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Gas Lift Modeling: A Viable Option for Oil Production Optimization

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ABSTRACT

Gas lift optimization is very challenging even in the mist of availability of gas assets as this involves modeling reservoirs accurately. Non availability of good software hinders best results such as obtaining critical gas lift design parameters like appropriate absolute open flow (AOF), skin factor, formation productivity index and the skin factor or even the reservoir pressure. The aim of this work is to design a model to gas lift an oil well in the Niger Delta for improved oil optimization. In other to achieve this aim the following objectives are considered; determine the maximum production rate achievable using gas lift, determine the optimum lift gas injection rate and depth and design the operating and unloading valves. Integrated Production Management (IPM) software was used with data from an oil well in the Niger Delta. Results show that the AOF gave 18026.3STB/day, formation PI gave 10.56STB/day/psi while the skin factor gave a positive value of 2. Pipe correlation used is Beggs and Brill. The maximum and minimum gases available are both 15mmscf/day. Water cut is 80%. The use of gas lift is very appropriate when the gas cap is a major source of reservoir energy.

Keywords: Gas lift; Skin; Beggs and Brill; Absolute open flow (AOF); Prosper software.

Introduction

Gas Lift is one of the number of processes used to artificially lift oil or water from wells where there is insufficient reservoir pressures to produce the required up-thrust force from the well. Gas lift is the process of injecting gas in the annulus between tubing and casing where it will enter the tubing via a gas-lift valve located in a side pocket (Zwaag, Van der Claas, 2006 and Zolutkhin and Hamouda 2006). The gas will then reduce the weight of the produced fluid column, which will lower the bottomhole pressure (Al Abidin, 2007 and Egu and Ilozobhie, 2015). Reservoir fluid will then experience lower resistance to flow, resulting in increased flow rates (Figure l.0) and increased production (Brown, 1980 and Kanu et. al. 1981).

Optimization problems are real world problems we encounter in many areas such as mathematics, engineering, science, business and economics. In these problems, we find the optimal, or most efficient, way of using limited resources to achieve the objective of the situation. This may be maximizing the production, minimizing the injected fluid, minimizing the total distance travelled or minimizing the total time to complete a project (Golan and Whitson,1991 and Ilozobhie, et. al. 2019).

Optimization was carried out using PROSPER, now PROSPER is designed to allow building of reliable and consistent well models, with the ability to address each aspect of wellbore modeling; PVT (fluid characterization), VLP (for calculation of flow line and tubing pressure loss) and IPR (reservoir inflow). By modeling each component of the producing well system, the user can verify each model subsystem by performance matching (Beggs, 2003, and Ilozobhie, and Egu, 2014). Once a well system model has been tuned to real field data, PROSPER can be confidently used to model the well in different scenarios and to make forward prediction of reservoir pressure based on surface production data.

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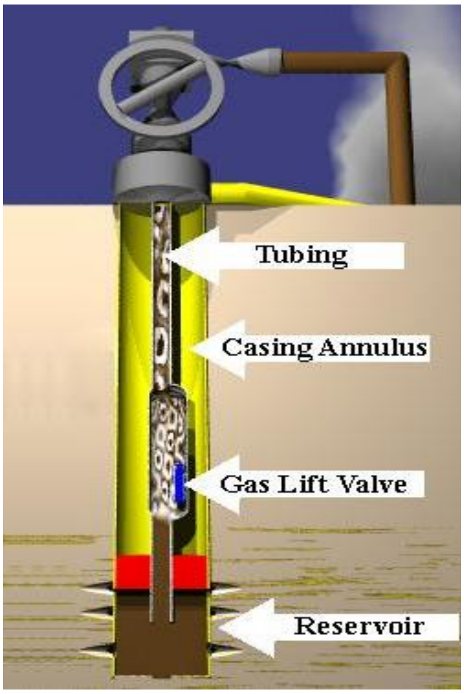

Figure 1.0. Gas Lift Well Schematic (SOURCE: Brown, 1982)

Statement of the Problem

Gas lift optimization is very challenging even in the mist of availability of gas assets as this involves modeling reservoirs accurately. Non availability of good software hinders best results such as obtaining critical gas lift design parameters like appropriate absolute open flow (AOF), skin factor, formation productivity index and the skin factor or even the reservoir pressure.

Aims and Objective

The aim of this work is to design a model to gas lift an oil well in the Niger Delta for improved oil optimization.

In other to achieve this aim the following objectives are considered:

- Determine the maximum production rate achievable using gas lift;
- Determine the optimum lift gas injection rate and depth;
- Design the operating and unloading valves.

Materials

Well Data which was useful in comparing the reservoir pressures and productivity index before modeling, The Production and Systems performance analysis (PROSPER) software is a well performance, design and optimization program which is designed to allow the building of reliable and consistent well bore modeling VIZ, PVT (fluid characteristics), VLP correlations (for calculation of flow-line and tubing pressure loss) and IPR (reservoir inflow) was used.

By separately modeling each component of the producing well system, then allowing the user to verify each model subsystem by performance matching PROSPER ensures that the calculations are as accurate as possible. Once a system model has been turned to real field data, PROSPER can be confidently used to model the well in different scenario and to make forward predictions of reservoir pressure based on surface production data.

Methods

For a continuous gas lift design a PROSPER model for a naturally flowing oil well was built; this was done to estimate the initial flow rate against a wellhead flowing pressure. It was then matched with the actual well test data. After some production, with the aid of the available lab PVT the PROSPER model built were calibrated to produce the well test results**.** Since the well has been in production for some time, it has to be converted to a gas lifted in order to improve well productivity (continuous gas lift design).

Description of the Gas Lift Design Condition

This option enables the user to design gas lifted artificial lift systems for new installations. This option can be used to determine the optimum gas lift design of a well by calculating the maximum production rate, the optimum gas lift rate, the valve spacing to unload the well and the test rack setting pressure for each valve. The gas lift design parameters are shown in Table 1.

Table 1. Gas Lift Design Parameter

Maximum liquid rate	30,000 stb/d
Maximum Gas Available	15 MMscf/d
Maximum Gas During Unloading	15 MMscf/d
Flowing Top Node Pressure	200
Unloading Top Node Pressure	200
Operating Injection Pressure	1500
Kick Off Injection Pressure	1500
Desired dP Across Valve	100
Maximum Depth of Injection	7500
Water Cut	80%
Minimum Spacing	250
Static Gradient of Load Fluid	0.46
Minimum Transfer dP	25%
Maximum Port Size	Set by valve series selection
Safety for Closure of Last Unloading Valve	0
Total GOR	400

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To start the gas lift design, the following procedures were followed on the software: select | Design | Gas lift | New Well then input the parameters given above. In order to proceed, select | Continue | Get Rate and a plot is generated with | OK | Plot. The performance curve generated is used by the gas lift design algorithm to define the oil rate which is one of the design will aim to produce. The performance curves also give us a plot of oil produced versus the gas injected. The injection gas rate that gives the highest production rate can be found, although that might not be the optimum point of injection in terms of revenue.

Results for Description of IPR

It can be seen from (figure 2.0) that the IPR describes pressure drawdown as a function of production rate. The drawdown is a complex function of pressure drawdown, fluid PVT properties, formation permeability (absolute and relative), effective overburden etc.

Results for Description of Gas Lift Design Condition (Performance Curve)

The performance curves give us a plot of oil produced versus the gas injected. The injection gas rate that gives the highest production rate can be found, although that might not be the optimum point of injection in terms of revenue. That point is where the incremental additional cost of compressing gas equals the incremental revenue of the additional oil produced. The economic optimum gas injection rate is often found to the left of the maximum production rate in such a curve (figure 3.0). It is seen that the injection rate that gives the maximum production rate is 9.90959MMscf/stb at 1520.72 STB/ day.

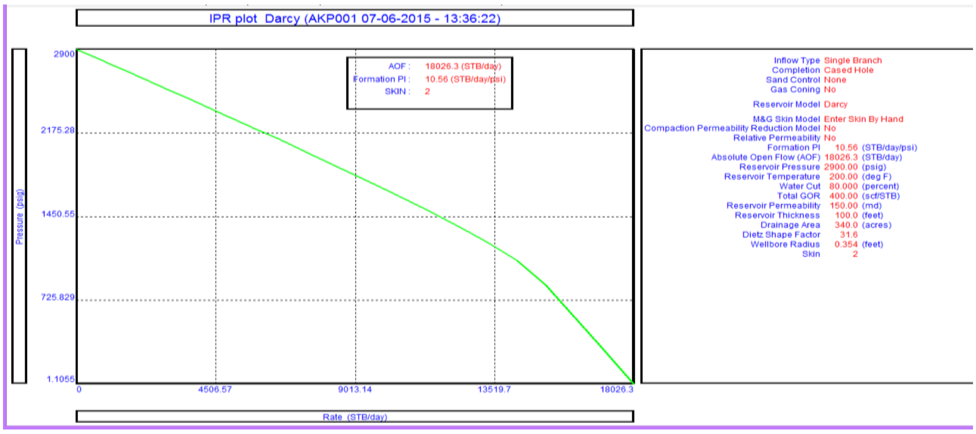

Figure 2.0. PROSPER Interface –IPR Curve

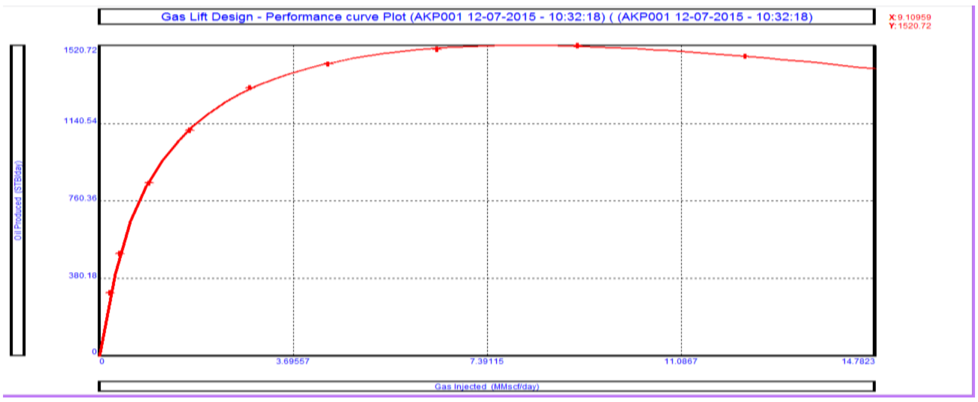

Figure 3.0. PROSPER Interface –Performance Plot Curve

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Results for Performimg the Gas Lift Design (NEW WELL)

The program determines the depth of the operating valve and the spacing for the unloading valves. Valve spacing is not affected by the choice of unloading method (casing or tubing sensitive), but whether the well IPR is used for calculating the unloading rate or not. When designing the valve system, PROSPER can be set to check whether the solution rate is achievable with respect to the IPR. IF necessary the design rate is reduced and the spacing calculation is repeated. The injection depth (orifice valve) is the depth at which the flowing tubing pressure equals the casing pressure gradient less the designed pressure loss across the orifice. However, injection depth is often limited by well design, for example by a production packer or weak casings (figure 4.0). In other words, as gas lift is carried out and the pressure drop decreases, an optimal gas rate is achieved before too much is injected allowing the pressure drop to increase due to the friction.

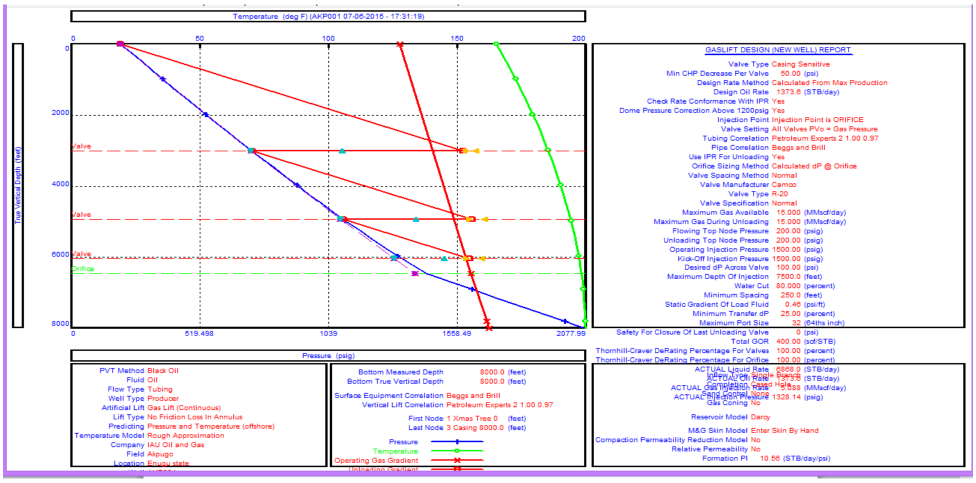

Figure 4.0. PROSPER Interface – Designing the valve system

Results for System Calculation for a Gas Lifted Well (Sensitivities of Injection Depth)

The sensitivity calculations capabilities allow the engineer to model and easily optimize tubing configuration, choke and surface flow line performance. To see the effect of injection depth a sensitivity analysis was run on this. PROSPER allows the injection depth to be a variable, and calculates production for each depth entered.

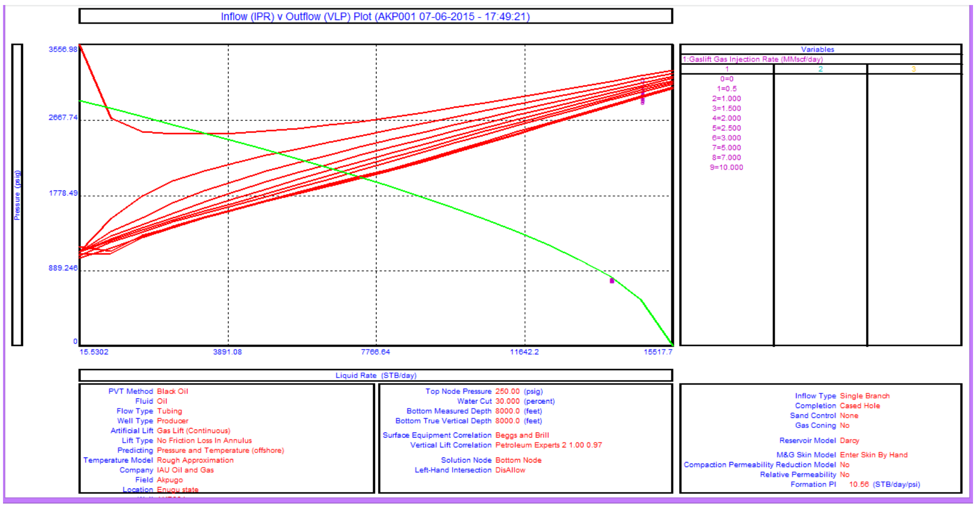

Figure 5.0. The figure shows how the VLP curve is moved as a function of injection depth

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The results show that a deeper setting depth of the operating valve gives an increased production (figure 5.0). This plot identifies the operating point and optimum liquid production is achieved in this point. It was also very useful to plot the oil rate versus the gas lift gas injection rate (figure 6.0).

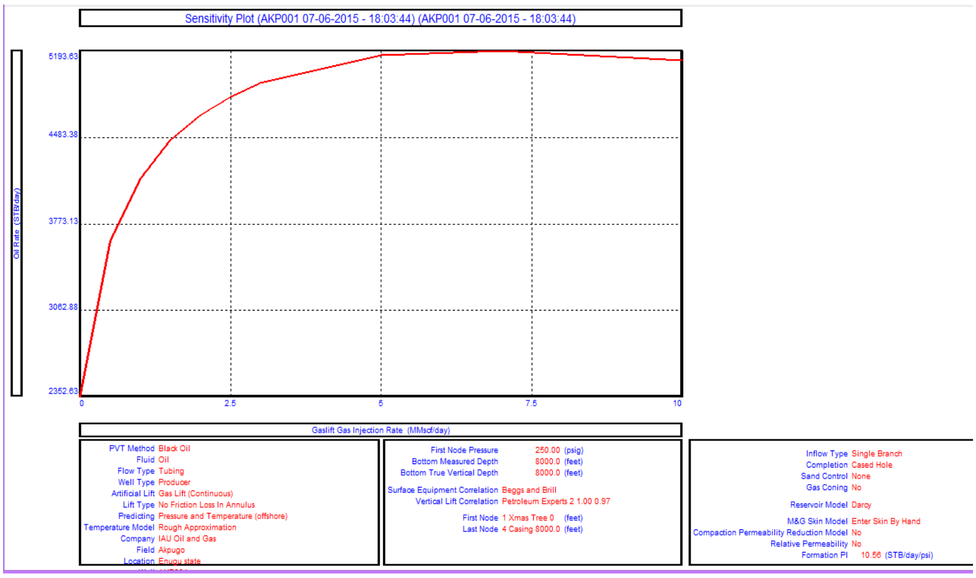

Figure 6.0. PROSPER Interface – sensitivity plot

Conclusions

At the end of the analysis, observations were made and the following conclusions were drawn based on the computed results: Gas lift process design can be performed to predict rates, generate the performance curve and other parameters during the gas lift process. Secondly, the generated gas lift performance curve can be used to know the gas injection rate required to achieve any oil production level. In other words, as gas lift is carried out and the pressure drop decreases, an optimal gas rate is achieved before too much is injected allowing the pressure drop to increase due to the friction.

Recommendations

The following recommendations within the scope of this research are: Production through gas lifting is not only dependent on injection rate, but also on the completion design hence the valves should be set deeper for an increased production furthermore, there should be availability of gas and the well should be quality checked before modeling a gas lift well.

Nomenclature/Abbreviation

q	-	Oil flow rate, bbl/day
k	-	Effective oil permeability, md
re	-	Drainage area radius, m
rw	-	Well bore radius, m
AOF	-	Absolute open flow rate, bbl/day

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Pwf - Well bore flowing pressure at, psi

µ - Oil viscosity, cp

B - Oil formation volume factor, rb/bbl

S - Skin factor

Rs - Solution gas oil ratio, Sm3/Sm3

Pb - Bubble point pressure, psi

P_{Re} - Average reservoir pressure, psi

BHP - Bottom hole pressure

VLP - Vertical Lift Performance

GOR - Gas Oil Ratio

IPR - Inflow Performance Relationship

bbl - Barrel

*P*bh - Flowing bottom-hole pressure

Fo - Oil cut

psig - Pounds per square inch

GLIR - Gas lift injection rate

PVT - Pressure-volume-temperature

GLR - Gas-liquid ratio

Qg - Gas Injection Rate

QL - Liquid Production Rate

M - Economic slope

scf - Standard cubic foot

md - Milidarcy

SSSV - Subsurface safety valve

MMscf/d - Million standard cubic foot per day

Stb - Stock tank barrel

P - Profit per barrel of oil produced

^oF - Degree Fahrenheit

Declarations

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The study has not received any funds from any organization.

Competing Interests Statement

The authors have declared no competing interests.

Consent for Publication

The authors declare that they consented to the publication of this study.

Authors' Contributions

All the authors took part in literature review, research and manuscript writing equally.

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