STUDYING GAS SEPARATION AT THE INLET OF THE OIL WELL BOTTOM PUMP

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Abstract. The paper describes a measuring method for gas/oil ratio with a mobile setup by means of sending the free gas from annular space of a well directly to the meter, bypassing the oil-gas separation tank. Such arrangement allows reducing separator loads for gaseous phase and increasing the accuracy of measurement of both oil and gas. To assess the amount of gas being separated at pump suction, experiments were conducted on a number of fields being developed by Lukoil-Komi LLC; the experiments aimed to measure the gas coming from the annular space bypassing the separator. An empirical formula has been obtained allowing calculating the gas separation coefficient at suction of calculation at bottom pump suction depending on well oil production and making it possible to predict an amount of gas taken out of the annular space of the well during the metering.

1. Introduction

Previous works [1, 2] describe a method of gas/oil ratio measurement with a mobile unit, which is based upon taking out the gas from the annular space bypassing the metering tank and introducing the gas directly into a gas meter. The issue is that when metering following the regular arrangement, all the volume of separated gas comes to the metering tank (separator), then it is separated from oil and directed to the gas meter [3, 4]. At that, free gas, passing through the tube string with the liquid to the separator is mixed with the gas coming from the annular space of the well. Inflow of all the free gas to the separator creates a significant gas load resulting in incomplete separation of oil and gas in the tank and subsequent errors in both oil and gas metering.

2. Methods and materials

It is evident, that the accuracy of measurements when determining the gas-oil ratio depends on how much free gas may be taken out of the annular space and directed to the gas meter bypassing the separator. The more is the volume of gas preliminary taken off, the less is the separator load and the higher is the separation quality. This, in its turn, will increase the accuracy of the gas/oil ratio.

The ratio of such gas amounts depends on the conditions under which the gas is separated from oil at the bottom pump suction. According to a reference [5], the gas separation coefficient at suction of the ESP unit with a production of 50..350 m^3/day is determined by:

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$$K_s = \frac{1}{\frac{0.52Q_L}{\pi(R_S^2 - R_{PS}^2)(1-0.06\beta)v_{gb}}} \quad (1)$$

where Q_L is the amount of liquid inflowing in the pump, m^3/day;

R_S, R_{PS} , are radii of the production string and pump suction;

$\beta = \frac{V_g}{V_g + Q_L}$ is the voluminous consumption gas-oil ratio before the liquid inflows in the pump;

v_g is the amount of gas inflowing in the pump;

v_{gb} is the gas bubble rate of ascent in the liquid.

At that, the separation coefficient is understood as a ratio between the amounts of gas going to the annular space to the total amount of free gas at pump suction.

Analysis of the formula (1) shows that the calculation for the gas separation coefficient involves the liquid flow Q_L. At that, water cut of the liquid is not taken into account. In wells with high water cut, where the water content may reach 97-98 %vol, it may lead to underestimating the calculated value of the separation coefficient.

However, the greatest disadvantage of the formula (1) lies in our inability to determine the gas bubble rate of ascent in the liquid. This would require, on the one hand, knowledge of the diameters of the gas bubbles, and on the other hand, knowledge of viscosity of the water-oil mixture at the ESP's suction. Besides, finding this parameter involves a significant error, mostly due to complexity of calculating the value of v_{re} at pump suction.

This cause does not allow calculating even approximate values of v_{re} with the formula (1).

3. Results and Discussion

Due to this, studies of K_s shall be performed experimentally, by measuring the amount of gas going to the annular space and that of gas inflowing with oil into the separation tank.

The setup of the developed mobile unit [1, 2] allows solving this problem by making it possible to measure the amount of gas in both lines [6-8].

The relevant research and measurements with the mobile unit were carried out at Vozeyskoye, Kyzyreyskoye, Pashorskoye, Kyrtayelskoye, South-Lyzhskoye, Tedinskoye and South-Shapkinskoye oil fields being developed by Lukoil-Komi LLC. Oil density in the fields is 800..860 kg/m^3, gas density is 1.05..1.41 kg/m^3, water cut is 0..95.3%.

While measuring the gas-oil ratio at the wells of Lukoil-Komi LLC, wellhead samples of oil and free gas were taken.

The following conclusions and recommendations were made from the performed measurements:

When measuring the gas-oil ratio at the wells of Vekhne-Vozeisky, South-Shapkinsky, Kyrtayelsky field and others that are developed with reduced formation pressure with respect to saturation pressure, use of mobile of stationary metering units is mandatory, as the presence of free and occluded gas in the formation leads to its advance filtration and increasing the current gas-oil ratio values for these fields. Efficiency of the advance filtration is defined by the content and properties of the free gas, as well as by properties of the oil-containing formation. The fact of advance filtration of the free gas through the formation is confirmed by the results of studying the recombined oil samples under the initial saturation pressure; the samples were taken from the wells of Verkhne-Vozeyskoye (well no. 2864) and South-Shapkinskoye (well no. 4005) fields in 2009. From the measurements, the gas content values are 84.0 and 501.0 m^3 /t respectively, from the studies of the recombined oil samples they are 55.3 and 152.1 m^3 /t respectively;

2. According to RD 153-39.0-109-01, measurements of the gas-oil ratio at these wells shall be performed monthly with the help of mobile or stationary measuring means. For the field developed under the formation pressure that is higher than the saturation pressure, the gas-oil ratio shall be

determined annually with any certified and verified measuring means, including by the results of studying deep and recombined samples, when there are data on saturation pressure;

3. For the wells characterized by unstable modes of operation, it is recommended to conduct monthly measurements for an extended period of time.

The following conclusions were made from measuring the gas-oil ratio at Inzyreyskoye field:

1. High degree of flow uniformity is remarkable for the well no. 400 as determined by measuring the gas-oil ratio during 12 hours. It allows concluding that for this well the obtained value of the gas-oil ratio is close to the true value and allows using the measured value in geological and field analysis of development. However, a significant discrepancy between this value and the data from deep sampling of the wells allows recommending repeated deep sampling for this well, as well as the well 403/2 to elaborate the formation fluid parameters in this part of the deposit.

2. For wells 402, 605 and 508bis - the value of measured gas-oil ratio may have been influenced by geological and field factors (the formation pressure is reduced in formation D2zv, also there is a change in hydrodynamic mode for this reservoir due to introduction of a formation pressure maintenance system in 2009). Thus, the data shown for these wells may be used in the geological and field analysis with a lesser degree of confidence until new data arrives from subsequent measurements.

Simultaneously, data for daily oil production (M), amount of gas taken from the annular space Q, total amount of gas produced with oil Q_g and gas-oil ratio Γ_f were analyzed.

Figure 1 shows the relations between the gas separation coefficient and the well oil production. It is evident, that with increased production, the separation coefficient is reduced, which is also reflected in the formula (1). This is due to reduced time that a gas bubble spends int he liquid while it is rotated at the inlet of the ESP [5, 9-12]. This time becomes insufficient for moving the bubble to the periphery of the stream and separation for continuing vertical movement through the static liquid at the ESP inlet. As a result, the gas bubble is enthralled with the stream and gets into the pump.

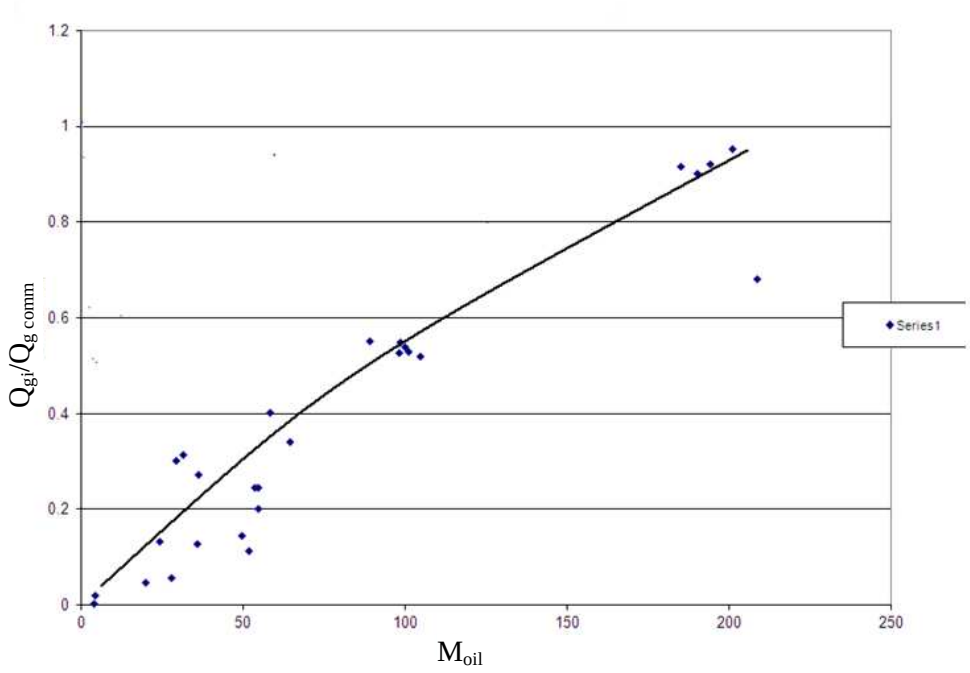


Figure 1. Relations between the gas separation coefficient and the well oil production.

Reversely, at very low oil production values, the gas bubble has enough time to move through the rotating stream of the liquid and go up into the annular space.

A group of points in Figure 1 is approximated with a function (R^2=0.8):

$$K_c = \frac{M}{0.34M + 149.6} \quad (2)$$

Where M is the oil production, t/day

The formula (2) firstly shows that a significant part of the free gas at the pump inlet goes into the annular space. Gas drawoff from the annular space directly to the gas meter bypassing the separator significantly reduces separator loads and as a result improves gas separation and increases the accuracy of measurements of both liquid and gas.

Conclusion

An experimental dependency has been obtained, linking the gas separated at the inlet of the bottom pump and the total gas-oil ratio to the well oil production. The dependency shows that this ratio increases with increased mass flowrate of oil.

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