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RESEARCH ARTICLE

GAS LIFT OPTIMIZATION OF A MATURE WELL IN NIGER DELTA, NIGERIA USING INCOMPLETE DATASET: A CASE STUDY

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ABSTRACT

Well DEF, a well located in Niger Delta region of Nigeria was shut down for 7 years. On gearing towards re-starting production, different options such as installation of gas lift mechanism, servicing and installation of packers and valves were evaluated for possibility of increasing well fluid productivity. Hence, this research was focused on optimizing well fluid productivity using PROSPER through installation of continuous gas lift mechanism on an existing well using incomplete dataset; in addition, the work evaluated effect of gas injection rates, wellhead pressure, water cut and gas gravity on efficiency of the artificial lift mechanism for improved well fluid production. Results of the study showed that optimum gas injection rate of 0.6122 MMscf/day produced well fluid production of 264.28 STB/day which is lower than pristine production rate (266 STB/day) of the well. Also, increment in wellhead pressure resulted in decrease in well production, increase in water cut facilitated reduction in well fluid productivity while gas gravity is inversely proportional to well fluid productivity. Based on results obtained, authors concluded that Well DEF does not require gaslift mechanism hence, valves and parkers need to be re-serviced and re-installed for sustained well fluid.

KEYWORDS

Optimization, productivity, gas injection rate, gas gravity, wellhead pressure, water cut.

1. INTRODUCTION

Production of well fluids is a function of natural driving mechanisms in the reservoir; however as well fluid production increases over time, natural driving mechanisms decrease which consequently impedes the natural economic production rate of hydrocarbon and profitability of the asset (Abdalsadig et al., 2016; Yakoot et al., 2014). As a result, there is a need to *assist* the primary production of hydrocarbons from the reservoir using artificial lift mechanisms or pressure maintenance systems to prolong the life of the well and economic value of the asset. These artificial lift mechanisms induce a pressure differential in fluid column in the well and production tubings, increase production pressure drawdown, reduce bottomhole pressure and ultimately facilitate improved production of well fluids; this is achievable by addition of external energy to the fluid that aids its production at the surface (Ghazali et al., 2014). Artificial lift mechanisms are divided into two categories – pump induced lift mechanism and gas lift mechanism. Pump induced lift mechanism comprises sucker rod, hydraulic and gas gravity while gas lift mechanism constitutes injection into a reservoir to lighten the density of well fluid column.

Gas lift mechanism, an artificial lift method that involves the injection of gas into the production tubings to lighten hydrostatic column of the fluid and reduce backpressure has been proven to be effective in improving the production of reservoirs whose primary driving mechanisms has diminished over time; about 98% of artificial lift mechanisms for improved production of crude oil are driven by gas-lift mechanism (Silverwell, 2016; Shokir et al., 2017). The mechanism behind gas lift entails two modes of operations – continuous-flow and intermittent flow (Vol et al., 2015; Shedid and Yakoot, 2013; Hamshary et al., 2015). Continuous-flow gas lift involves the injection of small volumes of high-pressure gas into wells with high Productivity Index (PI) of > 0.5BD/psi, high basic static pressure and Gas-Liquid Ratio (GLR) of up to 2000 scf/bbl while intermittent gas lift involves the injection of large volumes of gas into an accumulated slug for a short time to move the liquid slug to the surface (Abdalsadig et al., 2016). Regarded as the only artificial lift mechanism that utilizes primary energy in the reservoir, continuous-flow gas lift mechanism supplements the primary flow of well fluids to the surface by addition of high-pressure gas at a maximum depth from an external source (Shedid and Yakoot, 2013; Hamshary et al., 2015).

Successful implementation of the gas lift mechanism is influenced by different parameters such as injection depth, injection rate, valves spacing, wellhead pressure, reservoir pressure, water cut, PI, Gas-Oil Ratio (GOR), the performance of gas lift valve, gas gravity, and production tubing size (Abdalsadig et al., 2016). Amongst these parameters, the optimum injection rate has been identified to be highly critical in optimizing continuous-flow gas lift mechanism for improved well fluid production; this is because the over-injection of gas results in a decrease in well fluid production as slippage between liquid and gas phase is facilitated (Ebrahimi, 2010). Therefore, it becomes imperative to determine an optimum gas injection rate as the volume of gas injected is not directly

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proportional to recovered well fluids. Also, gas gravity, water cut, injection rate, and wellhead pressure have been highlighted as critical parameters that affect the efficiency of continuous-flow gas lift mechanism for improved well fluid productivity (Blann and Williams, 1984).

Gas lift optimization is a complex process that involves establishing an optimal distribution of gas to a network of wells and pipelines for improved well fluid production. This process entails an uninterrupted process of improvement that generates the need to optimize scenarios of production with recent production data (Shedid and Yakoot, 2013). Different methods such as Sequential Quadratic Programming (SQP), Augment Lagrangian Models (ALM), stochastic solvers such as Genetic Algorithm (GA), etc. exist for optimization of gas lift mechanism; however, nodal analysis is the technique used in the study. Nodal analysis is a systematic method of improving well fluid production by evaluating each section of the production system to optimize process parameters such as flow rates, production tubing string, horizontal flow lines, well completion, and separation facilities (Kisson et al., 2012). Integrated simulation models have been reported suitable for production field management; computer applications have proved highly useful in using these models for production optimization processes (Shedid and Yakoot, 2013).

1.1 Field Description

Well DEF, a mature well that was produced for 7 years before being shut down is located in Ughelli, Niger Delta region of Nigeria. Notably, the well was originally producing at a bottom hole flowing pressure of 2488 psig and at a flow rate of 266 STB/day. The well location is a seasonally flooded southern part of Nigeria, home to giant oil fields that falls within a narrow "bowlike" band which cuts across a structural sequence that is known to have geologic similarities across these bands. The productive sands found in formations made up of a cyclic sequence of transgressive marine and fluvial deposits. Additionally, it's a field known to contain a multi-reservoir system that has sands with high permeability.

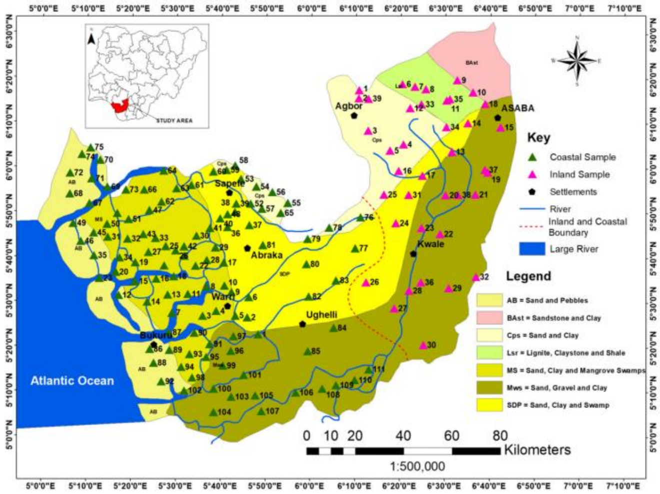

Figure 1: Geological Map of Delta State, highlighting location, reproduced from (Owoyemi et al., 2019)

2. Methodology

PROduction and Systems PERformance analysis software (PROSPER), a software suitable for design and modeling of reliable well configurations with abilities to simulate individual segments of well bore such as characterization of fluids, Vertical Lift Performance (VLP) correlation and reservoir inflow was used for simulation in this study, following a methodology outlined in Figure 1 (Ghazali et al., 2014). To successfully simulate the well, critical dataset such as gravel pack and Productivity Index (PI) are needed, however, these were not obtainable in the data gotten from the field hence, a novel approach was used to generate gravel pack and PI using sensitivity analysis.

Initially, parameters of the well were defined; specifics of well type, artificial lift and well completion type were selected. Other parameters such as oil and water, black oil method, and Newtonian, were selected for fluid description while the well was defined as a producer well using tubing flow. The well was a cased hole that used Gravel Pack for sand control with an artificial lift set to none; initially. Afterward, PVT data were inputted using correlations that can be modified by a non-linear regression technique to best fit measured data. After matching data, it was observed that Almahoun and Beggs correlations are the most suitable correlations hence; IPR (Inflow Performance Relationship) curve was generated and input Equipment data. However, there was difficulty in generating an IPR curve due to the absence of a critical dataset as a result; sensitivity analysis was carried out to generate data for Productivity Index (PI). A correlation comparison was carried out to generate a gradient (transverse) for our well model using standard correlations before estimating the overall heat transfer coefficient. Consequently, a VLP curve was matched with IPR using data such as top node pressure, solution node temperature, reservoir pressure, and test data points. Finally, gas lift mechanism was applied to the model using data such as placement of mandrels, type of valve, casing pressure, and pressure drop across valve hence, the effect of the flow rate of injected gas and gas gravity on the efficiency of gas lift mechanism for improved well fluid production was evaluated.

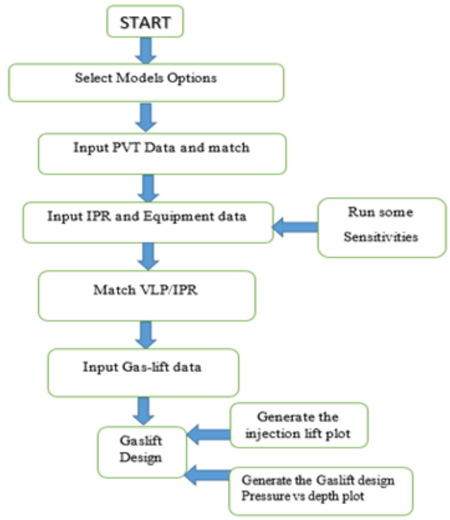

Figure 2: Steps for the simulation process

3. Results and Discussions

3.1 Modelling of Well DEF

As highlighted earlier, a sensitivity analysis was initially carried out to obtain data for gravel pack and PI due to incomplete datasets needed for successful well simulation. Figure 3 shows gravel pack sensitivity analysis carried out to generate gravel pack data highlighted in Table 1. Also, IPR sensivity analysis was carried out as shown in Figure 4 to generate value for PI - 0.305 STB/day/psi. These datasets generated and other field data were used to plot an IPR curve shown in Figure 5 by ensuring the curve passes through test data points of bottomhole pressure of 2488 psig and well fluid flow rate of 264 STB/day. Using equipment data, correlation comparison was carried out and results showed that test data points fell between Duns and Ross and Fancher and Brown correlations.

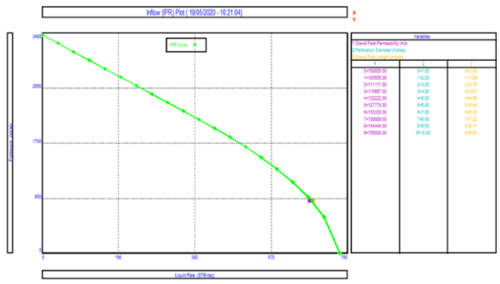

Figure 3: Gravel Pack Sensitivity.

Table 1: Gravel Pack Data (Sand Control)	
Parameter	Value
Gravel Pack Permeability	150000 md
Perforation diameter	4 inches
Shot density	4
Gravel pack length	6 inches
Perforation interval	$4\frac{1}{ft}$
Perforation efficiency	1
Method	Single

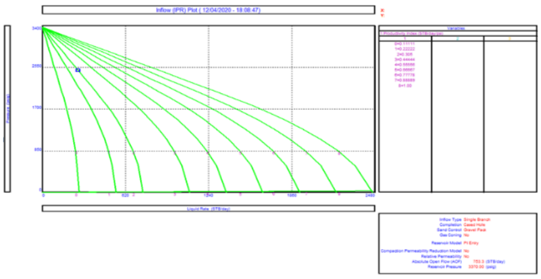

Figure 4: IPR Sensitivity Analysis.

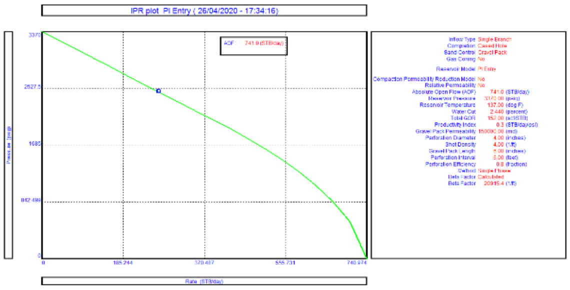

Figure 5: IPR curve

Thereafter, IPR and VLP were matched through the test data point as shown in Figure 6; simulation results modeled flow rate at 267.7 STB/day and pressure at 2488.92 psig respectively. Notably, results generated by the simulated model were close to field data; error difference of 0.63186 and 0.036186 was gotten for pressure and flowrate respectively using Petroleum Expert 2 as a selected correlation. Finally, the gas lift mechanism was installed on the modeled well with gas lift design data shown in Table 2; this resulted in the generation of a gas lift performance curve shown in Figure 7.

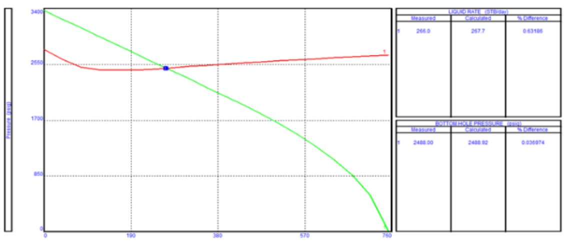

Figure 6: VLP/IPR Curve

Table 2: Parameters of Gas Lift Design	
Design rate method	Calculated max production
Maximum liquid rate	2000 STB/day
Maximum gas available	1 MMSCF/day
Maximum gas during unloading	1 MMSCF/day
Flowing top node pressure	66 psig
Operating injection pressure	66 Psig
Kickoff injection pressure	900 Psig
Water cut	2.44%
Desired dp across valve	50psi
Static gradient	0.46psi/ft
Total GOR	152 scf/STB
Unloading top node pressure	66 psig

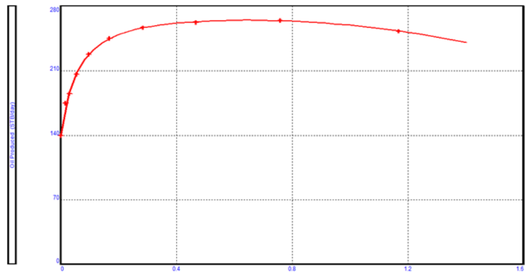

Figure 7: Gaslift Performance curve

After the gas lift was successfully installed on the well with a total of seven valves, critical parameters that affect the efficiency of gas lift mechanism for improved well productivity were evaluated. Results of this evaluation are highlighted below:

3.1.1 Effect of Gas Injection Rate

From the simulation, it was observed that well fluid productivity increased as the gas injection rate increased as shown in Table 2. However, a maximum well production rate was attained at 264.27 STB/day with a consequent gas injection rate of 0.6122 MMscf/day after which higher gas injection rates resulted in lower well fluid productivity. This can be attributed to the phenomenon of slippage between the liquid and gas phase were the injected gas moves faster than the oil thereby reducing its productivity. This is consistent with what other authors reported; once optimum gas injection rate is exceeded, well fluid production rate decreases (Ebrahimi, 2010; Khaled et al., 2017).

Table 2: Effect of Gas Injection rate on well fluid productivity	
Injection rate (MMscf/day)	Oil Flowrate (STB/day)
0.03053	185.062
0.05463	205.666
0.09712	227.261
0.1685	224.90
0.2841	224.90
0.4736	261.85
0.6122	264.27
0.758	264.03
1.1691	252.68

3.1.2 Effect of Water cut

Evaluation of the effect of water cut on the efficiency of gas lift mechanism for improvement of well fluid productivity revealed that the oil production rate declined as water cut increased from 0 – 50% as highlighted in Table 3; this trend agrees with the works of other authors (Abdalsadig et al., 2016; Recham and Bencherif, 2004). The inversely proportional relationship with oil production and amount of water cut can be attributed to the fact increasing water cut would facilitate a decrease in reservoir drawdown, increment in interfacial tension which would consequently reduce flow rate of oil from the well to the surface.

Table 3: Effect of water cut on Oil Flowrate	
Water Cut	Oil Flowrate (STB/day)
2.44	264.276
10	239.287
20	218.583
30	176.61
40	146.93
50	118.55

3.1.3 Effect of Wellhead Pressure

In this study, the effect of wellhead pressure on flowrate of a well fluid was evaluated using values ranging from 66psi to 100psi. Results of the analysis showed that as solution node pressure increased, oil production rate reduced as shown in Table 4. This result corroborates claims of other authors in literature that stated increase in well head pressure had

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minimal impact on oil production (Beiranvand et al., 2011; Abdalsadig et al., 2016). Reason for this can be attributed to slippage that occurs between liquid and gas which results in faster movement gas than oil with a consequent production of less well fluids at the surface.

Table 4: Effect of water cut on Oil Flowrate

Wellhead Pressure (psi)	Oil Flowrate (STB/day)
66	264.276
70	263.742
80	256.816
90	204.651
100	250.77

3.1.4 Effect of Gas Specific gravity

Effect of gas gravity on well productivity was evaluated; different values of specific gravity starting from well DEF specific gravity of 0.65 – 1.0 sg were analyzed. Results showed that oil production rates decrease when gas gravity increases from 0.65 to 1 as highlighted in Table 5. This trend was also highlighted (Ghazali et al., 2014). A reduction in well fluid production rate as specific gravity can be attributed to the fact that a lighter gas would produce less dense multiphase fluids whose hydrostatic column can be overcome. This would result in the production of more well fluids at the surface. However, it is stated that this relationship is only valid for the steady-state which PROSPER is modeled after (Maijoni and Hamouda, 2011).

Table 5: Effect of water cut on Oil Flowrate

Gas Specific gravity (sg)	Oil Flowrate (STB/day)
0.65	264.276
0.75	263.75
0.80	263.637
0.85	263.427
0.90	262.707
1.00	246.859

After completing the simulation, well fluid productvity rates showed that well DEF with a natural flow of 266 STB/day reduced to 264.276 STB/day when continuous gas lift mechanism was introduced into the production system for improved well fluid productivity. In other words, this meant that the well does not require gaslift mechanism to optimize its flow-rate. In this situation, if evaluation studies are to be carried out on the well before production kick starts, gravel packs and valves should be re-serviced or re-installed so as to save cost to installing gas lift mechanism that would not improve production.

4. Conclusions

The work has highlighted the feasiliblity of carrying out optimization studies on wells using incomplete dataset when gas lift mechanism is introduced for improvement in well productivity. Results of the study has shown that usage of PROSPER software can save time and resources when evaluation studies are to be carried out on wells for possibility of increasing well fluid production. In cases when artificial lift mechanisms are not needed, authors highlighted that gravel packs and valves can be re-serviced and re-installed for sustained well productivity.

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