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УВЕЛИЧЕНИЕ КПД РАБОТЫ СКВАЖИНЫ, РАБОТАЮЩИХ С УЭЦН, ПУТЕМ ПРИМЕНЕНИЯ ТАНДЕМНОЙ УСТАНОВКИ УЭЦН + СТРУЙНЫЙ НАСОС

INCREASING THE EFFICIENCY OF THE WELL WORKING WITH THE ESP BY USING THE TANDEM INSTALLATION OF THE ESP + JET PUMP

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Аннотация. В данной работе авторы предлагают способ, который позволил бы увеличить КПД подъемника, для скважин добывающих нефть механизированным способом с помощью УЭЦН. КПД подъемника при этом предлагается увеличить, за счет увеличения работы газа по подъему жидкости. Работу газа было принято увеличить с помощью применения тандемной установки УЭЦН + струйный насос. После был приведен примитивный расчет эффективности данной тандемной установки, и сделаны выводы.

Ключевые слова: работа газа, КПД подъемника, струйный насос, УЭЦН, тандем.

Annotation. In this article, the authors propose a method that would increase the efficiency of the lift for wells producing oil in a mechanized way using the ESP. At the same time, it is proposed to increase the efficiency of the lift by increasing the work of the gas to lift the liquid. It was decided to increase the operation of the gas by using the tandem installation of the ESP + jet pump. After that, a primitive calculation of the effectiveness of this tandem installation was given, and conclusions were drawn.

Keywords: gas operation, lift efficiency, jet pump, ESP, tandem.

To date, there are a large number of ways of mechanized oil production, and each method has its advantages and disadvantages. But the most common method of oil production in Russia today is production using the installation of an electric centrifugal pump (ESP).

The ESP transmits mechanical energy to the borehole fluid, which should be enough to perform the work of raising the fluid in the borehole. The ESP needs to perform work, in other words, transfer energy to the borehole fluid in order for this total energy to be enough to raise the fluid. Then the equation of the fluid energy balance in the borehole [1]:

$$W_{liq} + A_{gas} + A_{pump} = W_{req}, \tag{1}$$

where W_{liq} – this is the energy stored in the liquid. In our case, this energy is expressed in the pressure of a column of liquid; A_{gas} – this is the work of gas dissolved in oil. This is the work that the gas does to lift the liquid. The share of A_{gas} can be significant, for example, during the fountain operation of a well or during a gas lift; A_{pump} – this is the energy that the pump has transferred to the liquid; W_{req} – this is the amount of energy required by the borehole fluid to rise to the surface. W_{req} also takes into account all energy losses due to friction and the amount of energy that the liquid should have on the surface.

As can be seen from equation (1) in the case of well gushing $A_{pump} = 0$. And as soon as $W_{liq} + A_{gas} < W_{req}$, it becomes necessary to do work in order to raise the liquid to the surface. Then, on the one hand, in order to minimize the A_{pump}, it is necessary to maximize the use of A_{gas} (gas operation), but on the other hand, free gas is dangerous for the ESP. The ESP works stably when the free gas content is below 25%, and up to 50% with gas separator modules.

Problem statement

The current reservoir pressures for fields that are currently at the final stage of development are characterized by low values, and these values of the current reservoir pressure are quite close to the pressure of oil saturation with gas. This leads to the fact that the suspension depth of the ESP must be increased, or else a gas separator must be installed on the ESP [2].

An increase in the suspension depth leads to an increase in the metal content of the well. The gas separator, in turn, reduces the work of the gas to lift the liquid, that is, it reduces the coefficient of efficiency of the lift.

At the same time, we should not forget such a fact as the accumulation of gas in the annular space. This accumulated gas could perform useful work on lifting the liquid, but instead it accumulates in the annular space and at the same time often causes a number of problems. For example, in winter, the gas valve at the mouth is covered with gas hydrate and, accordingly, does not bypass gas. This leads to an increase in the annular pressure, and subsequently may lead to a failure of the ESP supply, due to the transfer of liquid gas before receiving the pump.

Combining all of the above, we can draw an intermediate conclusion that the most common method of oil production in Russia reduces A_{gas}, which means it increases A_{pump}, thereby reducing the efficiency coefficient of the lift. At the same time, gas always accumulates in the annular space, which does not perform work in any way.

Let's formulate a technological problem. It is necessary to improve the technology of oil extraction in a mechanized way with the help of the ESP in such a way that the efficiency coefficient of the lift increases by increasing the work of the gas to lift the liquid at these costs A_{pump}.

Solving a technological problem

To accomplish this task, it is proposed to use a tandem installation of the ESP + a jet pump (JP), that is, additionally mount a jet pump in the wells where the ESP is used in the zone above the liquid level. In this case, the jet pump will suck gas from the annular space and reduce the annular pressure. And the working fluid for the jet pump will be borehole products, which are lifted with the help of the ESP. This technological solution will make it possible to use this annular gas as a source of additional energy to raise borehole products to the surface [3-6].

Consider, for example, well N of field X. For simplicity of calculations, we will consider the productivity index of the well (K_{PI}) constant with small changes in the flow rate (Q).

Figure 1 shows that the gas accumulates in the annular space and does not perform any useful work on lifting the liquid. Moreover, annular gas has recently been a source of additional problems in the form of gas hydrates. This is due to the failure or failure of the working condition of the gas check valve.

The well operates with a flow rate of $Q = 75\ m^3/day$ at a downhole pressure of $P_{down} = 103.7\ atm$. This bottom-hole pressure, as can be seen from Figures 1–2, is the sum of the hydrostatic pressure and the gas pressure on the liquid (P_{annul}):

$$P_{down} = \rho g h + P_{annul}, \tag{2}$$

where ρ – this is the average density of the borehole fluid, kg/m^3; g – acceleration of free fall, m/s^2; h – height of the liquid column, m.

When installing the JP, the gas released from the borehole products and collected in the annular space will be sucked into the pumping and compressor pipes. Thus, the JP will reduce the P_{annul} of the pipes, thereby lowering the P_{down}. With a decrease in P_{down}, the depression on the reservoir (ΔP) will also increase, and it follows that the flow rate of the well will also increase.

Figure 2 shows the same well after installing the tandem. Figure 2a shows the process when $P_{annul} = 0$, while if Q does not change, then h will increase. After that, due to the fact that JP will increase Q, h will gradually decrease (Figure 2b).

Table 1 shows the values of the well operation parameters before and after the introduction of the tandem.

For example, JP sucks up all the gas. Then $P_{annul} = 0$ (let's take this as a convention for simplicity of calculations). Also, let's assume that the pressure change occurred instantly, this assumption is necessary in order not to take into account, at this stage, the influence of changes in the fluid level in the well. Then ΔP will increase by the value $P_{annul\,1}$. Then from the equation:

$$Q_2 = K_{PI} \cdot \Delta P_2, \tag{3}$$

where $\Delta P_2 = \Delta P_1 + P_{annul\,1} = 109.2 + 29 = 138.2\ atm.$

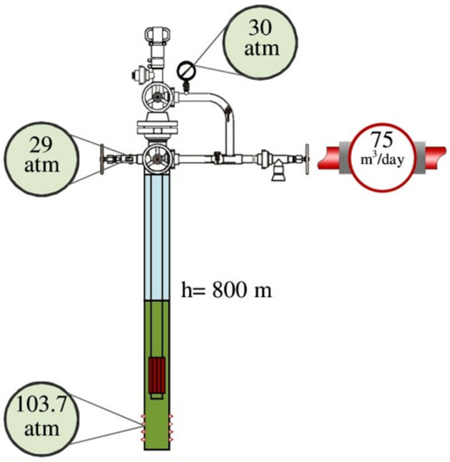

Figure 1 – Well operation with ESP

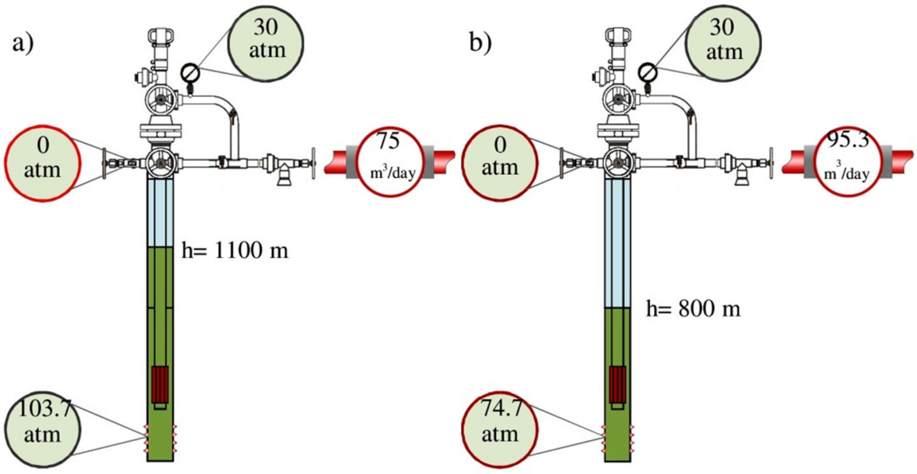

Figure 2 – Operation of the well after installation of the tandem ESN + JP

Table 1 – Parameters of the well operation before and after the introduction of the tandem

Parameter		The value of the value for the case:	
name	designation	before	after
Pressure in the annular space, atm	P_{annul}	29	0
Well length, m	L	2500	
Productivity coefficient, m^3/(day·atm)	K_{PI}	0.69	
Current reservoir pressure, atm	P_{res}	212.9	
Downhole pressure, atm	P_{down}	103.7	74.7
Depression, atm	ΔP	109.2	138.2
Flow rate, m^3/day	Q	75	95.3

Solving equation (3) with respect to Q_2, we obtain that $Q_2 = 95.4\, m^3/day$. This means that the flow rate increased by 20.4 m^3/day. At the same time, the risk of hydrates will decrease.

Since the mass of the extracted liquid has increased, with these energy costs (A_{pump}), it means that the efficiency of the lift has increased.

Note

When solving the problem, the authors agreed that the operating mode of the pump does not change, which means two cases of development of events are possible:

1) JP gives the same increase in productivity (flow rate) that the reservoir gives. In other words, the entire additional volume of liquid coming out of the reservoir will also be sucked in by the pump, due to the fact that the characteristics of the ESN + JP tandem have increased.

2) JP gives an increase in productivity, the value of which is less than the value of the increase in flow rate from the reservoir to the well.

In this decision, the authors considered the first case.

Conclusions

1) Tandem ESN + JP allows you to increase the efficiency of the lift, by increasing the jet pump gas work to lift the liquid.

2) The introduction of a tandem contributes to an increase in the productivity of the well, due to an increase in depression on the formation. But this effect requires separate consideration.

3) At the same time, it was also noted that this solution allows minimizing the formation of gas hydrates in the annular space in winter.

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