On the influence of the amount and viscosity of oil on the content of solid particles in the water injected into the reservoir

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Abstract. Based on the studies carried out, a statistical dependence is obtained for calculating the amount of oil carried over by the discharged water from the viscosity of the extracted oil and the daily loading of the apparatus by liquid, and also a statistical relationship is established between the content of oil and mechanical impurities in the discharged water and the dependence of this ratio from the viscosity of oil.

1. Introduction

As known, water injection into reservoir is one of the ways to improve the efficiency of oil field development [1–8]. However, the exploitation of oil fields using the reservoir pressure maintenance (RPM) method by injecting reservoir water discharged from the fields is inevitably associated with clogging of the bottomhole zone of injection wells with mechanical impurities. In the end, the injectivity of the well may decrease to almost zero if no measures are taken to restore it.

2. Materials and methods

In most cases, the reservoir water of the RPM system is supplied to the receiving pumps of cluster stations from preliminary (track) discharge units, and the quality of this water in terms of the content of suspended solids (SS) and oil depends on the efficiency of the apparatus. Below are the results of the analysis of the amount of SS and oil in the discharged water at the discharge units of a number of Bashneft-Dobycha OOO facilities.

3. Results and Discussion

In [9] it was shown that the loading (productivity) of the apparatus by liquid affects the residual content of petroleum products in the discharged water. It is quite obvious that their amount in water will also depend on the time the liquid stays in the apparatus and on the physical properties of the oil itself. Therefore, when calculating, it is necessary to take into account the specific loading of the preliminary water discharge unit (PWDU), determined by the formula:

$$Q_{sp} = \frac{V}{Q_{liq}} \text{ day}$$

where $V$ is the useful volume of the discharge apparatus filled with liquid, m$^3$. 
Formula (1) characterizes the residence time of a unit of liquid volume in the apparatus.
In accordance with the data on the operation of a number of pipe water separators (PWS) and the PWDU, statistical dependences of the amount of petroleum products in the discharged water on the specific load of the apparatus were built.

Figure 1 shows as an illustration a graph for the conditions of water discharge at the fields of Chekmagushneft NGDU. The graph shows that the amount of oil carried away by water increases with an increase in the specific load of liquid discharge units.

\[
Q_\text{v}, \text{mg} / \text{l} \\
\text{V/Q}_\text{i.l., day}
\]

**Figure 1.** The graph of the dependence of the amount of oil carried away by discharged water from the loading of the apparatus (Chekmagushneft NGDU, \( \mu_{\text{av}} = 41.8 \text{ mPa} \cdot \text{s} \))

The analysis also showed that the relative amount of oil carryover is different for different regions. The largest carryover value takes place at Krasnokholmskneft NGDU due to the fact that the average viscosity of degassed oil under standard conditions for this region is the highest and is about 45 mPa · s.

Figure 2 shows a graph of the dependence of the relative daily amount of oil phase carryover \( (Q_1 \cdot q_o / V) \) on the oil viscosity. A linear dependence of the daily oil carryover from the apparatus on the oil viscosity is noted \( (R^2 = 0.8) \):

\[
Q_1 \cdot q_0/V = 1.08 \cdot 10^{-2} \mu_{\text{av}},
\]

(2)

**Figure 2.** Graph of the dependence of the relative amount of carried over oil on the average value of \( \mu_{\text{av}} \).
its viscosity

Values are deferred on the ordinate axis

\[ \tan \alpha = \frac{q_o}{V/Q_1} = \frac{q_o \cdot Q_1}{V}. \]

According to formula (2), it is possible to roughly calculate the amount of oil carried over by discharged water at known values of the loading of the apparatus, its volume and average viscosity of degassed oil produced in the region where the apparatus is located.

In the discharged water, along with petroleum products, there are suspended solid particles that are carried out from the reservoirs or entering the extracted liquid from other sources, for example, metal corrosion products, etc. Acceptable concentrations of both oil in water and suspended particles are usually 40–50 mg/l.

Statistical dependence between the amount of oil \((q_o)\) and suspended particles \((q_{\text{mech. imp.}})\) during the year of operation was obtained for a number of preliminary water discharge units of the Tuimazinsky oil field.

**Figure 3.** The relation between the amount of oil carried over by water \((q_o)\) and mechanical impurities \((q_{\text{mech. imp.}})\) for water discharge units: 1 - TVO-20 (D); 2 - BKNS-28 (D); 3 - "Ardatovka" PDU

**Figure 4.** The relation between the amounts of oil carried over by water \((q_o)\) and mechanical impurities \((q_{\text{mech. imp.}})\) for the TVO-29 unit
Figures 3 and 4 show data for TVO-20 (D), BKNS-28 (D), "Ardatovka" PDU and TVO-29. During the year, the \( q_o/q_{\text{mech.imp.}} \) ratio for each unit fluctuates. Lines drawn through the groups of points make it possible to determine the averaged \( q_o/q_{\text{mech.imp.}} \) ratios for each discharge unit. The slopes of these lines are different for each unit. For a number of units, a graph of the dependence of the \( q_o/q_{\text{mech.imp.}} \) ratio on the viscosity of oil in the apparatus is built (Figure 5).

The resulting relation in the viscosity range of 15–45 mPa \( \cdot \) s is described by empirical dependence (\( R^2 = 0.7 \)):

\[
q_o/q_{\text{mech.imp.}} = 0.2 \exp(0.04\mu_{av}).
\]  

(3)

Formula (3) allows calculating the amount of suspended particles in the discharged water for a given production region by the amount of oil carried over.

The results obtained show a close relationship between the amounts of oil and mechanical impurities carried over. This indicates that the oil phase, carried over by water, is mainly located on solid particles, enveloping them due to adhesion forces.

Thus, a solid particle covered with a layer of oil loses the possibility of sedimentation due to the fact that the oil part tends, on the contrary, to float. It is obvious that there is a certain thickness of oil film on a solid particle, at which the average density becomes equal to the density of water and the solid particle loses its ability to float or settle.

In practice, such water has a darkish tint, it is called "black water" and is a big problem in water treatment [10].

The research results show a significant deterioration in the quality of discharged water with an increase in the viscosity of the extracted oil. Together with this, an increase in viscosity, ceteris paribus, leads to a decrease in the degree of destruction of the emulsion at the inlet to the apparatus and to an increase in the amount of residual water in the oil discharged from the apparatus.

Therefore, when preparing oils of high viscosity, the use of demulsifiers alone is not effective enough to ensure the quality of the discharge [11–13]. At the same time, more effective measures are needed to prevent, first of all, intensive emulsification of watered oil in wells equipped with electric centrifugal pumps.

4. Conclusion

1. A statistical dependence is obtained for calculating the amount of oil carried over by the discharged water from the viscosity of the extracted oil and the daily loading of the apparatus by liquid.
2. A statistical relation between the content of oil and mechanical impurities in the discharged water and the dependence of this ratio from the viscosity of oil are established.

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