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Simulation and Gas Allocation Optimization of Gas Lift System Using Genetic Algorithm Method in One of Iranian Oil Field

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ABSTRACT

Sometimes oil reservoirs may have not enough energy to push the reservoir fluid from the reservoir to the surface. It may be possible to maintain or even increase the production rate by using appropriate artificial lifting. Gas lifting is one of the most effective and cheapest method of artificial lift techniques that is used to reduce the oil density by mixing the oil with the gas which is injected at the lower part of the production string.

In this study, first experimental PVT data has been tuned. Also Comprehensive Ansari et al. method is used for vertical lift performance. In order to determine the optimal gas lift condition, Solution nodal method is used. Moreover Genetic Algorithm method is applied for Gas lift Allocation Optimization to determining the optimum gas injection rate for a group of well in order to maximize the total oil production rate. Finally effect of reservoir pressure and water cut is considered for future reservoir production evaluation.

By the Genetic Algorithm method of optimization, the total oil production rate will be increased by 32.14% at constant reservoir pressure and 0% water cut. Also For limited amount of available gas in Gas Lift system, the Genetic Algorithm method of optimization is the best method in comparison to other methods.

KEYWORDS: Gas Allocation Optimization, Gas Lift, Genetic Algorithm, Vertical Lift Performance, Gas Injection Rate.

1. INTRODUCTION

Artificial lift systems are required when the pressure of a well is not enough to maintain oil production with satisfactory economic return. This situation is typical in mature oil fields where, increasing water cut or direct decreasing reservoir pressure eventually cause wells to cease natural flow. Selection of the artificial lift system is often based on experience, non-technical preferences and even technical myths. Nowadays, the highest operation cost in the oil fields tends to be due to artificial systems, (Vázquez, et al., 2005). Gas lift is probably the most widely used artificial lift system. In fact, gas lift is often considered in some reservoirs as the only artificial lift system, (Chia, 1999). In these systems, a gas is injected in the production well to modify the mixture density and then provide sufficient energy to produce the petroleum flow. Gas lift is rather inexpensive, easy to implement, very effective in a wide range of operating conditions and requires less maintenance in comparison to other alternatives, (Vázquez, et al., 2005). The schematic diagram of Gas Lift operation is shown in Figure 1.

In this study gas lift operation is optimized for one of Iranian oil field reservoir. At the first stage, In order to calculate pressure drop, the appropriate correlations for fluid properties are determined by PVT data. In the second stage, based on the PVT correlations and Comprehensive Ansari et al. method a computer program was developed for production system analysis and determining the vertical two-phase flow pressure drop in the well. Gas allocation optimization is a type of nonlinear function maximization with gas injection rates as decision variables subject to physical restrictions. Various optimization methods are applied in previous works. In the third stage of this work Genetic Algorithm method is applied for Gas Lift allocation optimization and the various scenarios is compared. In the last stage all scenarios is compared together as future production evaluation in order to reservoir pressure reduction and water cut increasing.

The goal of the paper is optimization of Gas Lift design by various methods, selection of best method and future evaluation of the reservoir for one of Iranian oil reservoir. The Genetic Algorithm and Ant Colony methods of optimization are the smart method in comparison to other methods such as Equal Injection Rate and Production Weighted Injection Rate.

The scientific contribution of this paper are: 1) Development of computer program for production system analysis and determining the vertical two-phase flow pressure drop in the well. 2) Applying the newest and smart methods of optimization in order to Gas Lift allocation optimization and future production evaluation.

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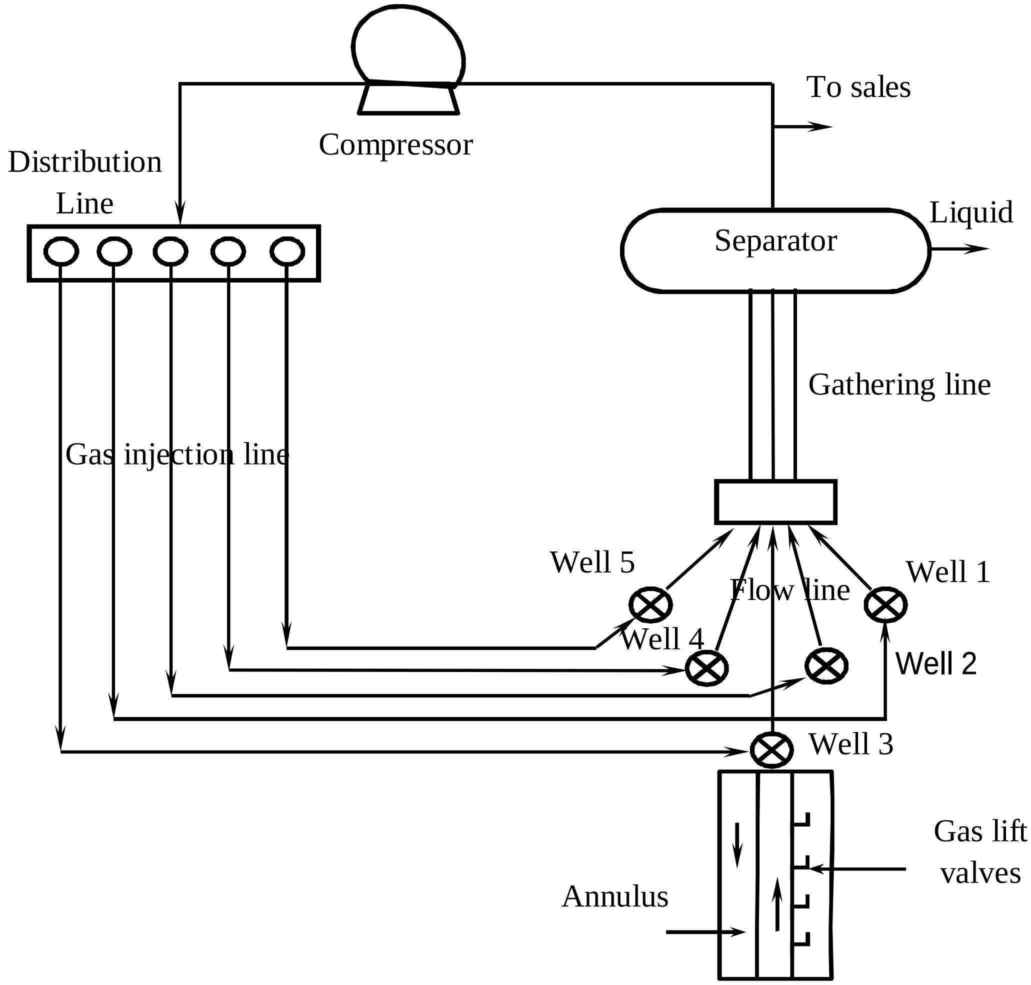

Figure 1: Schematic Diagram of Gas Lift Operation

1. Theory

Well performance is dependent on a large number of variables like pressures, formation properties and fluid properties. And these are again dependent on each other. All of the flow processes of oil and gas production must be studied simultaneously to insure good well design. Multiphase flow studies have sought to develop a technique with which the pressure drop can be calculated. Pressure losses in two-phase, gas-liquid flow are quite different from those encountered in single-phase flow.

1.1. Inflow Performance Relationship

The Inflow Performance Relationship (IPR) describes pressure drawdown as a function of production rate, where drawdown is defined as the difference between static and flowing bottomhole pressure (FBHP). In this investigation Multi-Rate Jones model is selected for IPR model, (Gabor 2005).

$$(P_r - P_{wf}) = aQ^2 + bQ \qquad (1)$$

1.2. Vertical Lift Performance

Oil wells normally produce a mixture of fluids and gases to the surface while phase conditions usually change along the path. At higher pressures, especially at the well bottom, flow may be single phase. But going up in the well the continuous decrease of pressure causes dissolved gas to gradually escape from the flowing liquid, resulting in multiphase flow. Gas injection into a well is also an example of multiphase flow. The well’s outflow performance, or Vertical Lift Performance (VLP), describes the bottomhole pressure as a function of flow rates. According to Michael Golan et al. (1985) the outflow performance is dependent on different factors; liquid rate, fluid type (gas-to-liquid ratio, water cut), fluid properties and tubing size.

1.3. Ansari et al. Method

In Comprehensive Ansari et al. (1994) method flow pattern can be predicted by defining transition boundaries among bubble, slug, churn and annular flows. They identified four distinct flow patterns and evaluated the transition boundaries among them; as it is shown in Figure 2.

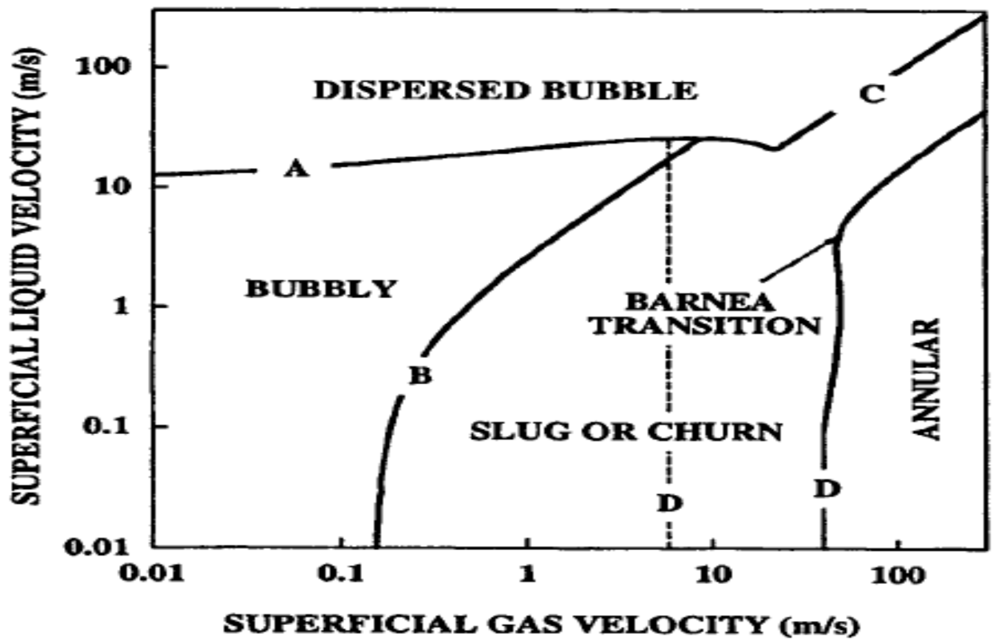

Figure 2: Flow Regimes Boundaries, (Shoham, 2006)

1.3.1. Bubble/Slug Transition.

In bubble flow, the gas-phase is dispersed into small discrete bubbles, moving upward in a zigzag motion, in a continuous liquid-phase. Bubble flow occurs at relatively low liquid rates, with low turbulence, and is characterized by slippage between the gas- and the liquid-phases, resulting in large values of liquid holdup. The Slug flow regime in vertical pipes is symmetric around the pipe axis. Most of the gas phase is located in a large bullet-shaped gas pocket termed "Taylor-bubble" with a diameter almost equal to the pipe diameter. The flow consists of successive Taylor-bubbles and liquid slugs, which bridge the pipe cross section. A thin liquid film flows downward between the Taylor-bubble and the pipe wall. The film penetrates into the following liquid slug and creates a mixing zone aerated by small gas bubbles. Using this value of void fraction, transition can be expressed in terms of superficial and slip velocities according to the following relation, (Taitel et al., 1980).

$$V_{sg} = 0.25V_s + 0.333V_{sl} \tag{2}$$

Where; V_s is the slip or bubble-rise velocity given by:

$$V_s = 1.53\left[\frac{g\sigma_l\left(\rho_l - \rho_g\right)}{\rho_l^2}\right]^{1/4} \tag{3}$$

This is shown as Transition B in Figure 2.

1.3.2. Transition to Dispersed Bubble

Dispersed-Bubble flow in vertical and sharply inclined pipes occurs at relatively high liquid-flow rates, under which conditions the gas-phase is dispersed as discrete bubbles into the continuous liquid-phase. For this flow pattern, the dominant liquid-phase carries the gas bubbles, and no slippage takes place between the phases. Hence, the flow is considered homogeneous no-slip. In high liquid flow rates, turbulent forces break large gas bubbles down into small ones, even at void fractions exceeding 0.25. This yields the transition to dispersed bubble flow, (Barnea et al., 1985):

$$2\left[\frac{0.4\sigma_l}{\left(\rho_l - \rho_g\right)g}\right]^{1/2}\left(\frac{\rho_l}{\sigma_l}\right)^{3/5}\left(\frac{f}{2d}\right)^{2/5}\left(V_{sl} + V_{sg}\right)^2 = 0.725 + 4.15\left(\frac{V_{sg}}{V_{sl} + V_{sg}}\right)^{0.5} \tag{4}$$

This is shown as Transition A in Figure 2.

At high gas velocities, this transition is governed by the maximum packing of bubbles to give coalescence. This occurs at a void fraction of 0.76, giving the transition for no-slip dispersed bubble flow as:

$$V_{sg} = 3.17V_{sl} \tag{5}$$

This is shown as Transition C in Figure 2.

1.3.3. Transition to Annular Flow

As in the horizontal case, this flow is characterized by a fast-moving gas core with entrained liquid droplets and a slow-moving liquid film flowing around the pipe wall. The flow is associated with a wavy interfacial structure, which results in a high interfacial shear stress. In vertical flow, the liquid- film thickness around the pipe wall is approximately uniform. The transition criterion for annular flow is based on the gas-phase velocity required to prevent the entrained liquid droplets from falling back into the gas stream. This gives the transition as, (Barnea, 1987):

$$V_{sg} = 3.1\left[\frac{g\sigma_l(\rho_l - \rho_g)}{\rho_g^2}\right]^{1/4} \tag{6}$$

Shown as Transition D in Figure 2, dash line.

Barnea (1990) modified the same transition by considering the effects of film thickness on the transition. Shown as Transition D in Figure 2.

Total pressure drop is due to friction loss, acceleration loss and as elevation change through the piping system as follows:

$$\left(\frac{dP}{dL}\right) = \left(\frac{dP}{dL}\right)_g + \left(\frac{dP}{dL}\right)_a + \left(\frac{dP}{dL}\right)_f \tag{7}$$

1.4. Gas Lift Performance Curve

The main objective in oil production system using gas lift technique is to obtain the optimum gas injection rate which yields the maximum oil production rate. Relationship between gas injection rate and oil production rate is described by a continuous gas lift performance curve (GLPC). Obtaining the optimum gas injection rate is important because excessive gas injection will reduce production rate, and also increase the operation cost (Saepudin et al. 2007). Gas lift Performance Curves for each well are typically derived through measurement of gas-oil production across a range of injection pressures. With continuous instrumentation at each well, these curves can be dynamically computed and used in optimization strategies to address well interaction as well as other operating conditions (Hatton et al. 2011).

1.5. Genetic Algorithm

A Genetic Algorithm (GA) is a search technique used in computing to find exact or approximate solutions to optimization and search problems. Genetic Algorithms are categorized as global search heuristics. Genetic Algorithms are a particular class of evolutionary algorithms (also known as evolutionary computation) that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover (Goldberg 1989). The Genetic Algorithm method was first introduced by Holland (1975), this technique has earned many interests among petroleum production specialists, (Mohaghegh, 2000).

GA allows precise modeling of the optimization problem, although not usually providing mathematically optimal solutions. Another advantage of using GA techniques is that there is no need to having an explicit objective function. Moreover, when the objective function is available, it does not have to be differentiable, (Lee et al., 2008).

The data needed to produce the best results by applying GA to Gas Lift allocation optimization problem is also given in Table 1.

Table 1: Well and Reservoir Data

	Well 1	Well 2	Well 3	Well 4	Well 5
Well Depth, m	3160	3200	3130	3070	3150
Reservoir Pressure, Psi	5260	5400	5020	5100	4970
Reservoir Temperature, c	101.7	102.3	101	101.7	102.1
Bubble Point Pressure, Psi	1184	1180	1210	1160	1193
Water Cut, %	0	0	0	0	0
Tubing Size, inch	3 ½	3 1/2	3 ½	3 1/2	3 1/2
Casing Size, inch	9 5/8	9 5/8	9 5/8	9 5/8	9 5/8
Oil Gravity, API	26.25	26.2	25.5	26.4	26.1
Well Head Pressure, Psi	317	317	317	317	317
Well Head Temperature, c	75	75	75	75	75
Bottom Head Pressure, Psi	4700	4750	4640	4790	4750
Surface Injection Gas Pressure, Psi	1500	1500	1500	1500	1500
Well Deviation	Vertical	Vertical	Vertical	Vertical	Vertical
Well Completion	Cased Hole	Cased Hole	Cased Hole	Cased Hole	Cased Hole

1.6. Future Evaluation

All steps of optimization procedure are repeated for production prediction in order to reservoir pressure reduction and water cut increasing.

2. RESULTS AND DISCUSSION

Matching procedure has been done and the resulted correlations is used for the calculation of fluid properties such as solution gas oil ratio, oil formation volume factor, oil viscosity, gas compressibility factor and gas viscosity which are presented in Table 2.

Table 2: Physical Properties Correlations

Properties	Correlation
Solution gas oil ratio	Glaso
Oil formation volume factor	Glaso
Oil viscosity	Beal et al.
Gas viscosity	Lee et al.
Gas compressibility factor	Katz et al.

The Comprehensive Ansari et al. method for vertical multiphase flow requires the production rate data and deviation, pressure and temperature surveys. After these data were entered into the modeling computer program, the program calculated pressure as a function of depth. Flow at the bottom of the well is single phase and change to multiphase flow when goes up in the well. Dominant flow pattern in multiphase flow is slug flow. Required data are presented in Table 1.

After Gas Lift design, Gas Lift Performance Curve (GLPC) is generated for all wells as shown in Figure 3. Consequently different scenarios for Gas Lift design such as unlimited available gas, equal gas injection rate, Production Weighted (PW) injection rate and Genetic Algorithm method of optimization were compared together. The results are presented in Table 3. Although unlimited available gas scenario causes the maximum oil production rate in comparison to other scenarios but due to limited available gas (total amount of 8 MMSCF/d), the other scenarios must be noted. As it shown in Table 3 GA, PW injection rate and equal injection rate has better performance, respectively. The optimal parameters for Genetic Algorithm used to reach the optimum gas lifting operation for Primary Population , Crossover, Mutation and Iteration are, 30, 0.8 (2 points), 0.2 (Gaussian) and 43 respectively.

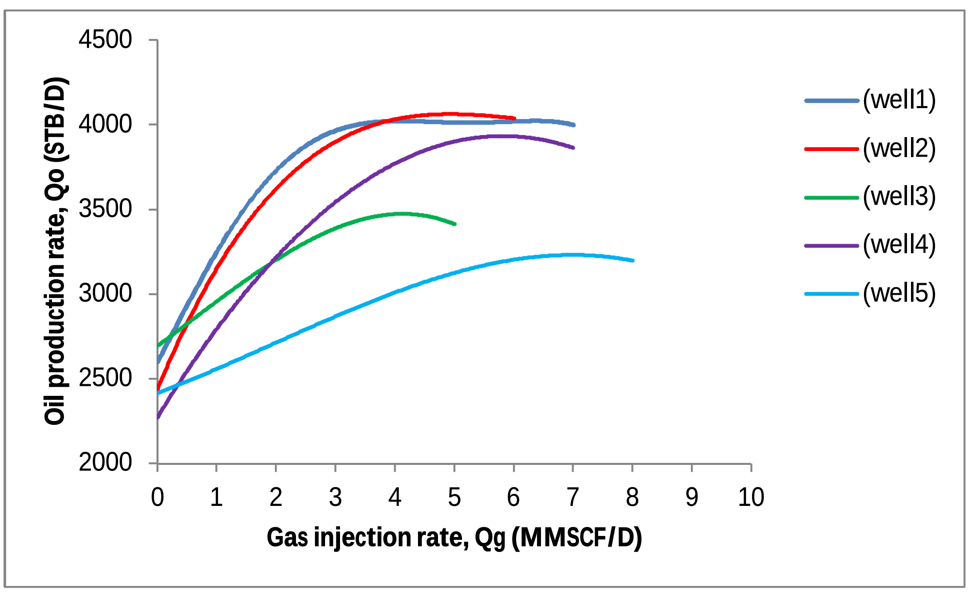

Figure 3: Gas Lift Performance Curves (Initial P_r and W.C = 0%)

Table 3: Gas Injection Rate and Oil Production Rate for a Set of 5 Wells (Initial P_r and W.C = 0%)

	Natural flow		Unlimited Available Gas		Equal Injection Rate		Production Weighted Injection Rate		G.A.	
	q_g (MMSCF/D)	q_o (STB/D)	q_g (MMSCF/D)	q_o (STB/D)	q_g (MMSCF/D)	q_o (STB/D)	q_g (MMSCF/D)	q_o (STB/D)	q_g (MMSCF/D)	q_o (STB/D)
Well1	0	2600	5	4015	1.6	3565	1.67	3605	2.1	3765
Well2	0	2450	4.5	4050	1.6	3425	1.57	3405	2.2	3775
Well3	0	2700	3	3435	1.6	3105	1.73	3130	0.9	2930
Well4	0	2300	5	3895	1.6	2985	1.48	2970	2.6	3545
Well5	0	2410	6	3215	1.6	2650	1.55	2645	0.2	2450
Total	0	12460	23.5	18610	8	15730	8	15755	8	16465

As the same natural production case, in Gas Lift procedure oil production rate will decrease as time passes and reservoir pressure declines. The important point here is that optimized gas injection rate will not be constant for all wells with reservoir pressure decline. This procedure is investigated for reduction of reservoir pressure to 4500 psi and increasing of water cut to 40%, as shown in Figure 4 and Table 4.

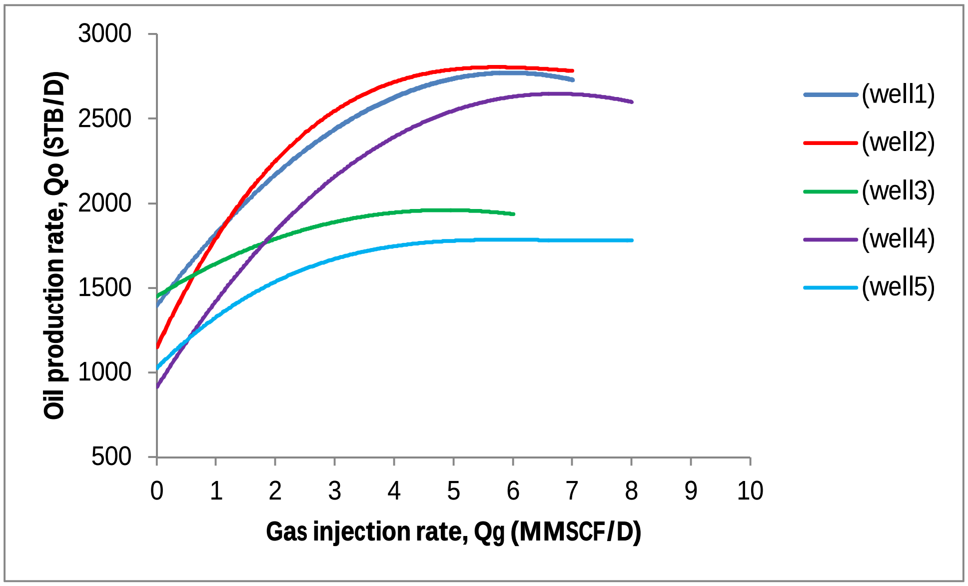

Figure 4: Gas Lift Performance Curves (P_r = 4500psi and W.C = 40%)

Table 4: Gas Injection Rate and Oil Production Rate for a Set of 5 Wells (P_r = 4500psi and W.C = 40%)

	Natural flow		Unlimited Available Gas		Equal Injection Rate		Production Weighted Injection Rate		G.A.	
	q_g (MMSCF/D)	q_o (STB/D)	q_g (MMSCF/D)	q_o (STB/D)	q_g (MMSCF/D)	q_o (STB/D)	q_g (MMSCF/D)	q_o (STB/D)	q_g (MMSCF/D)	q_o (STB/D)
Well1	0	1400	5	2750	1.6	2035	1.92	2065	2.05	2275
Well2	0	1150	5	2800	1.6	2090	1.58	2085	2.25	2335
Well3	0	1460	4	1950	1.6	1770	2	1795	1.05	1615
Well4	0	900	5.5	2620	1.6	1630	1.23	1610	2.3	1925
Well5	0	930	6	1790	1.6	1415	1.27	1400	0.35	1280
Total	0	5840	25.5	11910	8	8940	8	8955	8	9430

3. Conclusion

At the first experimental PVT data has been tuned. Also Comprehensive Ansari et al. method is used for vertical lift performance. In order to determine the optimal gas lift condition, Solution nodal method is used. Moreover Genetic Algorithm method and four other scenarios are applied and compared for Gas lift Allocation Optimization to determining the optimum gas injection rate for a group of well in order to maximize the total oil production rate. Finally effect of reservoir pressure and water cut is considered for future reservoir production evaluation.

Gas Lift operation is optimized in one of Iranian oil field reservoir and the following results has been obtained according to this research.

- By the Genetic Algorithm method of optimization, the total oil production rate will be increased by 32.14% at constant reservoir pressure and 0% water cut.
- As time passes, the total oil production increasing by the Genetic Algorithm method of optimization will be 61.47% according to reduction of reservoir pressure to 4500 psi and increasing of water cut to 40%.
- As future evaluation of production, the percentage of total oil production rate reduction for natural production is 53.13 whereas this is 42.73 for Gas Lift optimization by GA method.
- For limited amount of available gas in Gas Lift system, the Genetic Algorithm method of optimization is the best method in comparison to other methods.

REFERENCES

- Chia, Y.C., 1999 “Gas lift optimization efforts and challenges”, Paper SPE # 57313.
- Gabor Takacs, 2005 “Gas Lift Manual”, PennWell Corporation.
- Goldberg D.E., 1989 “Genetic Algorithms, in Search, Optimization & Machine Learning” Addison Wesley.
- Holland, J.H., 1975 “Adaptation in Natural and Artificial Systems” University of Michigan Press. Ann Arbor.
- Lee, K.Y., El-Sharkawi, M.A., 2008 “Modern Heuristic Optimization Techniques” The Institute of Electrical and Electronics Engineers, Inc. ISBN 978-0471-45711-4 Published by John Wiley & Sons, Inc., Hoboken, New Jersey.
- Michael Golan and Cutis H. Whitson, 1985 “Well Performance”, Prentice-Hall Inc..
- Mohaghegh, S., 2000 “Virtual Intelligence Applications in Petroleum Engineering: Part 2; Evolutionary Computing” Journal of Petroleum Technology.
- Shoham, O., 2006 “Mechanistic Modeling of Gas-Liquid Two-Phase Flow in Pipes” University of Tulsa.
- Vázquez-Román, R., Palafox-Hernández, P., 2005. “A New Approach for Continuous Gas Lift Simulation and Optimization” Inst. Tecnológico de Celaya, Mexico, SPE 95949.
- Robert N. Hatton and Ken Potter, 2011 “Optimization of Gas-Injected Oil Wells” SAIC, Huntsville, AL, U.S., Paper 195-2011.
- Deni Saepudin, Edy Soewono, Kuntjoro Adji Sidarto, Agus Yodi Gunawan,Septoratno Siregar, and Pudjo Sukarno, 2007 “An Investigation on Gas Lift Performance Curve in an Oil-Producing Well” Hindawi Publishing Corporation, International Journal of Mathematics and Mathematical Sciences.