THE OPTIMIZATION OF THE TECHNOLOGICAL PARAMETERS AT THE STAGE OF THE DECLINE IN THE OIL PRODUCTION

Abstract.
The effectiveness of the oil industry in the management of complex technological processes associated with oil production. In order to solve the problem of positive periodic dissertation work method to lift some of the problems were solved. Based on the analysis of mathematical models for gas-lift wells, oil production in optimal conditions. Have been investigated and developed a dynamic model of the periodic gas-lift wells. Some features, such as gas-lift wells operated facilities management and optimization of processes is one of the key issues. Mainly differ in terms of the characteristics of gas-lift wells. This can include: depth of filter, amount of product produced from well, pressure in the well, etc. Therefore, the well exploited in the process of continuously changing characteristics of physical factors in the change of the hole, and it appears the issue of identification. Difficult tasks during the operation of the above-mentioned factors causes gas-lift wells. These issues should be taken into account during the optimization of the gas-lift wells.
As is well known in gas-lift wells drilled in the primary tech working modes depends on superfluous use of agent productivity workers. We can come to the conclusion that the operation of gas-lift wells is very difficult and there are a group of different issues. Despite the variety of problems, they are part of a single optimization problem.

Keywords:gas-lift wells, gas-lift method, mathematical models, optimal conditions, optimization problem.

INTRODUCTION

One of the important directions of technical progress in the oil industry is the improvement of the technical and economic indicators of the gas-lift method of oil production, which has become widespread both in our country and abroad, due to several its advantages over other mechanized methods of well operation.
The purpose of the study of gas-lift wells is to determine the parameters of the reservoir, formation fluids and bottomhole zone to assess the allowable bottomhole pressures and rational distribution of working agent resources between wells according to the criterion of maximizing the total oil production or other accepted optimality criterion.
Gas-lift wells are currently being explored by tracking levels or pressures and test pumping. In all cases, it is necessary to conduct a complete study of the well and, on their basis, establish the flow rate, select equipment and its mode of operation so that the given flow rate is obtained with the greatest efficiency [1, 2, 5]. Along with a full study of the characteristics of the reservoir, it is necessary to study the operation of the elevator for optimization to clarify the amount of gas that should be injected into the well to obtain a given flow rate. This method, in comparison with the previous one, has the advantage that, in addition to determining the type of the inflow equation, it allows specifying the amount of injected gas to obtain a given flow rate [3, 4]. These circumstances determine the relevance of the work carried out in this project.
A rational system for supplying a working agent coming from compressor stations to wells is its distribution through air (gas) distribution booths. In the fields, distribution booths are placed in the center of a group of serviced wells [6]. Compressed gas is supplied from the

compressor station to the distribution booths through high-strength steel pipelines. Two, three, and sometimes four lines are laid to each booth. With two lines, one of them serves as a starting line for supplying high-pressure gas from starting compressors, and the other is a working line supplying gas of normal working pressure. When laying three lines, one line is used to start wells, and in the other two lines, having one - increased (medium) and the other - low pressure, the pressures necessary for the normal operation of the wells are maintained, depending on the operational characteristics of the group's wells connected to each of these lines.

TECHNOLOGICAL FEATURES OF GAS-LIFT OIL PRODUCTION

A gas-lift well is a well in which the gas missing for the necessary degassing of the liquid is supplied from the surface through a special channel (Fig. 1). Through the pipe string 1, gas from the surface is supplied to the shoe 2, where it mixes with the liquid, forming a GSL, which rises to the surface through the lifting pipes 3. The injected gas is added to the gas released from the reservoir fluid. As a result of the mixing of gas with liquid, GLS is formed of such a density at which the available pressure at the bottom of the well is sufficient to lift the liquid to the surface [7]. The point of gas entry into the lifting pipes (shoe) is submerged under the liquid level by the value h; the gas pressure P1 at the point of its entry into the pipes is proportional to the immersion h and is related to it by the obvious relationship P1 = hρg.

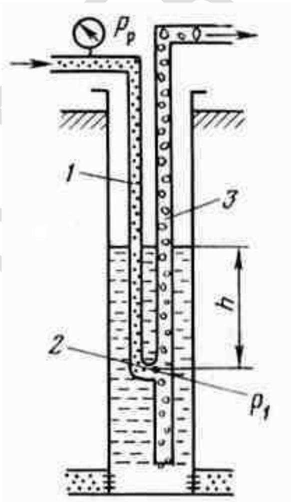

Figure 1.Schematic diagram of a gas lift

The pressure of the injected gas, measured at the wellhead, is called the working pressure Pp. It is practically equal to the pressure at the shoe P1 and differs from it only by the value of the hydrostatic pressure of the gas column ΔP1 and the pressure loss due to gas friction in the pipe ΔP2, and ΔP1 increases the pressure below P1, and ΔP2 decreases. Thus,

$$P_1=P_P+\Delta P_1-\Delta P_2$$

In real wells, $\Delta P1$ is a few percent of P1, and $\Delta P2$ is even less. Therefore, the working pressure Pp and the pressure at the shoe P1 differ little from each other. Thus, it is quite simple to determine the pressure at the bottom of a working gas-lift well by its working pressure at the wellhead. This simplifies the procedure for examining a gas-lift well, adjusting its operation and establishing the optimal mode. A well into which gas is pumped in order to use its energy to lift liquid is called a gas-lift well, when air is injected for the same purpose, an air-lift well.

The use of air contributes to the formation of a very stable emulsion in the tubing, the decomposition of which requires its special treatment with surfactants, heating, and long-term settling. The gas-air mixture released during separation on the surface is dangerous in terms of fire since it forms an explosive mixture at certain ratios 8, 9]. This creates the need to release the spent gas-air mixture after separation into the atmosphere.

The use of hydrocarbon gas, although it contributes to the formation of an emulsion, but such an emulsion is unstable and is often destroyed (stratified) by simple sludge without the use of expensive processing to obtain clean conditioned oil. This is due to the absence of oxygen or its low content in the hydrocarbon gas used and the chemical relationship of gas and oil, which have a common hydrocarbon base. Oxygen contained in the air contributes to oxidative processes and the formation of stable shells on water globules, which prevent water from merging, enlargement of globules and their subsequent settling during sedimentation. Due to its relative explosion safety, the exhaust gas after separation is collected in a gas collection system and disposed of. Moreover, the separated gas of a gas-lift well, when it is vigorously mixed with oil while moving along the tubing, is enriched with gasoline fractions.

LAUNCHING A GAS LIFT WELL

Let's consider the process of starting a gas-lift well using the example of a single-row lift with direct gas injection. When gas is supplied to the annulus, the gas pushes the static level down; at the same time, bottomhole pressure increases. Part of the fluid from the annulus enters the riser, the other part can be absorbed by the formation. As the gas pressure increases, the volume of liquid absorbed by the formation increases (due to the increase in overbalance). Now the liquid level reaches the shoe, the gas pressure becomes maximum, and the gas begins to break through the shoe, saturating the liquid in the lifter. The density of the resulting gas-liquid mixture decreases, and at a certain gas flow rate, the mixture reaches the mouth and begins to pour out. After gas breakthrough into the shoe, the gas pressure decreases, which leads to a decrease in bottomhole pressure and fluid flow from the formation to the well. Liquid enters the lifter and the annulus, shutting off the shoe and gas flows to the lifter. The fluid level in the annulus rises over time. Starting from the moment the lifter shoe is covered with liquid, the gas pressure in the annulus increases. After a certain time, the gas pressure becomes sufficient to push the liquid level to the shoe, after which the gas breaks into the lifter, and the cycle repeats. Thus, during stationary operation of the system, the above-described process periodically occurs at the hoist shoe, leading to some change in the gas injection pressure.

The maximum pressure of the injected gas, corresponding to the displacement of the liquid level to the lift shoe, is called the starting pressure Ppusk. The average pressure that is established during the normal operation of a gas-lift well is called the working pressure Ppa6. The calculation of the starting pressure under specific conditions is of practical interest, because. associated with the need to select equipment for gas compression. As can be seen from Figure 1, the start-up curve can be used to determine the pressure at which a gas-lift well operates. In the process of gas injection, depending on the mode of optimal operation of the well, gas is injected into it in certain portions until the optimal well flow rate is reached. This is due to the above reasons for downloading. Further, after processing the data in the gas injection control system, this pressure is set depending on the operating mode of the gas lift well.As you can see, the working pressure has a pulsation, which affects the effective production rate of a gas lift well. Pressure pulsation is one of the most important problems in operation.

MATHEMATICAL MODEL OF THE OPTIMAL DISTRIBUTION OF THE WORKING AGENT

In practice, most often they are limited to research for the construction of so-called control curves, i.e., dependences of the well flow rate Q(V) and the specific flow rate of the injected gas R(V), on the flow rate of the injected gas Q(V)= f(V) and R(V)= f1(V). To build these curves in field conditions, the number of investigated modes of operation of the lift must be at least six.

The dependence of the well flow rate on the injected gas flow rate is proposed as a parabolic function. The proposed form of the approximating function of the gas lift well survey data, which makes it possible to increase the accuracy of the approximation, was obtained by introducing an additional nonlinearity in the form of a logarithm into the original parabolic function, i.e.:

$$Q(V) = \beta_0 + \beta_1 \ln V + \beta_2 (\ln V)^2$$

One of the main parameters characterizing the operating mode of a gas-lift well is the specific consumption of the working agent R, which in this case is defined as:

$$R(V) = V / Q(V) = V / (\beta_0 + \beta_1 \ln V + \beta_2 (\ln V)^2)$$

To obtain the dependence of the well flow rate on the flow rate of the injected gas, the research process requires long-term experiments associated with the overconsumption of the working agent and the loss of oil production, and in some cases with the risk of disrupting the technological regime of the well. Under these conditions, the issues of determining the coefficients of the mathematical model based on the data of normal operation of wells without introducing deliberate disturbances become urgent. The coefficients, $\beta_0, \beta_1, \beta_2$, are determined by various identification methods based on the quantitative results of natural science experiments, technical data of observations and measurements (Table No. 1). The use of modern statistics makes it possible to more accurately and fully use the information extracted from observations by the least squares method, and to better understand the meaning and significance of the data obtained by this method.

The task of identifying the characteristics of a gas-lift well, due to the inaccuracy of the survey data and conducting a survey in a narrow range, in some cases, turns out to be incorrectly set [10-12]. The incorrectness of the characteristic identification problem is mainly manifested in the fact that, based on the processing of research data, an inverted parabola is obtained, for which the characteristic feature is the positiveness of the coefficient β_2.

As a result of applying the above least squares method, based on the quantitative results of natural science experiments, technical data of observations and measurements indicated in The coefficients (β_0, β_1, β_2), are determined, characterizing the initial parabolic function of the dependence of the well flow rate on the flow rate of injected gas: β_0 = -567,5299; β_1 = 435,2467; β_2 = -74,7523. Thus, we obtain a general view of the function of the dependence of the well flow rate on the flow rate of the injected gas:

$$Q(V) = -567{,}5299 + 435{,}2467 \ln V - 74{,}7523(\ln V)^2$$

Therefore, the specific consumption of injected gas is represented by the following relationship:

$$R(V) = V / Q(V) = V / (-567{,}5299 + 435{,}2467 \ln V - 74{,}7523(\ln V)^2)$$

Based on the research results, control curves are built (the construction can be carried out both in Microsoft EXCEL and in the MATLAB software package) (Fig. 2, 3).

The extremum on the curve (Q=66.0282 m3/day) corresponds to the maximum feed of the lift (point B). When this point is reached, a further increase in the flow rate of the injected gas above the mark corresponding to the extremum of the curve ($\overline{V}$ =18.3807 m3/day) leads to a decrease in the lifter supply and an increase in the operating pressure, as well as the specific flow rate. To obtain the specific flow rate corresponding to the extremum of the curve of dependence of the well flow rate on the injected gas flow rate, we substitute the value $\overline{V}$ in equation (1.4), the resulting corresponding value of the specific gas flow rate is equal to: $\overline{R}$ =0.2784. Also, if we equate expression (1.4) to and solving the equation, we get the roots $\overline{V}$ = 18.3807 m3/day and V´=9.679 m3/day.

Optimal from an energy point of view is the feed corresponding to the coordinate of the point of contact of the straight line drawn from the origin to the curve Q(V) = f(V) (Q). This point corresponds to the minimum specific flow rate of injected gas at the volume of injected gas equal to $\underline{V}$ =12.6900 m3/day. at $\underline{Q}$ = 55.7699 m3/day (point A).For this purpose, the minimum of the specific consumption function (1.4) $\underline{R}$ = 0.2275 (point B) is found. At this point, the maximum efficiency of the lift is ensured. The optimal operating mode of the lift can also be determined in another way, for which, at the point of the lowest specific flow rate of the injected gas, a tangent to the curve R(V)=f1(V) is drawn. The perpendicular drawn through this point to the tangent at the intersection of the curve Q(V)=f(V) gives a point corresponding to the optimal lift feed.

The above optimal and maximum parameter values can be calculated using the following formulas:

$$\overline{V} = e^{\frac{-\beta_1}{2\beta_2}} \tag{1}$$

$$\overline{Q} = \beta_0 - \beta_1^{\,2} / 4\beta_2^{\,2} \tag{2}$$

$$\underline{V} = e^{1-\frac{\beta_1}{2\beta_2}-\sqrt{(\frac{\beta_1}{2\beta_2})^2-\frac{\beta_0}{\beta_2}+1}} \tag{3}$$

$$\underline{Q} = 2\beta^2 + \sqrt{\beta_1^{\,2} - 4\beta_0\beta_2 + 4\beta_2^{\,2}}$$

$$\overline{R} = \frac{e^{\frac{-\beta_1}{2\beta_2}}}{\beta_0 - \beta_1^{\,2} / 4\beta_2^{\,2}} \tag{4}$$

$$\underline{R} = \frac{e^{1-\frac{\beta_1}{2\beta_2}-\sqrt{(\frac{\beta_1}{2\beta_2})^2-\frac{\beta_0}{\beta_2}+1}}}{2\beta^2 + \sqrt{\beta_1^{\,2} - 4\beta_0\beta_2 + 4\beta_2^{\,2}}}$$

In field conditions, as a rule, the well operation mode is selected in the interval $(\underline{V}, \overline{V})$ and is intermediate between points A and B. However, in conditions of a sharp lack of incoming gas, it may become less than the sum of the lower flow rates, which may necessitate turning off one or several wells. This decision is irrational since the restart of the well is associated with certain difficulties. Under these conditions, the possibility of expanding the ranges of well operation modes becomes important, i.e., the possibility of well operation at values of the injected gas volume is less than optimal, which will be associated with a certain increase in the specific flow rate. Studies show that, on average, the expansion of the range for the considered wells is 60% of the original. It shows that it is possible to increase the range of changes in the supply of the working agent by one and a half times without the need to shut down wells that are not prone to plugging. Under normal conditions, the expansion of the dynamic range of the well will increase the depth of redistribution of the working agent to optimize production.

Thus, in addition to the correct choice of the observation interval, when using averaged daily data for statistical identification of the parameters of the mathematical model of gas lift wells, it is necessary to carefully analyze the initial data to ensure their necessary information content. If these requirements are not met, it is not advisable to use the identification results for automatic control of gas-liftwells. In this case, the results of identification are used to roughly determine the range of change in the consumption of the working agent for the purposes of conducting active experimental studies.

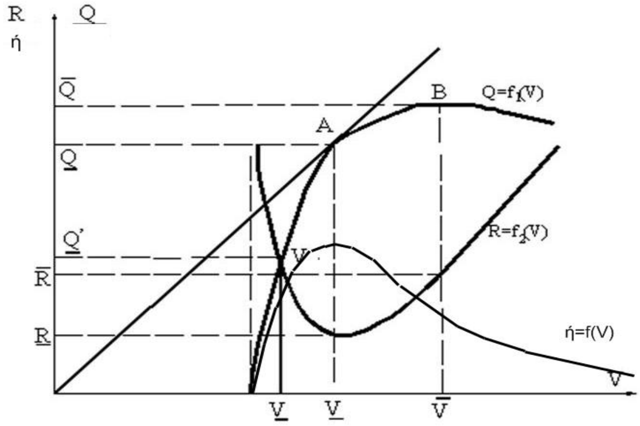

Figure 2. Characteristic dependences of the parameters of gas-lift wells

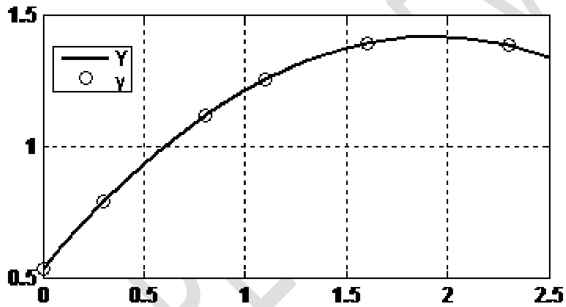

Figure 3. Approximation with the polyfit function

SOLUTION OF THE PROBLEM OF OPTIMAL DISTRIBUTION OF THE WORKING AGENT

To comprehend the above theory and terms of reference, we will solve a specific problem of optimizing experimental studies of the gas lift process: the process of measuring the parameters of a gas lift well is given, which are necessary for deciding and plotting the dependence of the well flow rate on the flow rate of the injected gas. Measurements consist of three main components (stages of measurement types). All components are interconnected, therefore, an error in readings at any one stage leads to a violation of the curve of the relationship between the flow rate of the well (lifter supply) and the flow rate (volume) of the injected gas. The reliability of instrument readings can be improved by duplicating each measurement in steps. Based on this, measurements can be carried out repeatedly. The maximum allowable number of measurements in each step is three.
The result is shown in Figure 4. As we can see, the experimentally obtained values of the variable y are practically located on the approximating curve.

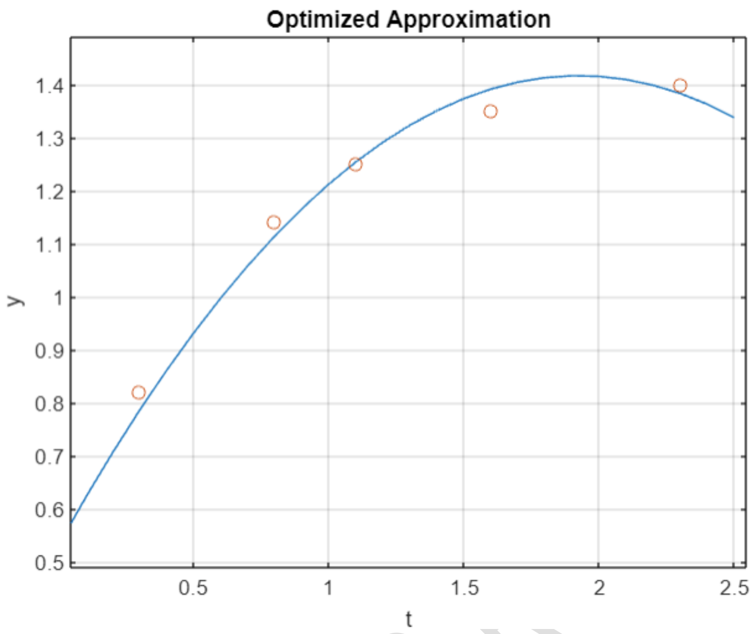

Figure 4. Optimization approximation

CONCLUSION

Taking into account the low efficiency of oil extraction by gas lift method, its complex optimization is an important issue. Taking into account that the identification model of the gas lift well was in the form of a parabolic dependence, the efficiency of the work increases when we switch to the logarithmic model. That is, logarithmic dependence is more adequate than parabolic dependence. A logarithmic model is better. Thus, during the execution of the work, the following results were obtained: Finding a "better" model of wells. Solving operations on this model in the program. This makes it easier. Application of dynamic programming in optimal distribution. Taking into account the possibility of applying this algorithm on a computer, it allows to optimize any number of wells. The possibility of remote control of the process through the server.

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