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Study of the process of changing of the effective gas factor in time under the conditions of gaslift flowing

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SUMMARY

The paper puts forward the calculation of the change in time of the minimum downhole pressure of flowing due to the joint interaction of the well and the oil pool under the dissolved gas regime, as well as the method of calculating the conditions of joint operation of the oil pool and the folowing well. The method is based on solving the equations of fluid filtration in the oil pool and the movement of gas-oil flow in the wellbore.

Introduction

In the process of wells operation, when the oil deposit operates in the mode of dissolved gas , the pressure at the bottom of the production well is lower than the saturation pressure of oil with gas, and at first free gas flows from the reservoir into the well in large quantities;therefore,it is only flowing of a well that can be applicable for a well operation (gas lift flowing; the third type of flow wells). Consequently, as the consumption of free gas lessens, one may use mechanized methods (gas lift or pump) (Boiko, 2018).

Method and Theory

Gas lifting condition of the flow well of the third type where there has begun the process of gas exhaustion in the producing payout bed is given as effective gas factor G_{eff} (Boiko, 2018):

$$G_{\text{eff}} \geq R_{0\text{opt}} , \tag{1}$$

or in the expanded view

$$\left[G_0 - \alpha_s\left(\frac{p_{\text{bh}} + p_2}{2} - p_0\right)\right](1 - n_{\text{w}}) \geq \frac{0,282L\rho g\left[L\rho g - (p_{\text{bh}} - p_2)\right]}{d^{0,5}(p_{\text{bh}} - p_2)\,p_0 \ln\dfrac{p_{\text{bh}}}{p_2}} , \tag{2}$$

де $R_{0\text{opt}}$ – specific gas consumption equired for fliud lifting in awell; G_0 – operational gas factor; α_s – coefficient of solubility of gas in oil; p_{bh} – down hole pressure; p_2 – pressure at the mouth (one mission) of the well (connects the work of the well with the system of gathering and transportation of products in the field); p_0 – standard pressure; n_{w} – water content to products (in the model of dissolved gas it mostly shows as $n_{\text{w}} = 0$); L – length of tubing in the well (in wells of the third type tubing should be lowered to the middle of the interval of inflow of liquid, i.e. to the middle of the interval of perforation); d – inner diameter of the tubing (for preliminary calculations one can set a priori depending on the flow rate; nominal diameter, which is set, usually equals to 73 mm); ρ – average density of oil in a well; g – free fall acceleration.

The effective gas factor G_{eff} characterizes the amount of reservoir energy formation energy (free gas expansion energy) coming from the formation (i.e. what one has), and the specific gas consumption $R_{0\text{opt}}$, which is required to lift the fluid in the well (what one has to have),is calculated according to the O.P.Krylov's formula on the optimal mode at the highest efficiency of the lifting process (one can take the maximum mode, if necessary).

Figure 1. demonstrates the graphical interpretation of the condition of the gas lift flowing of the well.

Thus, the condition of gas-lift flowing, with the sign of equality in it, describes a long-term, controlled, jointly coordinated operation of the flowing well and oil reservoir. Regarding the condition of flowing, it appears that the coordination of the well and formation operations happens "automatically" (due to self-regulation) because of due to the down hole pressure , while the other parameters are known and they are a priori predetermined values. The operational gas factor is considered set as well. Still,on the planning satege for the flowing well operation the operational gas factor is set constant for conditions at the beginning and end of the flowing period (it is only the effective gas factor that changes), and the calculation is reduced to the minimum down hole pressure at the end of the flowing period at a given flow and well mouth pressure and corresponding flow at the beginning of the flowing period (Boiko, 2018).

Regarding the operational gas factor, it is determined by the work of the reservoir and it is calculated following any method of design and develop of oil fields under the dissolved gas regime. The results of experiments (Kachmar, 2004) show that initially,during the operation of the oil pool,the gas factor increases slowly (during the first phase, even with some decrease), then it increases intensively, reaches a maximum, and due to the exhaustion of the oil pool it decreases sharply, i.e. operational gas factor is variable over time. In practical implementation of exploitation of wells under the dissolved gas regime of and in the process of calculation of the expected oil production it serves as the basis to set conditions of constant flow rate at the flowing and mechanized extraction at an early stage of production, when the formation pressure is high, and though formation pressure and reservoir pressure do lower, but their values are still high , and it is still possible to carry out controlled fluid withdrawal. At a later stage of development of the well, when the well equipment is already worn outand down hole and formation pressures do not provide well flowing, and the power of the mechanized method (subsiding of tubing or pump below the liquid level) is fully used, the condition of constant selection is impossible; therefore, it makes perfect sense to operate the well at constant down hole pressure (Kachmar, 2004, Poberezhnyi, 2017).

To substantiate the nature of the flowing well in terms of self-regulation with the operation of the formation, we limit ourselves to the probability-statistical cumulative S - similar growth curve, such as the Gompertz curve to describe the change in the accumulated operational gas factor $\overline{G_0}\left(t\right)$ over time t:

$$\overline{G_0}\left(t\right)=G_{00}+Ae^{-ae^{-bt}} \quad , \tag{3}$$

where G_{00} stands for the operational gas factor at a time $t=0$, which is equal to the formation gas-oil ratio (or, alternatively, the gas saturation of formation oil; A, a, b –constant coefficients. Here coefficient A one can put as:

$$A=abA_0, \tag{4}$$

where A_0 stands for the accumulated gas factor at the time $t\to\infty$.

Taking the derivative of expression (Baturyn, 2016), we get the differential curve for the current gas factor:

$$G_{\text{eff}}\left(t\right)=Aabe^{-b\cdot t_1}e^{-a\cdot e^{-b\cdot t_1}}, \tag{5}$$

and taking into account the period of the constant gas factor until we get the differential curve for the beginning of the countdown t_1

$$G_{\text{eff}}\left(t\right)=G_{00}+Aabe^{-b\cdot t_1}e^{-a\cdot e^{-b\cdot t_1}}. \tag{6}$$

To describe the dependence $G_{\text{eff}}\left(t\right)$ we select the coefficients A, a, b according to the nature of the change of the curve and two points that determine:

a)multiplicity of growth of the gas factor

$$\varphi_{\text{eff}}=\frac{G_{\text{eff}}\left(t_n\right)-G_{00}}{G_{00}}=\frac{bA}{e}; \tag{7}$$

b) moment of time t_n, when the current gas factor goes to maximum (then it falls)

$$t_{\text{n}} = \frac{\ln a}{b}. \qquad (8)$$

According to the experimental, calculational an dindustrial data (Telkov, 2001, Basnyev, 2005) it is established (Fig. 3), that for analysis one can take $\varphi_{\text{eff}} = 7{,}5$, $t_{\text{n}} \approx 6\,\text{years} \approx 1{,}9 \cdot 10^8$ c, and then find the coefficients A, a, b of the system of equations(Boiko, 2011), (10), (11), where the accumulated gas factor of known value : $\overline{G}_0(t_{\text{n}})$:

$$A_0 = \overline{G}_0(t_{\text{n}}) \cdot e^{a \cdot e^{-bt_{\text{n}}}}, \qquad (9)$$

that is

$$b^2 \cdot e^{bt_{\text{n}}} G_{\text{eff}}(t_{\text{n}}) - \varphi_{\text{eff}} = 0; \qquad (10)$$

$$a = e^{bt_{\text{n}}}, \qquad (11)$$

where $b = 0{,}8\,\text{c}^{-1}$; $a = 125$; $A_0 = 140\,\frac{\text{m}^3}{\text{m}^3}$; $A = 3800\,\frac{\text{m}^3}{\text{m}^3 \cdot \text{c}}$.

For calculations we take: $G_{00} = 140\,\frac{\text{m}^3}{\text{m}^3}$; $H = 2000$ m; $d = 0{,}062$ m; $p_2 = 0{,}5 \cdot 10^6$ Pa; $p_0 = 0{,}1 \cdot 10^6$ Pa; $g = 9.81\,\frac{\text{m}^2}{s}$; $\alpha_s = 10^{-5}\,\frac{\text{m}^3}{(\text{m}^3 \cdot \text{Pa})}$; $\rho = 860\,\frac{\text{kg}}{\text{m}^3}$ $\varphi_{\text{eff}} = 7{,}5$; $t_{\text{n}} = 6$ years.

Consequently, the flowing condition looks like:

$$\left(G_{00} + Aabe^{-b \cdot t_1} e^{-a \cdot e^{-b \cdot t_1}}\right) - \alpha_s \left(\frac{p_{\text{bh}} + p_2}{2} - p_0\right) = \frac{0{,}282 L\rho g \left[L\rho g - \left(p_{\text{bh}} - p_2\right)\right]}{d^{0{,}5}\left(p_{\text{bh}} - p_2\right) p_0 \ln \frac{p_{\text{bh}}}{p_2}}, \qquad (12)$$

Or

$$G_{\text{eff}}\left[p_{\text{bh}}(t)\right] \geq R_{0\text{opt}}\left[p_{\text{bh}}(t)\right], \qquad (13)$$

therefore, we find the down hole pressure p_{bh} as a function of time t, that is

$$p_{\text{bh}} = p_{\text{bh}}(t). \qquad (14)$$

The solution of this equation can be obtained with the help of a computer by the method of iteration in the machine environment MathCad or by the graphical and analytical way. (Fig. 1). We shall demonstrate the solution graphically.

Examples (Optional)

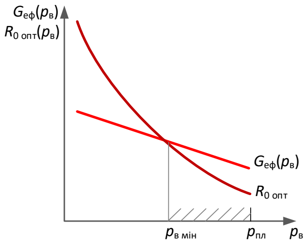

Figure 1 *Graphic in terpretation of the conditions of the gaslifting flowing of a well (possible lowing is depicted with cross-hatched are a in between oil-pool bottom-hole pressure* $p_{пл}$ *and minimal bottom-hole pressure* $p_{в\,мін}$*).*

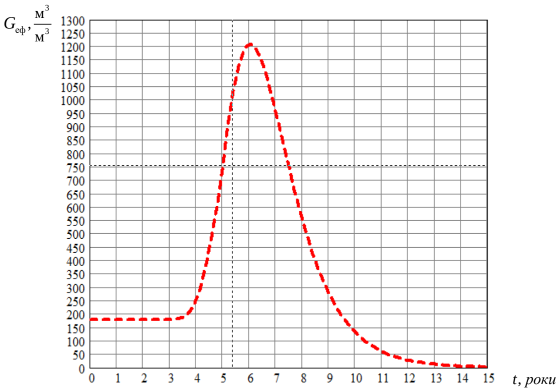

Figure 2 – Graphic interpretation of the change of an effective gas factor $G_{еф}$ with/against time t

Conclusions

Therefore, with time t effective gas factor G_{eff} as send sand then descends. Based on this, the prospect of the further research is to improve the design methodology of oil field development in the mode of dissolved gas by clarifying the boundary conditions. According to our approach, the boundary conditions are not set as constant, but they change with time irrespective of whether analytical methods or a modern numerical mathematical model is employed while working on the process of oil field exploitation.

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