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Continuous Gas Lift Optimization on the Productivity of Oil Wells: A Case Study of an Oil Well (B-04) in OBB Field

*Oghenefega E. Unuavwodo *, Efeoghene Enaworu, Ifeanyi Seteyeobot, Yunusa C. Onuh*

Petroleum Engineering Department, Covenant University, Ota, Nigeria

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Abstract

In the oil and gas industry, when a well is completed, perforated, and is under production; a time would come when the natural energy of the reservoir will not be adequate to lift the reservoir fluid to the surface. Therefore, an artificial lift system is utilized to transport the reservoir fluids to the surface because the fluids cannot be lifted naturally to the surface. The methods of artificially lifting the reservoir fluid to the surface involve the use of rod pumps, plunger lifts, gas lifts, etc. This study focuses on the use of artificial gas-lifts in an oil well to enable it produce effectively. In this work, the simulation of a gas lift operation was studied in detail, by analyzing its operational mechanics. The simulation is done using Production and System Performance (PROSPER) analysis software, which is a production software used in the petroleum industry for simulation, design, and optimization of the performance of the well. The project also centered on the various factors affecting the installation of a gas lift in a well (B-01). Furthermore, a gas lift operation is simulated on the well to see the effect of the gas-lift operation on this well. The simulation is used to determine the optimum gas injection depth, optimum gas injection rate, and the required valve spacing. The simulation for the gas lift operation and the optimum gas injection rate are carried out and calculated respectively at various reservoir conditions.

Keywords *Gas lift, Simulation; Optimization; Gas injection; Production.*

1. Introduction

A gas lift is an artificial lift system that entails injecting compressed gas into a well to kick-off or improve the productivity of a well. The gas, typically highly pressurized, is normally injected into the annulus between the casing and tubing, via the gas lift valves or the sliding sleeve, which is normally situated above the packer [1]. When a well has insufficient pressure to produce hydrocarbons at an economic or a desired rate, a gas lift can be used to lighten the fluid hydrostatic column, enabling the reservoir pressure to be able to lift the hydrocarbons to the surface; the gas is usually injected in the tubing at a computed optimum depth [2]. During gas lift operation, for us to have an effective operation, we must have an optimal gas injection rate, because injecting too much gas can impede production, conversely, injecting less gas can also reduce operational efficiency. A well test analysis is used to determine the optimal gas injection rate, where the produced oil, water, and gas is measured, while we vary the rate of injected gas.

Whenever there is a surplus or ample gas volume to be used for artificial lift purposes, this commonly yields positive economic feedbacks. In the Oil and gas industry, this mode of artificial lift has earned much interest [3]. During gas lift operation, for us to have an effective operation, we must have an optimal gas injection rate, because injecting too much gas can impede production, conversely, injecting less gas can also reduce operational efficiency. A well test is used to determine the optimal gas injection rate, where the produced oil, water, and gas is measured, while we vary the injected gas. Gas injection depth, producing rate, bottom-hole pressure are some of the factors that affect gas lifting procedures.

Most completed oil wells, flow naturally to the surface for some period after perforation. The original energy, which is the driving mechanism that causes this natural flow is mainly the rock and liquid expansions, solution gas and gas cap expansion. As the well produces, the energy of the well reduces, until it does not have enough energy to flow up to the surface. When the pressure of the reservoir is inadequate or too low for fluids to flow, or the economic production rate required is much more than what can be delivered from the reservoir, then, a solution to this challenge must be found. This involves the introduction of an artificial lift system to supplement the energy of the reservoir, hence leading to more fluids being produced from the reservoir. For this work, an oil well (B-04) located in the OBB field is unable to continue production at an economical rate, so to be able to continue production, a gas lift system should be optimized and installed into the well.

This study is aimed at designing a continuous gas lift system for this well (B-04 located in OBB field), currently under low production because of the current reservoir conditions using the PROSPER software. Also, the continuous gas lift system would be designed to lift the reservoir fluid at different reservoir conditions. To achieve this, the top valve and optimum depths, optimum gas lift injection rates, and the effect of the gas lift injection operation on this well will be determined.

2. Background

In the oil and gas industry, as the pressure of the reservoir depletes over time, it leads to a reduction in oil production. To control this effect, various researchers over time, have been able to develop correlations, models, and solutions to the various challenges encountered while trying to artificially lift a well.

Ferrer *et al.* [4], developed a computerized model, which they used in the continuous gas lift operation optimization process. The computerized model contained two modules, which are SIMULAG and CORPOLAG. SIMULAG has to do with the interpretation of well and reservoir information, Furthermore, it prepares the unit for optimization. SIMULAG performed these functions by carrying out analyses on the setting up of the design, diagnostics, redesign, and modification in the distribution of the gas-lift. CORPOLAG was used to obtain the optimum gas distribution, between various inter-related wells. The system which was used in the CORPOLAG section consists of the following diagnostic analysis on the well, the well's dynamic behavior. Fortran 77 was where the calculations were carried out, while turbo basic was used to handle the user interface and graphics routines.

Badahori *at al.* [5],researched the optimization and simulation of a continuous gas lift, and from their experiment, the optimization of the gas lift was done by altering either the temperature, volume, pressure, or a combination of two or three of the factors, with a combination of the multiphase-flow or fluid correlations. After optimization, the appropriate correlation was selected, and with this correlation, calculations were made at varying injection depths. Using the temperature and pressure survey data at various injection depths, a gas lift performance curve was deduced. The optimum injection head, wellhead pressure, valve spacing, minimum gas injection volume, and optimum production rate were determined from solution nodal analysis. Their experiment was tested on the Aghajari oil field, and with the simulation system, the optimum gas-lift injection rate and the valve placement were determined. From their research, they stated that the oil production could be increased by multiples of two, because of continuous gas lift operation.

Orioha *et al.* [6], conducted research on how IPM (Integrated Production Modelling) suite could be very useful in the petroleum industry. They showed how the IPM software could be used for managing and optimizing the production of hydrocarbons from a field. This was illustrated by taking a case study on two fields, where they had to history match the field production for various years, allocate productions accurately to various reservoirs, history match the production from various individual wells before optimizing the usefulness of gas lift in the fields. Emphasis was made on the fact that while modeling various scenarios, any mistake or improper calibration could lead to sparse decisions that would play a major role in the economics of the project.

The application of a Single Point Gas Lift (SPGL) system on the productivity of an oil field at the coast of India (east coast) was researched by [7]. The benefits the SGLV would have against the conventional gas lift system is that there won't be a need for the various unloading valves, domes, and nitrogen-charged bellows, so this would limit the failure that could be associated with a gas lift installation operation. This form of installation would also need a higher compression plant to be able to work properly, so, an analysis should be done on the advantages and disadvantages before venturing into this operation.

3. Methodology

3.1. Setting up the model in PROSPER

Part of the aim of building the reservoir model is to develop a mathematical model, which describes the real model as accurately as it possibly can and accurately predicts the well's behavior in different scenarios when compared to the real model. Every class of information of the reservoir and well will be modeled independently and the created sub-models will be connected to build a total model fit for forecasting both the inflow and outflow well performance.

Table 1. Methodology for creating the model in PROSPER

Option summary	Fluid, viscosity model, Artificial lift method
PVT data Input	GOR, oil gravity, water salinity, correlations
Equipment data input	Deviation, surface and downhole equipment
IPR data input	Dietz shape factor, well bore radius, Pr, Skin
Gas lift data input	Gas lift valve depth, Gas lift gas gravity
VLR/IPR quality check	Correlation comparison, IPR/VLP matching

The full work process (Table 1) begins by inputting the basic information of the analyzed well in the options summary section which includes: the type of fluid, the artificial lift method, the viscosity model, etc. After this, the Pressure-Volume-Temperature (PVT) information is inputted and the correlations, which best matches, the reservoir fluid is chosen. The equipment data section is then chosen. This is where the deviations of the down-hole tubing and the identity of the various equipment are all documented. The data for the surface and down-hole equipment are also inputted in this section. As the temperature assumes a vital part in the calculation of the pressure drop, the geothermal gradient and average heat capacities are also inputted. For the IPR section, the available reservoir properties data are used in generating the curve for the IPR at the current reservoir pressure. At that point, quality control of the well test information is run in the VLP section, which eliminates unrealistic measured data. Thereafter, the correlation that best defines the flow of the multiphase fluid in the tubing is compared with the data which has been measured. Nodal analysis and accurate forecast for future production scenarios are then possible after setting up the model. The table below shows the methodology for the model setup.

3.2. Gas lift design procedure

In designing the gas-lift system for the well of study, the occupying positions for the gas-lift mandrels on the production tubing and the gas-lift valve spacing are computed at the poorest reservoir conditions concerning the well productivity.

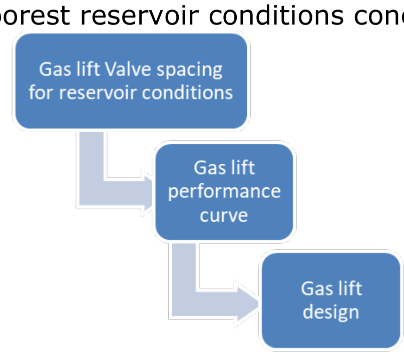


Figure 1. Work flow chart for setting up a gas lift model in PROSPER

This coincides with the point where the reservoir pressure drops to 208Bars with water cut increasing to 80%. In this gas-lift design for this well, the injection point would have to be located very deep down the tubing around the packer, this is because the deeper we inject gas into the tubing for artificial lift, the more fluid column we must lighten so that fluid pressure would be reduced, and would hence increase production. After the design of the gas lift spacing, the gas lift performance curve was deduced using the PROSPER software, to determine the optimum gas injection rate, which was used in the gas lift design screen. Below (Figure 1) is a gas-lift design procedure flowchart.

4. Results and discussions

4.1. The design process for gas lift installation

4.1.1. Case 1: Pr = 208 Bars; Water cut = 80%

This case was used as the base work for the re-completion design. The information inputted in this section was used for the design and spacing of the valves for the re-completion process. Firstly, an IPR was created for the new reservoir conditions with new reservoir pressure, and the water cut level inputted into the IPR section of the software. After the new IPR data was inputted, the continuous gas-lift system was designed by entering the right information in the gas-lift design screen.

After entering the data in the gas-lift design section, we then proceed to calculate the rate of fluid which would be produced because of the gas-lift operation, and the optimum gas injection rate, from the software, the optimum gas injection rate is 188 (1000Sm^3/d), but this is not the final injection rate because the unloading process has not been taken into consideration.

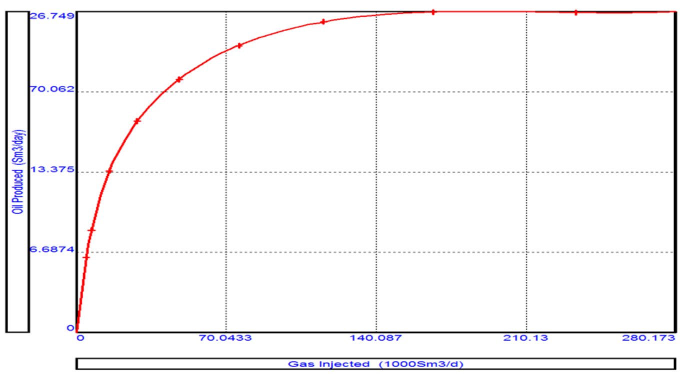


Figure 2. Case 1, Gas lift performance curve

From the gas lift performance curve displayed in Fig. 2, it is seen that as the injected gas increases beyond 210 (1000Sm^3/d) the oil been produced reduces, this is because when the volume of gas inside a tubing string is too high, pressure drop due to friction increases and it gets to a point where it becomes dominant over the gravity term reduction, at this point, there is an increase in the pressure drop in the tubing, which then leads to a reduction in the rate of production.

After putting into consideration the depths of the various valves, the optimal gas injection rate is calculated as the previously computed injection rate was for the maximum gas injection depth. After designing the various gas injection depth using the PROSPER software, we see that the gas injection depth reduces to 6038 feet, while the calculated gas injection rate at this point reduces to 134 (1000Sm^3/d). This reduction is because at this depth, gases would have evolved from the oil, and if a high amount of gases is injected, this would lead to an increase in pressure drop due to an increase in friction caused by the high gas velocity in the production string. So injecting the amount of gas we would have injected at a deeper depth would lead to a decrease in produced oil.

Table 2 shows the output from the design of the gas-lift system from the PROSPER software, the various depths of the valves for the installation of the gas lift system, the tubing pressure, casing pressure, valve opening and closing pressure are also shown in the table. The figure below shows a plot of the true vertical depth vs the pressure, also showing the various at which the gas lift valves are installed, the orifice depth is also shown.

Table 2. Case 1, Gas lift design result

Valve	Valve type	MD (ft)	TVD (ft)	Tubing pressure (bar_a)	Casing pressure (bar_a)	Opening CHP (bar_a)	Closing CHP (bar_a)	Gas lift rate gas (1000Sm^3/day)	Port size (64th inch)
1	Valve	2981.9	2981.6	54.62	112.82	104.44	102.22	13.399	12
2	Valve	4764.2	4762.7	79.84	114.56	100.99	97.41	65.633	20
3	Valve	5734.14	5731.4	94.5	114.01	97.54	93.64	106.28	28
4	Orifice	6038.1	6034.9	100.93	109.38	93.64	N/A	133.989	32

4.1.2. Case 2: Pr = 215 Bars; Water cut = 60%

A gas-lift design process also has to be done for the reservoir condition with a slight drop in reservoir pressure to 215 bars and a cut of 60%. The re-completion string has already been designed for the worst-case scenario. This means that the depth of the gas injection valves also remains constant. So, to account for this present reservoir scenario, the reservoir model in the IPR section of the software is changed by increasing the reservoir pressure to 215 bars and reducing the water cut to 60%. After this point, the optimum designed rate is calculated

We can see from Fig. 3, that the optimum designed rate is 164 (1000Sm^3/d) and the amount of produced oil is 448 (Sm^3/d). This is before considering the unloading process. After, we proceeded in clicking on the 'design button'. This reduced the injected gas rate to 114.431 (1000Sm^3/d), with the amount of oil produced increasing a bit to 448.028 (1000Sm^3/d). We can also see the gas lift design table below, showing the various valves opening and closing pressure. Fig. 3 also shows a plot of the TVD versus the pressure, showing the various functioning injection valves at various depth.

Table 3. Case 2, Gas lift design result

Valve	Valve type	MD (ft)	TVD (ft)	Tubing pressure (bar$_a$)	Casing pressure (bar$_a$)	Opening CHP (bar$_a$)	Closing CHP (bar$_a$)	Gas lift rate (1000Sm^3/day)	Port size (64th inch)
1	Valve	2981.9	2981.6	55.8	113.95	104.44	103.45	11.443	8
2	Valve	4764.2	4762.7	82.12	116.37	100.99	97.46	58.429	20
3	Valve	5734.14	5731.4	98.2	116.19	97.54	94.89	87.293	24
4	Orifice	6038.1	6034.9	103.45	113.79	94.09	N/A	114.431	31

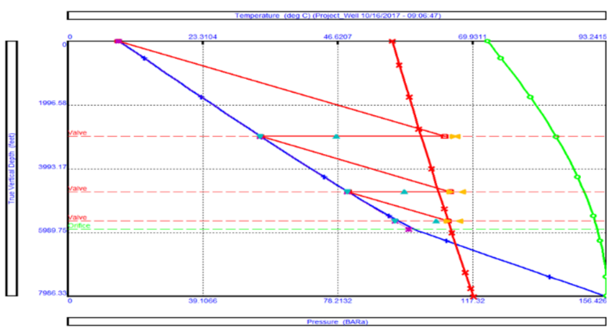


Figure 3. Case 2, Gas lift Design Plot

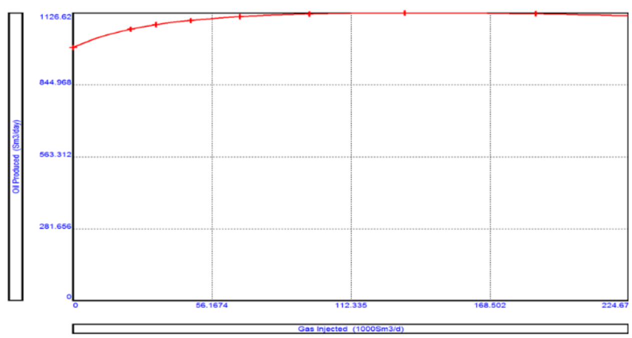


Figure 4. Case 3, Gas lift performance curve

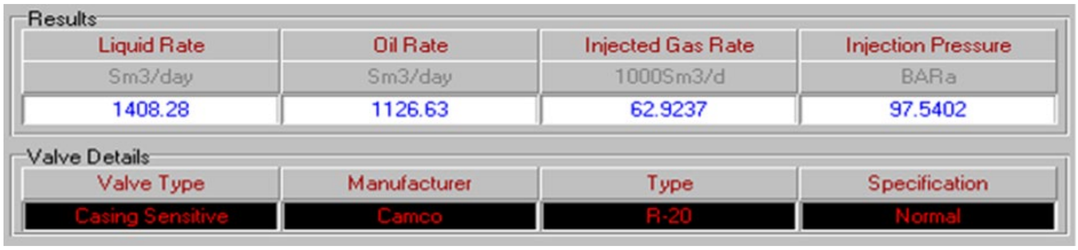
4.1.3 Case 3: Pr = 242 Bars; Water cut = 20%

Like was done in previous cases, the new IPR and water cut values are inserted in the PROSPER software which produces the gas lift sate (Table 4 and Fig. 4).

Table 4. Case 3, Gas lift design result

Valve	Valve type	MD (ft)	TVD (ft)	Tubing pressure (bar$_a$)	Casing pressure (bar$_a$)	Opening CHP (bar$_a$)	Closing CHP (bar$_a$)	Gas lift rate gas (1000Sm^3/day)	Port size (64th inch)
1	Valve	2981.9	2981.6	61.5	114.02	104.44	102.44	18.715	12
2	Valve	4764.2	4762.7	93.41	116.47	100.99	99.47	39.54	16
3	Orifice	5734.14	5731.4	112.39	116.3	97.54	N/A	62.924	29
4	Dummy	6038.1	6034.9	N/A	N/A	N/A	N/A	N/A	39

After the design of the unloading, valves are been taken into consideration, we see that there are new values for oil produced and gas injected rate which is 1126.6 (1000Sm^3/d) and 62.9 (1000Sm^3/d) respectively (Fig.5). This is the base case used to position the valves while currently inserting the re-completion string with the various gas-lift valves. It can be seen from the gas lift design results that the previous orifice valve, is now a dummy valve for this present reservoir condition, and the previous gas lift valves at the third side pocket mandrel now acts as the orifice for this current situation. The amount of oil being produced also increases significantly at this current reservoir condition, while the injected gas-rate reduces. For a better understanding of this work a resultant case detailing the optimized injection rate and corresponding oil flow rate is shown on Fig. 5.


Results

Liquid Rate	Oil Rate	Injected Gas Rate	Injection Pressure
Sm3/day	Sm3/day	1000Sm3/d	BARa
1408.28	1126.63	62.9237	97.5402

Valve Details

Valve Type	Manufacturer	Type	Specification
Casing Sensitive	Camco	R-20	Normal

Figure 5. Result for Case 3

5. Conclusion

A continuous gas lift system has been designed for well (B-04) to aid in the lifting of reservoir fluid from the well to the surface.

The continuous gas lift design was done at the worst forecasted predicted state, which was when the pressure of the reservoir was 208 bars, and the water cut was at 80%. The maximum depth of gas lift injection was set at 7500 feet, but when the design process was being carried out, the maximum gas lift injected depth was calculated to be 6038.1 MD and 6034.9 TVD, both depth measured in feet. For the reservoir operating condition for case 3, the pressure at the casing head for this operating condition was inadequate to inject the gas lift to the last valve, so the orifice valve utilized here was at an MD of 5734.1 and TVD of 5731.3 TVD, both also measured in feet. The highest oil rates for the gas lift design was achieved at case 3 when the reservoir pressure was at 242bars and the water cut 20%, the oil rate at this reservoir condition is 1126.63 Sm^3/day. The lowest oil rate for the gas lift design was also achieved at the first reservoir operating condition; the oil rate obtained then is 205.125 Sm^3/day.

The simulation and optimization analysis now resulted in a reduction of the gas lift injection depth and also gave us the optimum gas injection rate to use, to bring about optimum oil production.

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To whom correspondence should be addressed: Oghenefega E. Unuavwodo, Petroleum Engineering Department, Covenant University, Ota, Nigeria. Email: ofegaemmanuel@gmail.com