Artificial Lift Design of Mishrif Formation in Nasiriyah Oil Field

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Abstract:

The possibility of improving the oil production rate for Mishrif formation in Nasiriyah oil field, located in Thi-Qar Governorate – southern province of Iraq, proposed in this paper. Electrical submersible pump (ESP) and gas lift techniques were applied to one well (NS-Y) in the studied reservoir. Firstly, the mathematical model has been built and validation has been done using PIPESIM software in order to select the best correlation (Duns & Ros correlation) for the pressure gradient calculation in the wellbore. The effect of decreasing reservoir pressure and increasing water cut on production rate has been studied through the evaluation of the well performance. The production rate was decreased to 1917 STB/D when reservoir pressure reached to 2750 psi, and flow rate decreased to 1210 at water cut 60%. Therefore, the artificial lift techniques were applied to increase the oil production rate. The result showed that Gas lift system contributed to increase production rate to (3198) STB/D at reservoir pressure equal to 2750 psi, while using the ESP system improved oil production rate to (2800) STB/D at reservoir pressure 2750 psi. The results also showed that gas lift system contributed to increase production rate to (3805) STB/D at water cut 60% and ESP raised the production rate to 3087 STB/D at water cut 60%. The comparison between them showed that the gas lift technique gave the highest production rate at different reservoir pressure and water cut.

تصميم منظومة الرفع الصناعي لطبقة المشرف في حقل الناصرية النفطي

الخلاصة:

إن إمكانية تحسين معدل إنتاج النفط لطبقة المشرف في حقل الناصرية النفطي الذي يقع في محافظة ذي قار جنوب العراق تم تناولها في هذه الدراسة. حيث تم استخدام تقنيات الرفع بالغاز والمضخات الكهربائية الغاطسة في البئر (NS-Y) التابع للحقل المختار لهذه الدراسة. تم بناء موديل
Introduction:

There are a number of oil wells, can flow naturally depending on the reservoir energy in the first life of production. After a period of production, the flow rate decreases until it is not possible for natural flow to continue. In order to maintain production for as long as possible, new methods were developed to resume or increase production. Artificial lift represents the one of these methods, which used when decreasing reservoir pressure and the well wouldn’t be able to lift fluid up to the surface [1]. Approximately 50% of wells need artificial lift systems. The commonly used method is artificial lift [2]. The most used methods in Iraqi oil fields are Gas lift and Electrical Submersible Pump, where the Gas lift method takes place through injection of a specific amount of compressed gas in the annular between casing and production tubing, which works by reducing the density of liquid in wellbore and lightening the hydrostatic column. This helps to raise the fluid...
to the surface, Gas lift is utilized in one of the two ways: (1) continuous gas lift by continuous gas injection into annular between the production tubing and casing (2) intermittent lifting by rapid injection of very large quantities of gas into the tubing, causing a slug of fluid in the tubing to be carried to the surface. The valve then closes, awaiting another column of fluid to build in the tubing [3]. The Electric submersible pump ESP use multiple-stage centrifugal pump with electric motor in the base of tubing and attached to a power source by cable. All these parts work together with lifting the fluid to the top [4]. In this study Mishrif Formation in Nasiriyah Oil Field was selected to build a gas lift and ESP models. This field is located in the south of Iraq in the Thi-Qar governorate about (38) KM northwest of the Nasiriyah center [5].

**Mathematical models:**
A Mathematical model used to simulate fluid flow for the system. It contains complete information on the well, including wellbore construction, downhole equipment and artificial lift equipment. This model has been developed based on the available data from well completion reports as shown in Table (1).

| Well name | Well depth (m) | Tubing depth (m) | Perforation intervals, (m) | Middle perforation, (m) |
|-----------|----------------|------------------|---------------------------|------------------------|
| NS-Y      | 2039           | 1910             | 1995 –2037                | 2016                   |

**Fluid model:**
This model is created by inserting fluid properties and then calibrate PVT data depending on the reports of the physical and thermodynamic properties of the oil (PVT data).

**Pressure gradient matching:**
The data matching task has been used to select the suitable flow correlations for the pressure drop and heat transfer calculations in the wellbore. Measured flow data available in (Production Log Interpretation Report) has been used Table (2). This data has been inserted in Survey data catalog of PIPESIM. The next step is to run data
matching and choose the appropriate correlation among the correlations available in PIPESIM. The selection of the correlation is based on the optimal flow rate should give the lowest error ratio for the measured flow rate. The best flow rate gives the lowest value of (RMS).

Table (2) PLT data for pressure gradient.

| Well name | Well head Pressure, psi | Well head Temperature, F | Test oil Flow rate STB/D | Depth m | Pressure, psi | Temperature, F |
|-----------|------------------------|--------------------------|--------------------------|---------|---------------|---------------|
| NS-Y      | 490                    | 70                       | 3106.8                   | 1995    | 2397.2        | 164.94        |
|           |                        |                          |                          | 2010    | 2418.7        | 165.74        |
|           |                        |                          |                          | 2025    | 2436.8        | 166.58        |
|           |                        |                          |                          | 2023    | 2443.4        | 166.79        |

Matching results showed that Dun & Rose was the best fit for well NS-Y as shown in Figure (1). A comparison was made between the correlations should that results for calculating the optimized flow rate Table (3).

![Data matching: Well - Data matching](image)

**Fig. (1) Optimized flow rate match for well (NS-Y).**
Table (3) Flow rate correlation comparison for well (NS-Y).

| Correlation                  | Test liquid flow rate, STB/D | Calculated liquid flow rate, STB/D | Error % | RMS   |
|------------------------------|------------------------------|------------------------------------|---------|-------|
| Ansari                       | 3106.84                      | 3110.06                            | 0.103   | 6.315 |
| Gomez                        | 3106.84                      | 3050                               | -1.8    | 15    |
| Mukherjee&Brill (baker jardine) | 3106.84                      | 3110.88                            | 0.13    | 6.35  |
| Biggs & Brill original       | 3106.84                      | 3112.65                            | 0.18    | 6.4   |
| Duns & Ros (Tulsa)           | 3106.84                      | 3109.89                            | 0.09    | 6.307 |
| Orkiszewski (Tulsa)          | 3106.84                      | 3110.52                            | 0.11    | 6.93  |

**Nodal analysis and bottom hole pressure \( (P_{wf}) \) match:**

After selecting the appropriate correlation for the well, a nodal analysis has been built which represent the relationship between vertical lift performance curve (VLP) and inflow performance relation curve (IPR), as shown in Figure (2). PIPESIM Software calculates the values of liquid flow rate and bottom hole pressure \( (P_{wf}) \) from the intersection point between the curves of (VLP) and (IPR). A good matching between the calculated \( P_{wf} \) (2421.49 psi) by using nodal analysis and measured \( P_{wf} \) (2424 psi) achieved with the error of 0.084%, see Table (4).
Well performance with the reduction of reservoir pressure:

Evaluation of well performance was considered using Nodal analysis (inflow sensitivity) by evaluating the effect of reduction of reservoir pressure on production flow rate for the well. The result showed that the production rate of well (NS-Y) reached 1917 STB/D when reservoir pressure decreased to 2750 psi, as shown in Table (5) and Figure (3). The value of bubble point pressure was 2105 psi.
Table (5) Summary Results well (NS-Y) at reservoir pressure (3120.8 - 2750) psi, WC= 0, well head pressure = 490 psi, (natural flow)

| Reservoir pressure, (Psi) | Liquid flow rate, (STB/Day) | Bottom hole pressure, (Psi) |
|--------------------------|-----------------------------|----------------------------|
| 3120.8                   | 3109                        | 2421                       |
| 3050                     | 2897                        | 2398                       |
| 2950                     | 2594                        | 2367                       |
| 2850                     | 2266                        | 2340                       |
| 2750                     | 1917                        | 2319                       |

Fig. (3) Nodal analysis, sensitivity for well (NS-Y) at reservoir pressure = (3120.8–2750) psi, WC = 0%, well head pressure = 490 psi

Well performance with the increase in water cut:

As the water cut increases to 60%, the production rate reaches to 1210 STB/D. Table (6) shows that the liquid flow rate and bottom hole pressure for different rates of water cut. The values of Nodal pressure against nodal point are shown in Figure (4).
Table (6) Summary Results well (NS-Y) at WC= (0 – 60%) , well head pressure = 490 psi, (natural flow)

| Water cut % | Liquid flow rate (STB/Day) | Bottom hole pressure (psi) |
|-------------|-----------------------------|-----------------------------|
| 0           | 3109                        | 2421                        |
| 10          | 2961                        | 2455                        |
| 20          | 2735                        | 2506                        |
| 30          | 2464                        | 2566                        |
| 40          | 2129                        | 2642                        |
| 50          | 1717                        | 2734                        |
| 60          | 1210                        | 2848                        |

Figure (4) Nodal analysis, sensitivity for well (NS-Y) at reservoir pressure = 3120.8 psi, WC = 0%–60%
Gas lift design:
The objective of this work is to find the best location for unloading valves and operating valves for the gas lift plant.

Determine optimum surface injection pressure and Optimum gas injection rate:
From a gas lift response simulation in PIPESIM, the well performance under gas lift with the surface injection pressure (casing head pressure, CHP) and target injection gas rate (Qgi) have been determined. The ranges of sensitivity data for gas lift response contain ten values for target injection gas rate and three values for surface injection pressure; therefore, the sensitivity was repeated twice for each well in order to take more values of (CHP). The results of gas lift response in PIPESIM for well (NS-Y) can be seen in Table (7) and Figures (5 and 6), which explained the optimum gas injection rate of 3MMSCF and optimum surface injection pressure of 1800psi.

Table (7) Summary Results well (NS-Y) at a gas injection rate (1 – 10) MMSCF, surface injection pressure (1000 – 2750) psi

| Qgi MMSCF/D | QL@CHP=1000 psi | QL@CHP=1500 psi | QL@CHP=1750 psi | QL@CHP=2000 psi | QL@CHP=2500 psi | QL@CHP=2750 psi |
|-------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 1           | 3117            | 3486            | 3611            | 3668            | 3669            | 3669            |
| 2           | 3145            | 3683            | 3861            | 3920            | 3921            | 3921            |
| 3           | 3123            | 3724            | 3948            | 4010            | 4011            | 4011            |
| 4           | 3090            | 3686            | 3963            | 4031            | 4032            | 4033            |
| 5           | 3057            | 3635            | 3920            | 4007            | 4007            | 4008            |
| 6           | 3023            | 3576            | 3859            | 3960            | 3960            | 3961            |
| 7           | 2989            | 3516            | 3794            | 3967            | 3907            | 3908            |
| 8           | 2957            | 3462            | 3729            | 3852            | 3853            | 3854            |
| 9           | 2922            | 3407            | 3664            | 3799            | 3799            | 3800            |
| 10          | 2886            | 3357            | 3607            | 3747            | 3748            | 3749            |
**Gas Lift valves Installation design**

The objective of the valve design is to determine the position of the process and Unloading Valves, which depends on the gas injection pressure to calculate the opening and closing pressures for gas lift valves. Figure (7) showed the results of well (NS-Y) as listed in Table (8).
Fig. (7) Gas lift valves design for well (NS-Y)

Table (8) Gas lift valve design results for well (NS-Y)

| Parameters                        | Valve 1 | Valve 2 | Valve 3 | Valve 4 |
|-----------------------------------|---------|---------|---------|---------|
| Measured Depth (m)                | 946     | 1434    | 1660    | 1761    |
| Series                            | R20     | R20     | R20     | R20     |
| Port size (inches)                | 0.25    | 0.25    | 0.25    | 0.5     |
| Production pressure psi           | 1281.7  | 1673.8  | 1868    | 1958    |
| Unloading liquid rate, (STB/D)    | 4264    | 3283    | 2319    | 3914.6  |
| Valve opening Pressure, psi       | 1984.7  | 2038.3  | 2053.4  | 2075.5  |
| Valve closing pressure, psi       | 1938    | 2014    | 2041.2  | 2045    |
| Test rack opening pressure, psi   | 1779.9  | 1770.5  | 1763    | 2211.8  |
| Valve temperature (F)             | 127.7   | 149.3   | 158     | 161.9   |
Electrical Submersible Pump Design:

Electrical Submersible Pump (ESP) Design task in PIPESIM can be used to select suitable ESP from the database and performs necessary calculations to determine the number of stages required to achieve a target flow rate under given well, fluid and operating conditions. Multiple operations are performed as part of the well's ESP design to calculate and report well performance before and after an ESP is installed. The important parameters for ESP design are.

**Pump depth:** The depth at which the pump is to be installed. This depth must be above the perforation interval, so the depth was chosen depending on the depth of tubing of well which equal to 1910 meter.

**Design production rate:** Desired flow rate through the pump in stock-tank units. This value is selected depending on bubble point pressure (2105 psi) and operating envelope area which specifies values of reservoir pressure, drawdown limit, erosional velocity ratio maximum and inversion point for stable tubing production, as shown in the yellow rectangle in Figure (8). The design flow rate has been selected as 3750 STB/D in this value was selected depending on operation envelope area. After inputting the required data for ESP design the software will suggest the suitable pump type. The results have been summarized in the Table (9). Figure (9) showed the performance curve for the pump.

![Fig. (8) The performance curve of pump for well (NS-Y)](image-url)
Table (9) Summary results of the pump selected for well NS-Y

| Parameters                  | Value    |
|-----------------------------|----------|
| Manufacturer                | XPC      |
| Model                       | G5800EZ  |
| Diameter, in                | 5.13     |
| Series                      | 540      |
| Min. Flow, STB/D            | 3834     |
| Max. Flow, STB/D            | 6902     |
| Operating frequency, Hz     | 60       |
| Operating speed, RPM        | 3450     |
| Number of stages            | 31       |
| Intake pressure, psi        | 2165     |
| Intake liquid rate, bbl/d   | 4930     |
| Intake gas rate, MMSCF/d    | 0        |
| Efficiency, %               | 71       |
| Power, HP                   | 36       |
| Head, m                     | 299      |
| Differential pressure, psi  | 316      |
| Discharge pressure, psi     | 2482     |
| Fluid temperature rise, F   | 1.1      |
Fig. (9) The performance curve of pump for well (NS-Y)

Results:

1- The results of reservoir pressure decreasing showed that production rate after installation of the gas lift system was increased from 3109 STB/D at natural flow to 3931 STB/D at reservoir pressure of 3120 psi, and increased from 1917 STB/D to 3198 at reservoir pressure of 2750 psi. While, the ESP increases the oil production rate from 3109 STB/D to 3754 STB/D at reservoir pressure 3120, and from 1917 to 2800 STB/D at reservoir pressure 2750 psi, this results are listed in Tables (10 and 11), and showed in Figures (10 and 11). All values of flow rate and $P_{wf}$ have been calculated by PIPESIM software based on the principle of nodal analysis. The $P_{wf}$ in ESP case was higher than the Gas lift case because the design flow rate has been selected at $P_{wf}$ above Bubble point pressure (2105 psi). Finally, the Gas lift system has achieved quantities of production rate was more than ESP at different reservoir pressure as shown in Figure (12).
Table (10) Summary Results well (NS-Y) at reservoir pressure (3120.8 - 2750) psi, (Gas lift )

| Reservoir pressure (Psi) | Liquid flow rate (STB/Day) | Bottom hole pressure (psi) |
|--------------------------|----------------------------|---------------------------|
| 3120.8                   | 3931                       | 2237                      |
| 3050                     | 3791                       | 2197                      |
| 2950                     | 3591                       | 2142                      |
| 2850                     | 3393                       | 2087                      |
| 2750                     | 3198                       | 2030                      |

Table (11) Summary Results well (NS-Y) at reservoir pressure (3120.8 - 2750) psi, (ESP)

| Reservoir pressure (Psi) | Liquid flow rate (STB/Day) | Bottom hole pressure (psi) |
|--------------------------|----------------------------|---------------------------|
| 3120.8                   | 3754                       | 2277                      |
| 3050                     | 3583                       | 2244                      |
| 2950                     | 3335                       | 2200                      |
| 2850                     | 3074                       | 2159                      |
| 2750                     | 2800                       | 2120                      |
Fig. (10) Nodal analysis, sensitivity for well (NS-Y) at reservoir pressure = (3120.8–2750) psi with Gas lift system

Fig. (11) Nodal analysis, sensitivity for well (NS-Y) at reservoir pressure = (3120.8–2750) psi with ESP.
Fig. (12) Comparison of production rates between Gas lift and ESP at different reservoir pressure.

2- The impact of water cut demonstrates that ESP system achieved higher production rates than Gas lift system at water cut 0 and 10%, while the gas lift system achieved higher production rates than ESP system at water cut 20%, 30%, 40%, 50% and 60% as given in Tables (12, 13) and Figures (13, 14 and 15).

**Table (12) Summary Results well (NS-Y) at water cut (0 – 60%), (Gas lift)**

| Water cut % | Liquid flow rate (STB/Day) | Bottom hole pressure (psi) |
|-------------|---------------------------|---------------------------|
| 0           | 4022                      | 2216                      |
| 10          | 3989                      | 2224                      |
| 20          | 3955                      | 2231                      |
| 30          | 3921                      | 2239                      |
| 40          | 3884                      | 2247                      |
| 50          | 3845                      | 2256                      |
| 60          | 3805                      | 2265                      |
Table (13) Summary Results well (NS-Y) at water cut (0 – 60%), (ESP)

| Water cut % | Liquid flow rate (STB/Day) | Bottom hole pressure (psi) |
|-------------|-----------------------------|---------------------------|
| 0           | 4089.603                    | 2201.788                  |
| 10          | 4028.851                    | 2215.44                   |
| 20          | 3920.217                    | 2239.852                  |
| 30          | 3789.334                    | 2269.264                  |
| 40          | 3601.29                     | 2311.521                  |
| 50          | 3362.783                    | 2365.118                  |
| 60          | 3087.65                     | 2426.946                  |

Fig. (13) Nodal analysis, sensitivity for well (NS-Y) at water cut (0 – 60%) with Gas lift system
Fig. (14) Nodal analysis, sensitivity for well (NS-Y) at water cut (0 – 60%) with ESP system

Fig. (15) Comparison of production rates between Gas lift and ESP at different water cut
Conclusions:

1. Pressure gradient matching (Duns & Rose) was the best correlation for the pressure drop in wellbore for well NS-Y.

2. The optimum surface injection pressure was found to be 1800 psi and optimum gas injection rate was 3 MMSCF.

3. It was found that the pump model suitable for well NS-Y (XPCG5800EZ) with efficiency of 71%.

4. The comparison of gas lift system and ESP production rates showed that the gas lift system offers highest oil production rate at different conditions of reservoir pressure and water cut.

Nomenclature:

ESP : Electric submersible pump.

CHP : Casing head pressure or surface injection pressure, Psi

Qgi : Gas injection rate, MMSCF/D

QL : Liquid flow rate, STB/Day

GOR : Gas oil ratio, %

Pr : Reservoir pressure, Psi

WC : Water cut

RMS : Root mean square
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