The Development Experience of Bobrikovian Horizon in Sabanchinsky Deposit Using Computer Simulation

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Abstract. In the fields of Tatarstan pilot projects for testing cyclic flooding are being conducted since 1972. Following the success of cyclic waterflooding in the early stages of the development, this technology was rarely changed, and for most wells the length of half-cycle remains unchanged for many years. Experimental data indicate that the cyclic exposure parameters are reduced in terms of completeness of injection with an increase in cycle duration. The effectiveness of the technology after 5-7 cycles is significantly reduced; there is need for periodic revision on the basis of correction time of injection well cycles, changing the direction of filtration flow and treatment of bottomhole zones in injection wells.

The article includes the following conclusions based on the implemented computer simulations: the effectiveness of cyclic waterflooding falls after 4-5 cycles; when changing unsteady injection parameters the positive results are obtained in the form of increase in oil production and reduction of water content; the use of flow deflection technologies in injection wells increases the technological effect from the event, simulation in conjunction with analytical methods allows us to choose the optimal adjustment of process parameters in unsteady exposure. The practical implementation of the cyclic flooding changes, utilized in the production and implemented at the operational facilities, provides a significant increase in the hydrocarbon production efficiency to ensure high economic effectiveness.

Keywords: computer modeling, water production, development, Bobrikovian horizon, additional oil production, efficiency.

DOI: 10.18599/grs.18.2.6

For citation: Khabibrakhmanov A.G. The Development Experience of Bobrikovian Horizon in Sabanchinsky Deposit Using Computer Simulation. *Georesursy = Georesources*. 2016. V. 18. No. 2. Pp. 107-110. DOI: 10.18599/grs.18.2.6

In 1963, the well number 27 drilled in the crest of the uplift on the Bobrikovian roof and discovered Sabanchinsky oil field. According to the results of geophysical investigations Sabanchinsky field did not represent commercial value, but the management of geological survey, contrary to the actual material, proved the necessity of drilling this field. Additional exploration of Sabanchinsky field was made by means of appraisal wells due to the failure of expensive exploration footage. Appraisal wells were drilled from the 'known to the unknown' that accelerated the study of Sabanchinsky field.

For additional study of the geological structure and field outlining in 1971 the drilling section of oil and gas production department "Bavlyneft" started drilling the field with appraisal wells, the results of research and testing of which led to a fundamental re-evaluation of oil reserves. In a relatively short period of time, recoverable reserves of 20 times greater than those that had previously been transferred to the balance sheet of the management. Drilling by the technological scheme was launched in 1973, and in the same year it was put in the commercial development.

The Bobrikovian deposit, as planned by technological scheme, was developed using perimeter, selective and linear water flooding. Water injection was initiated in 1974. In the reservoir 4.8-6.1 thousand m^3/day of water was pumped that was 96-115 % for the selection of the liquid. During the development of Bobrikovian deposit in Sabanchinsky field, the high efficiency of perimeter, selective and linear water flooding was noted. As a result of flooding, reservoir was developed rapidly, causing intense flooding of producing wells (Khisamov et al., 2016).

Currently in development there are all operating formations – Bobrikovian, Dankovian-Lebedyanskian and Pashiyskian. The maximum oil production 1586 thousand tons on the field was achieved in 1982, the rate of selection of the initial recoverable reserves was 3.7%. A total 35.3 million tons of oil and 171.9 million tons of liquid was produced in the field. The basic operational object is Bobrikovian in which 34.1 million tons of oil was produced, accounting for 96.6% of the total oil production of the deposit as a whole, 18 oil deposits are in operation.

As of 01.01.2016, the cumulative oil production in Bobrikovian formation – 85.9% of the initial recoverable reserves, accumulated liquid extraction – 168.9 million tons, the current oil recovery factor – 0.334 share of unit. Development dynamics of Bobrikovian is shown in Fig. 1.

Currently in Bobrikovian formation block waterflooding system is formed, supplemented by aquifer and focal injection wells. Since the beginning of the development, 166.7 million m^3 of water was pumped, accumulated compensation of fluid withdrawal by water injection amounted to 100.7%, the average acceleration – 128 m^3/day.

In 2015, 509.8 thousand tons of oil and 5163.8 thousand tons of liquid was produced, the water cut was 90.1%. 4833.6 thousand m^3 of water was injected, the current compensation of the withdrawal by selection – 100.3%. The average daily production rate of existing wells for oil – 4.9 tons/day, for liquid - 48.9 tons/day.

Since the time when Sabanchinsky field was entered in the last stage of development, characterized by high water cut and a drop in oil production, there is the need to additional recovery of a residual oil by increasing the sweep

displacement, as large oil reserves remain undeveloped due to the low coverage of layers with displacement due layered and zonal heterogeneity.

Under these conditions, the use of non-stationary flooding with changing directions of flow filtration became effective. Non-stationary method of flooding are the most common and proven and, most importantly, does not require significant capital expenditures to implement it in the fields. The mechanism of its action is based on the increase in coverage of productive strata not involved in the development. It gives rise to a pressure gradient between the high- and low-permeability interlayers, thereby introducing water into the zone with low reservoir properties and their involvement to the active development (Surguchev, 1965).

Experimental evidence suggests that the indicators of cyclical impact in terms of the completeness of injection with increasing cycle times are improved, and the effectiveness of the technology after 5-7 cycles is significantly reduced, and periodic modification is required (Vladimirov, 2004).

It has been suggested the possible need for the periodic adjustment of the length of the half-cycle and the injected volume to increase process efficiency.

In 2012, the oil-and-gas production department "Bavlyneft" initiated work to improve the development of Bobrikovian horizon of Sabanchinsky oil field on the basis of geological and hydrodynamic modeling. From January 2013 to May 2014 geological and hydrodynamic models of operational object were created. In the pilot area (area of wells No. 1558-2193-2105, Fig. 2) geological and technical measures (GTM) were modeled, the most effective ones were chosen. Then they were conducted in wells, and the actual result was estimated with the expected parameters for the model.

The priority direction was chosen to optimize fluid production volumes and pumping water from wells. The analysis of the geological and technical measures showed an acceptable convergence in the forecast and actual growth and hence viability of approach to optimize the development systems based on simulation.

Hydrodynamic simulation tools allow us to determine the best modes of production and injection wells. The solution is based on geological and hydrodynamic model, which takes into account peculiarities of the geological structure of site. The representation is given of the distribution of filtration flows.

Maintenance of constant levels of oil production was adopted as a basic option. To comply with this requirement in the first phase injection volumes of injection wells were selected in the stationary mode, ensuring minimal water cut increase at a fixed withdrawal of oil. In the future, to involve low-permeability interlayers we calculated the cyclic injection to comply with the conditions to minimize the excess water cut relative to the basic. Selection of cycles change frequency was initially performed using analytical methods. In implementing the approach, the selection of cycles change frequency was based on the elastic characteristics of the formation, taking into account the position of the injection front for each injection well defined on the basis of adapted geological and hydrodynamic model (Loscheva et al., 2015).

Calculation of cyclic injection on the hydrodynamic model with adjustments of analytical data allowed us to specify the cycle time (40 days) and to achieve the greatest reduction of water cut in wells for the same level of oil production.

Since 01.05.2014, the commercial implementation started by adjusting the injection volume in the pilot area, as well as changing the length of the half-cycle to 20 days (Fig. 3). With forecast additional oil production on pilot area of 2.1 tons, we actually obtained 3.1 tons. Average oil flow rate of one well

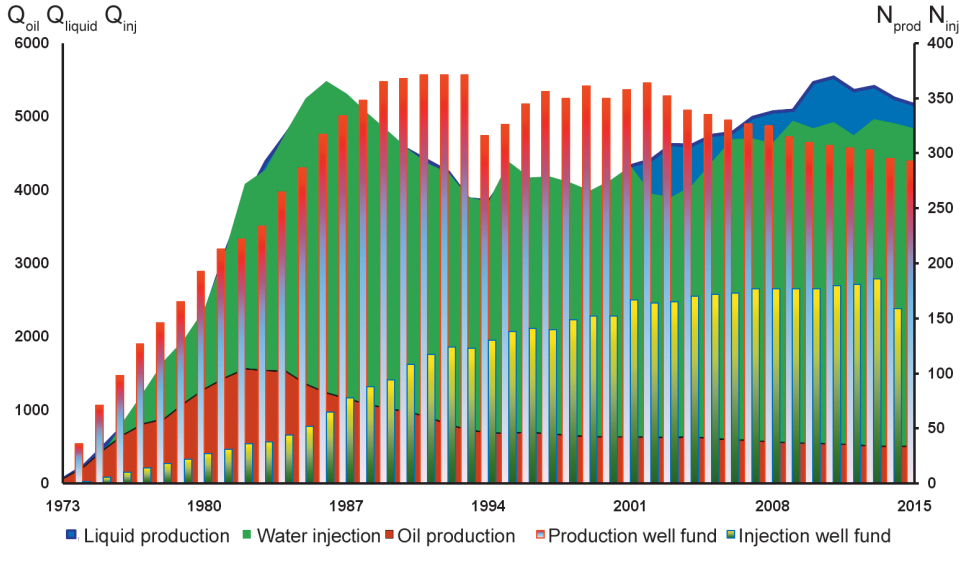

Fig. 1. Dynamics of the main development parameters of Bobrikovian operational object.

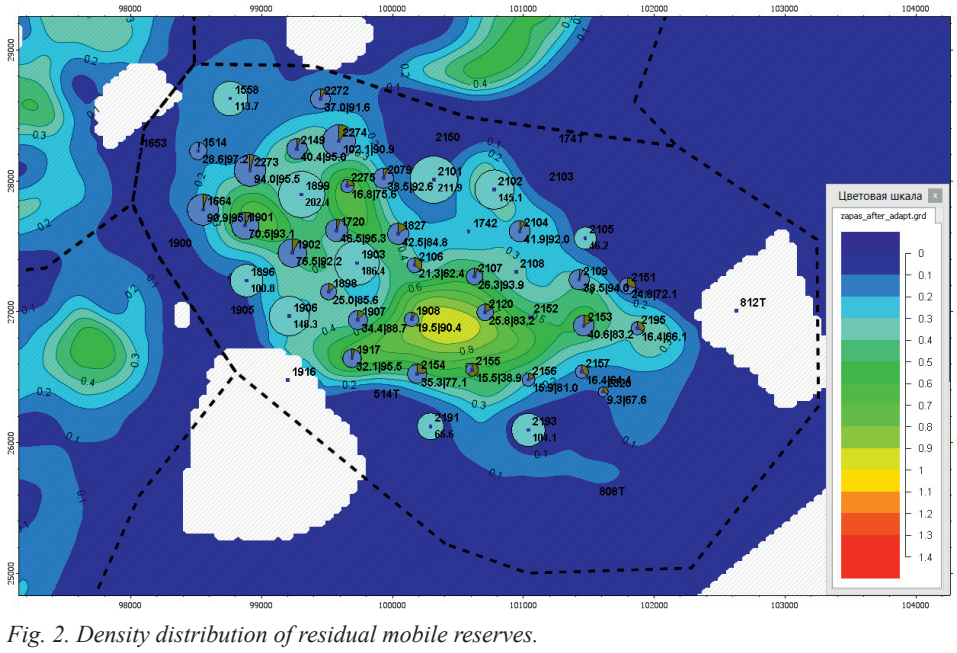

Fig. 2. Density distribution of residual mobile reserves.

in pilot area increased by 13% – from 4.64 to 5.25 tons/day, with virtually unchanged fluid production rate – from 40.64 to 40.98 tons /day. Water production of wells was decreased from 89 to 86%. Exploitation factor of producing wells in the whole area, and individual wells did not substantially changed. By the end of 2014, measures to optimize the reservoir pressure maintenance system have been carried out around the experimental plots. Additional reduction of water cut through a number of diverter technologies applied in injection wells in 2014 can be considered as the reason for the excess of calculated indicators.

The complex of activities implemented on an experimental plot included the following:

- Cycle time correction of injection wells;
- Changing the direction of filtration flows;
- Treatment of bottomhole zone of injection wells by diverter compositions.

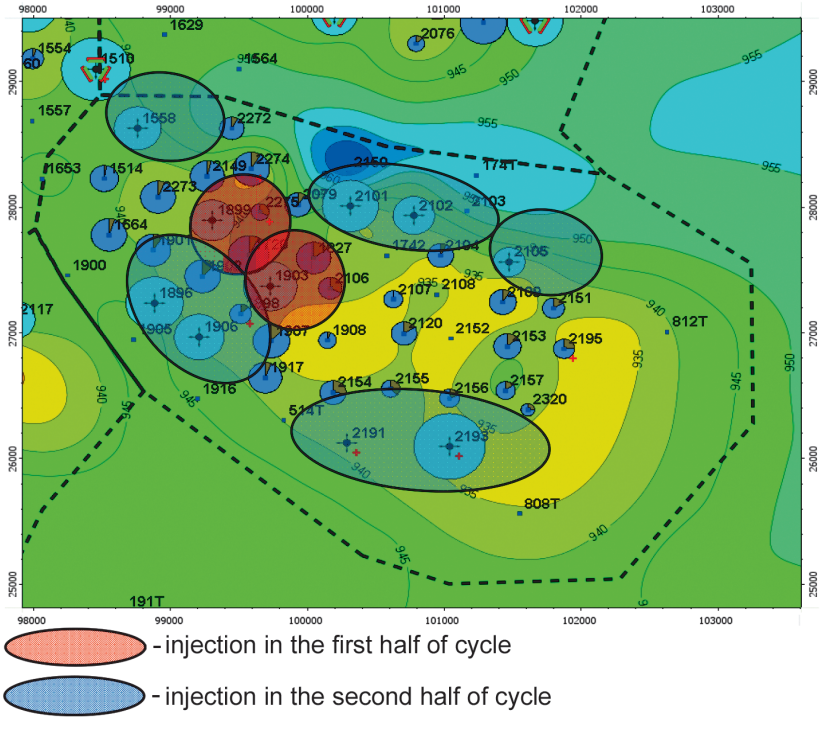

Fig. 3. Diagram of the cyclic flooding. 1 – injection wells in the first half of injection cycle, 2 – injection wells in the second half of injection cycle.

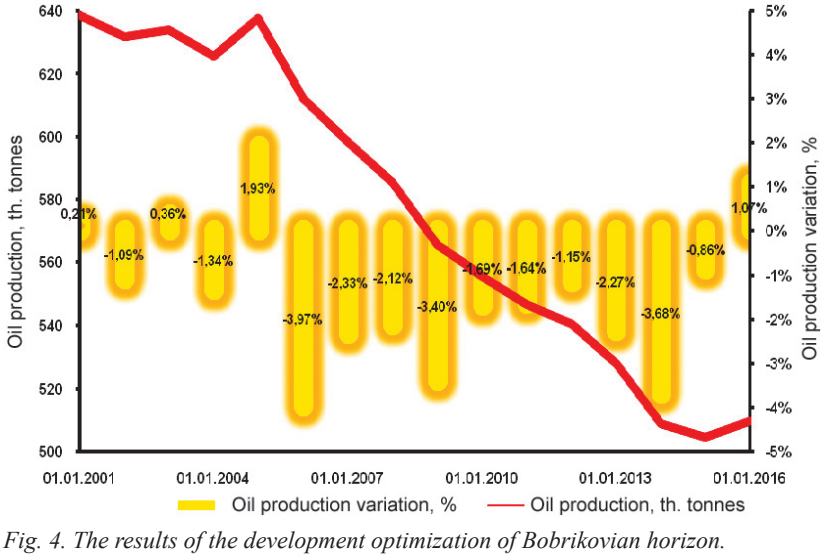

Fig. 4. The results of the development optimization of Bobrikovian horizon.

The results of the commercial implementation (Fig. 4.) were as follows:

- From May 2014 – the rate of decline in oil production reduced from 3.68 to 0.68%;
- In 2015 – the rate of oil production increased by 1.07% compared to 2014;
- Additional oil production in 2015 compared to 2014 amounted to 5.4 thousand tons.
- Additional oil production from baseline was 24 thousand tons.

In 2015, for the implementation of measures that have passed industrial approbation, another 5 plots were chosen:

- Site of wells area No. 2310-2292-127, extracted from initially recoverable reserves – 40.6%, water cut – 92.1%;
- Site of wells area No. 1721 -1572-2136, extracted from initially recoverable reserves – 64.5%, water cut – 91.7%;
- Site of wells area No. 1821-2041-98, extracted from initially recoverable reserves – 35.5%, water cut – 92.8%;
- Site of wells area No. 1564-1614-1617, extracted from initially recoverable reserves – 46.7%, water cut – 94.9%;
- Site of wells area No. 1558-2193-2105, extracted from initially recoverable reserves – 83.7%, water cut – 86.6%;

Additional oil production at five sites as of 01.01.2016 totaled 3.4 thousand tons at reducing water withdrawal in the amount of 248.5 thousand tons.

In sum, technological effect in two years of the project amounted to 35 thousand tons of additional oil when water withdrawal reduction amounted to 885.2 thousand tons.

Expenses of oil-and-gas production department “Bavlyneft” of PJSC Tatneft for the creation and maintenance of the existing model for Bobrikovian horizon of Sabanchinsky field in 2013-2015 amounted to 4.9 million rubles. Net present value of the additional oil production amounted to 155.9 million rubles, and by reducing the extraction of produced water of 9.7 million rubles.

On the basis of the obtained results the following decisions are taken:

1. To cover all the areas of Sabanchinsky oil field with with detailed consideration;
2. To develop and test on permanent model measures to improve development system for Bobrikovian horizon by each separate portion and in general for the field in order to ensure oil production according to strategic levels in 2016;
3. To choose optimal operation mode for each production and injection wells;
4. To stop applying models provided by the institution TatNIPIneft, for which reason to equip the workplace with necessary office equipment and start modeling GTM independently;
5. To start simulation work on GTM for Bavlinsky, Tat-Kandyzsky, and Matrossovsky fields of oil-and-gas production department “Bavlyneft” in addition to Sabanchinsky field.

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Manuscript received April 04, 2016