Modelling and assessing the effectiveness of developing the Shumovskoye field

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Abstract. With the depletion of light oil stock, the heavy high-viscosity oil stock is rising. In this regard, there appear the technologies allowing to provide industrial levels of high-viscosity oil extraction. Therefore, the research of effective methods of developing heavy high-viscosity oil pools is one of the important development directions in the oil industry. One of the most cost-effective technology is non-stationary waterflooding (NW). There are currently not so many examples of using the technology of non-stationary waterflooding at the HVO pools. This is due to the fact that waterflooding as a development method has low efficiency at the HVO pools. The obtained results, based on modelling, showed that the technology of non-stationary impact is quite effective.

1. Introduction
Non-stationary waterflooding is a common enhanced oil recovery technology, which allows increasing the impact coverage in developing heterogeneous-permeability reservoirs. Implementation of non-stationary waterflooding is quite simple and does not require any additional costs, and the impact of this technology is significant. Therefore, this technology is widely used in the development of oil fields. To date, we have accumulated large experience in the application of non-stationary waterflooding in different geological and technological conditions.

Under non-stationary impact (for example, cyclic water injection) there appear pressure gradients, triggering intense flows of reservoir fluids, between hydrodynamically coupled collector layers with different permeability. Thus, the NW technology allows involving oil stocks in the filtering process which are concentrated in the non-draining formation zones, thereby increasing the impact coverage ratio [1]. The NW efficiency is provided by two main processes – the accumulation of water in low-porosity and low-permeability reservoir layers and the further capillary hold-up effect.

2. Methods and materials
The results, obtained and discussed in the article, are justified through the application of hydrodynamic simulators, tested and recommended for using in the petroleum industry. When processing the field data, the well-known and proven methods of analysis through computers were widely used. The developed recommendations passed field-testing with positive technological effect.

The results presented in this paper were used in planning and implementing programs of non-stationary waterflooding at the Shumovskoye field.

3. Results and discussion

Let us consider the results of the implementation of non-stationary waterflooding at the Shumovskoye field [2].

There are several reasons among others for choosing this field for the application of non-stationary waterflooding. Firstly, an oil-saturated field reservoir has significant zonal and stratified heterogeneity of the permeability field. Secondly, oil pools were operated in the depletion mode for a long period of time which has led to significant changes of properties of reservoirs and reservoir fluids. This, in turn, contributed to the increase in heterogeneity of the reservoir systems. Thirdly, the currently used waterflooding system of the main object under the development, the Verey horizon, is built on the principle of four-point (seven-point converted) system for placing production and injection wells, each injection well is located in the centre of a regular hexagon formed by the production wells. In addition, each production well is located in the centre of the triangle formed by injection wells. Fourthly, stationary waterflooding of the reservoirs of Verey horizon and Bashkir tier led to a progressive flooding of the production wells. All of this makes the oil pools data an object for applying non-stationary waterflooding.

The Shumovskoe field is confined to the dome-shaped brachianticlinal fold of the North-Eastern stretch. Its size on the roof of Verey deposits is 11x6 km. The field includes industrial oil-bearing deposits of the Yasnaya Polyana superhorizon, Moscow and Samara tiers. In the Bashkir tier, there are also the layers of oil-saturated limestone. The field oil is thick and viscous.

In the frame of the Verey horizon, there are two productive oil-saturated formations – V3 and V4. In the frame of the Bashkir tiers, there are also allocated two oil-saturated formations – BSh1 and BSh2.

The distribution of formation and bottom hole pressures among existing production wells showed that the half of the wells of the Verey horizon work with the formation and bottom hole pressures at the level below the oil-gas saturation pressure. Despite the fact that the accumulated compensation of liquid extraction by water injection at both operating facilities has reached 77-78 %, the location of the majority of wells in areas with formation pressures below the oil-gas saturation pressure indicates poor performance of water injection, from the point of maintaining formation pressure in a highly heterogeneous reservoirs of Verey horizon and Bashkir tier.

In 39% of the Verey horizon injection wells and in 73% of the Bashkir tier injection wells, perforations opened only one of the two layers. Apparently, in the layers that were not opened by perforations in the injection wells but perforated in the development wells, there occurs a decrease in the formation pressure below the oil-gas saturation pressure which in turn lessens the performance of these layers to compare with the perforated ones and accelerates the process of water encroachment through the perforated layers. Perforation intervals need adjusting in the injection (primarily) and in development wells [3, 5].

In practice, cyclic waterflooding is implemented with symmetrical cycles of work/idle of the injection wells. To reduce the fluctuation of CPS the authors offered the original scheme that simultaneously implements NW at two development targets. The essence of the scheme was that cyclic water injection was carried out alternately at two targets in antiphase. Thus, when the injection wells of Verey horizon stopped, all the water was pumped into the injection wells of Bashkir tiers. Conversely, when the injection wells of Bashkir tiers stopped, the injection wells of Verey horizon started functioning, and all the water flowing through the CPS was pumped into the layers of Verey horizon. The duration of the cycles was justified according to the Well Testing data and amounted to 15 days.

Application of the NW technology was carried out during the period between March and November 2006 [1, 4, 8].

Evaluation of the operational benefit of using NW on the heavy oil pools was carried out on the basis of the characteristics of the displacement characteristic (DC), although the conditions of the method application are performed only for the Verey horizon (water content more than 65-70%). Evaluating DC for Bashkir tier showed a good linear relationship in coordinates f (Q_{oil} ($1/Q_{liquid}$))

(Kambarov method), therefore, the evaluation of the benefit was conducted on the basis of this displacement characteristic.

The estimation of the operational benefit of using non-stationary waterflooding at Shumovskoye field showed the high effectiveness of the technology (figure 1). For 9 months of using the NW, the operational benefit amounted to 10.7 thousand tons for the Verey horizon wells, to 10.4 thousand tons of additional oil produced for Bashkir tiers wells, the total benefit amounted to 21.1 thousand tons or 19.3% of the total oil production at the two development targets over the period of using the technology.

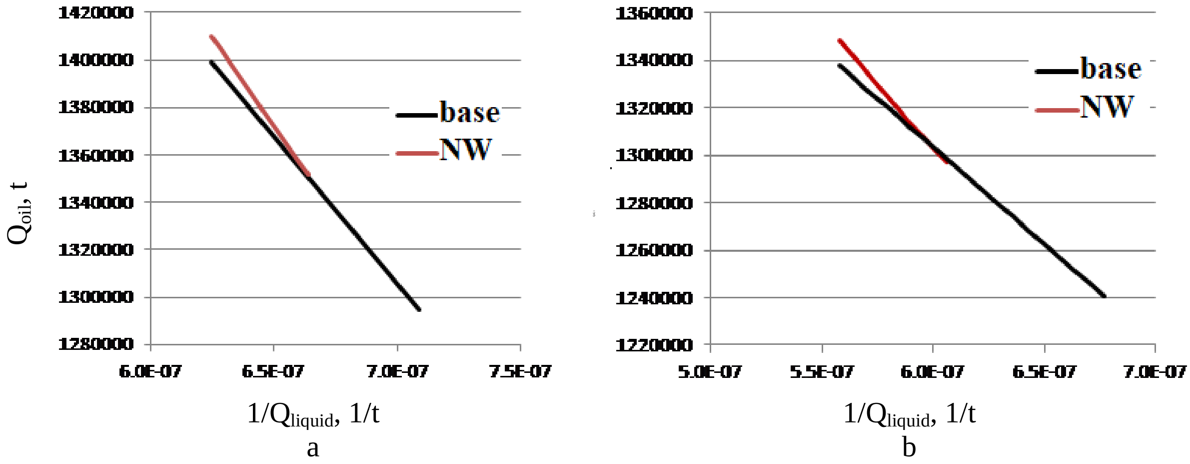

Figure 1. Displacement characteristics by Kambarov to evaluate the benefit of cyclic waterflooding in the conditions of the Verey horizon (a) and Bashkir tiers (b).

Application of the NW technology at the high-viscosity oil pools has shown its real effectiveness.

The established ideas about the development of HVO pools disturb the search for new approaches that can significantly increase the effectiveness of existing development systems. In this respect, we should note that according to the obtained results this technology is an effective method of enhanced oil recovery at the high-viscosity oil pools [7, 9, 10].

4. Conclusion

Currently, there are not so many examples of the NW application in the development of high-viscous oil pools. We reviewed the results of the NW application at the HVO pools of Shumovskoye field, Perm region. With oil viscosity of about 30 cPs and a mixed fissure pore reservoir, the benefit of cyclic waterflooding turned out to be positive, that gives us hope that NW will be effective in developing higher viscosity oil pools.

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