinity	110.000	PPM

Table (2) Deviation survey for well (X001)

Parameter	Quantity	Unit
Reservoir pressure	3600	Psig
Reservoir temperature	230	F
Water cut	35.9	%
PI	2.6	STB/Day/psig

Table (3) down hole equipment for well (x001).

Parameter	Depth ft.
7" Casing	8580
3.5" Tubing	8356
Valve	3056
Valve	4739
Valve	5829
Valve	6868

Table (4) geothermal data for well (X001)

Depth ft.	Temperature F
0	80
9016	230

2.2 Model Development and Calibration

A steady-state production model was developed in PROSPER using a black-oil fluid description. The model calibrated by matching simulated oil production rates and flowing bottom-hole pressures with actual field measurements. A satisfactory match was achieved with deviations of less than 5%, confirming the reliability of the model for optimization and sensitivity analysis purposes.

2.3 Inflow Performance Relationship (IPR) Model

In this study, the inflow performance relationship (IPR) represented using the linear Productivity Index (PI) model. This approach was selected because the reservoir under investigation is classified as an under saturated oil reservoir, where the reservoir pressure is higher than the bubble-point pressure. The PI model adopted due to its simplicity and suitability for wells operating above the bubble-point pressure. During the model calibration stage, the PI-based IPR showed a good agreement with actual production data, with deviations of less than 5%, confirming its applicability for gas lift optimization and sensitivity analysis in this study.

2.4 Sensitivity analyses.

Conducted to evaluate the impact of key parameters, including gas injection rate, injection gas gravity, and water cut.

3. RESULTS AND DISCUSSION

3.1 Gas injection rate sensitivity:

The sensitivity analysis of gas injection rate revealed a strong relationship between injected gas volume and oil production rate. As shown in Figure (1), Table (5), oil production increases with increasing gas injection rate during the initial stages. This behavior attributed to the reduction in hydrostatic pressure within the tubing

as injected gas lightens the fluid column, thereby increasing drawdown and enhancing reservoir inflow. However, beyond a certain injection rate, the oil production trend begins to plateau and eventually becomes inefficient. The results indicate that gas injection rates higher than approximately 0.4 MMscf/day do not result in a proportional increase in oil production. Instead, excessive gas injection leads to higher gas slippage and increased frictional losses, which negatively affect lifting efficiency. The optimum gas injection rate, for well X001 identified at approximately 0.4 MMscf/day, corresponding to a maximum oil production rate of about 1201 STB/day. Injection rates exceeding this value were considered uneconomical, as they increase gas consumption without significant production gain. These findings are consistent with established gas lift theory, which emphasizes the existence of an optimum injection point rather than maximum gas input.

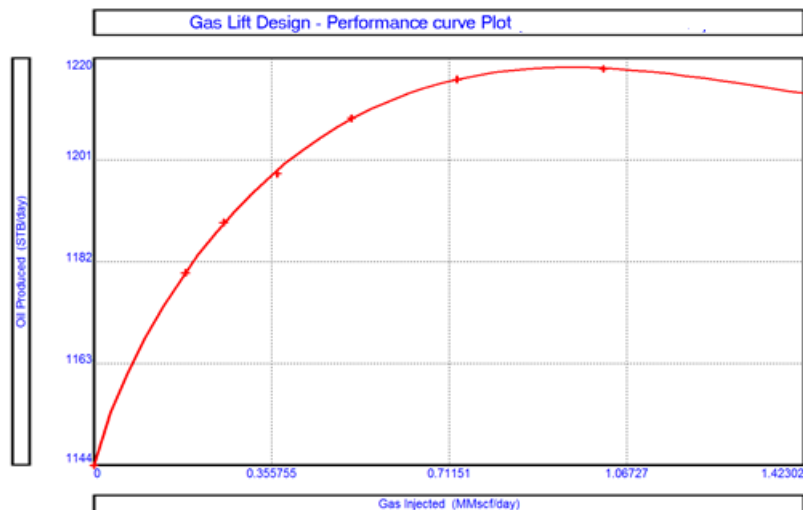


Figure (1) Gas Injection Rate

Table (5) data of Injection Rate

Parameter	Gas injection rate (MMscf/day)							
	Optimum				Max		uneconomical	
Injection Rate (MMscf/day)	0	0.05	0.1	0.275	0.4	0.45	0.5	0.55 0.6
Oil Rate STB/day	1144	1157	1167	1187	1201	1204	1207	1201 1212

3.2 Optimum injection Gas Gravity.

Injection gas gravity found to have a noticeable impact on gas lift performance. The sensitivity analysis demonstrated that lighter injection gas results in higher oil production rates, as illustrated in Figures (2) and (3), Table (6). At a fixed injection rate of 0.4 MMscf/day, oil production decreased progressively as gas gravity increased. This behavior can be explain by the superior lifting efficiency of lighter gas, which provides better expansion characteristics and more effective reduction of fluid density in the tubing. Heavier gas, on the other hand, reduces the overall lifting efficiency due to its higher density, leading to less effective pressure reduction and lower drawdown at the reservoir.

The results confirm that, for optimal gas lift performance, the lightest available injection gas should be selected whenever operationally feasible. This parameter plays a critical role in maximizing oil production under stable injection conditions.

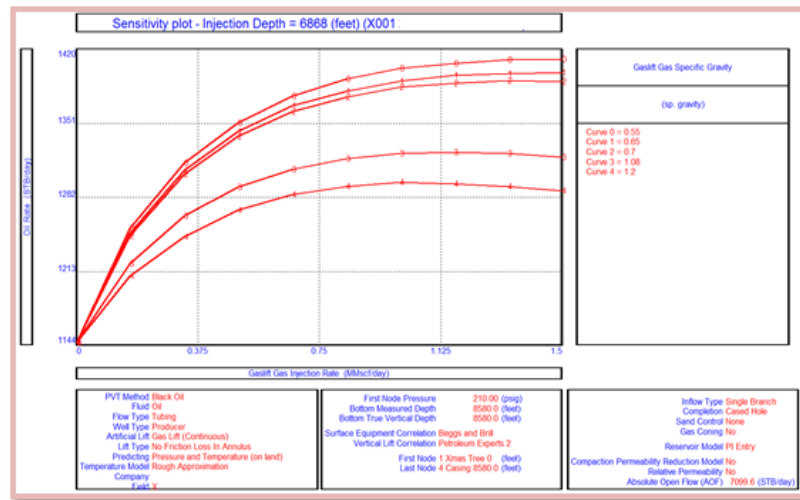


Figure (2) effect gas gravity on oil production rate

Table (6) the effect gas gravity on oil production at injection rate 0.4 MM scf/day.

Injection Gas Gravity (sp.g)	Oil rate (STB/day)
0.55	1203.
0.65	1201
0.7	1198
0.83	1193
1.08	1189
1.2	1182

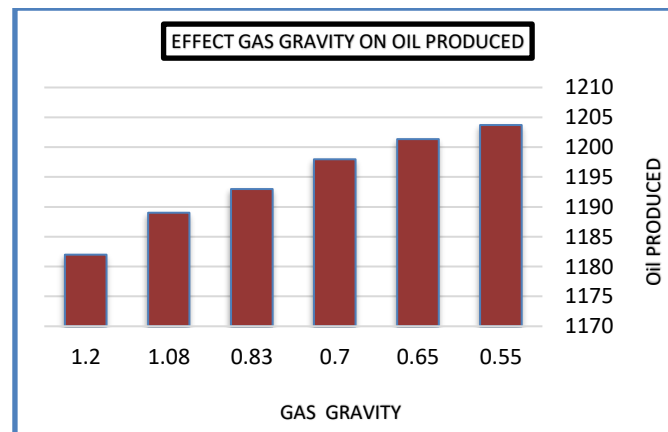


Figure (3) effect gas gravity on oil production rate at injection rate 0.4 MMscf/day

3.3 Effect the water cut on oil production

The effect of water cut on oil production also evaluated through sensitivity analysis. The results clearly show that increasing water cut has a significant negative impact on oil production rates, as presented in Figures (4) and (5) Table (7). At an injection rate of 0.4 MMscf/day, oil production declined steadily as water cut increased. This trend is primarily due to the higher density and viscosity of the produced fluid mixture at higher water fractions, which increases the hydrostatic head and reduces gas lift efficiency. Additionally, higher water cut leads to increased liquid loading, requiring more gas to lift the same volume of oil. For well X001, the actual water cut of approximately 35.9% corresponds to an oil production rate of about 1201 STB/day. Any further increase in water cut would result in a continuous decline in oil production, emphasizing the importance of water production management in mature gas-lifted wells.

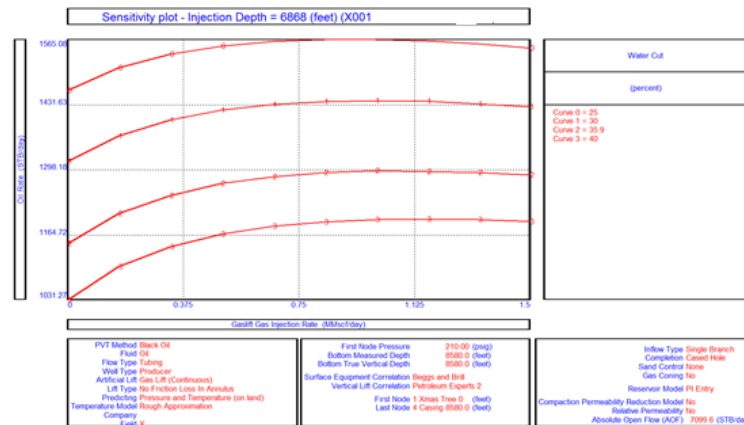


Figure (4) effect the water cut on oil production

Table (7) Data effect of water cut on the oil production rate at injection rate 0.4MMscf/da

Water cut (%)	Oil rate (STB/day)
0	2244
5	2092
10	1942
15	1794
20	1648
25	1502
30	1362
35.9	1201.47
40	1090
45	966
50	843
55	728
60	612
65	507
70	408

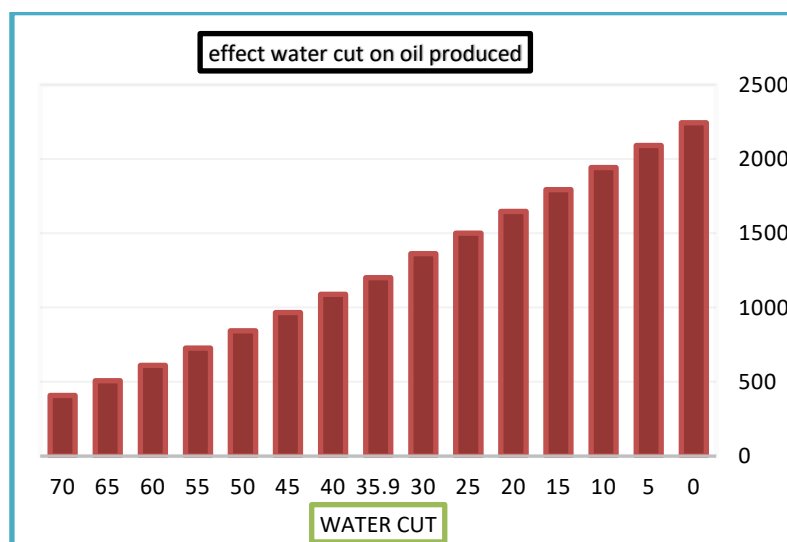


Figure (5) effect the water cut on oil produced at injection rate 0.4MMscf/day.

3.4 Discussion

The optimum gas injection rate identified in this study (≈ 0.4 MMscf/day), which resulted in a maximum oil production rate of approximately 1201 STB/day, is consistent with findings reported in the literature for

mature oil wells operating under similar conditions. Alarcón et al. (2020) investigated continuous gas lift optimization using nodal analysis and reported optimum injection rates ranging between 0.35 and 0.50 MMscf/day, beyond which oil production showed marginal improvement due to increased gas slippage and frictional losses. The close agreement between the present results and those reported by Alarcón et al. confirms the reliability of the calibrated PROSPER model and supports the existence of an optimum gas injection point rather than maximum gas input.

Regarding the effect of injection gas gravity, the results demonstrate that reducing gas gravity from 1.2 to 0.55 led to an increase in oil production from approximately 1182 to 1203 STB/day, representing an improvement of about 1.8%. Similar trends were reported by Ahmed et al. (2022), who observed oil rate improvements of 1–3% when lighter injection gas was used, attributed to better gas expansion and more effective reduction of hydrostatic pressure in the tubing. Guo et al. (2019) also emphasized that lighter injection gas enhances gas lift efficiency by improving gas–liquid interaction and reducing mixture density, which is in good agreement with the observed behavior in this study.

The sensitivity analysis of water cut revealed a pronounced negative impact on oil production performance. Increasing water cut from 0% to 35.9% resulted in a reduction in oil production from approximately 2244 to 1201 STB/day, corresponding to a decline of nearly 46%. This result is comparable to the findings of Mohammed et al. (2020), who reported oil production losses ranging between 40% and 55% as water cut increased from 0% to 40% in gas-lifted wells. The strong agreement highlights the dominant role of water cut in increasing fluid density and liquid loading, thereby reducing gas lift efficiency and requiring higher gas volumes to sustain production.

Overall, the quantitative agreement between the present results and previous studies confirms that the proposed gas lift optimization method robust and applicable to mature oil fields. The calibrated production model successfully captures the key physical mechanisms governing gas lift performance and provides reliable guidance for selecting optimum operating conditions under real field constraints.

4. ASSUMPTIONS AND LIMITATIONS The developed model assumes steady-state flow conditions and homogeneous reservoir properties. Transient effects, scale formation, and valve performance degradation over time not considered, the results are most applicable to wells operating under similar conditions and should be update periodically as reservoir and production conditions change.

5. CONCLUSION

This study successfully demonstrated a systematic approach for optimizing gas lift performance using production modeling and sensitivity analysis, the optimum gas injection rate for the studied well, was identified at approximately 0.4 MMscf/day, achieving maximum oil production with efficient gas utilization. Lighter injection gas was show to enhance lifting efficiency, while increasing water cut negatively impacted oil production. The methodology provides a practical framework that applied to similar gas-lifted wells to improve production efficiency and reduce unnecessary gas consumption.

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