

Optimization of Multilateral Well Placement in a Thin Oil Rim Complicated by a Large Gas Cap

Gulmurodov J. N, Ravshanov Z. Y, Mamirov J. X

Tashkent State Technical University named after Islam Karimov

Abstract: The proportion of hard-to-recover hydrocarbon reserves is steadily increasing, making it critical to develop technologies that enhance hydrocarbon recovery rates. One effective method to increase oil recovery and extend the reach of reserves is drilling multilateral wells with a fishbone trajectory. In the Russian Federation, the most complex multilateral well was drilled at the Srednebotuobinskoye oil and gas condensate field in the Republic of Sakha (Yakutia). The main development target, the Botuobinsky horizon, contains about 75% of its reserves in a thin oil rim, with an average oil-saturated thickness of 10 meters and an extensive gas cap, making development challenging. One of the critical design stages for such wells is determining the optimal placement within the oil-saturated reservoir. This paper presents sector modeling results using the Tempest simulator to find the best location for multilateral wells at the Srednebotuobinskoye field.

Key words: Srednebotuobinskoye oil and gas condensate field, multilateral well, oil production, gas cap, gas factor, bottom water, thin oil rim, inclined oil-water contact.



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Introduction: Discovered in 1971 and commercially operational since 2013, the Srednebotuobinskoye oil and gas condensate field (SBNGKM) is a key development in the Republic of Sakha (Yakutia). The Botuobinsky horizon, which accounts for 77% of initial recoverable oil and 99% of production, is developed using horizontal wells with lengths of 1250 meters and spacings of 100 to 300 meters. The Botuobinsky horizon is composed of terrigenous sandstones formed during slow marine basin transgression. Considering its complex geological structure, the field's development increasingly relies on multilateral fishbone wells, which cover larger areas than single horizontal wells, thereby boosting productivity and reducing drilling costs. These wells are especially effective for thin oil rims under extensive gas caps, where other productivity-enhancing technologies, such as hydraulic fracturing, are impractical. This study focuses on optimizing the placement of these wells in the gas-oil-water zone of the reservoir, aiming to maximize cumulative oil production while avoiding gas and water breakthroughs.

Methods: The fishbone well used in the simulation has the following characteristics: a total horizontal length of 6052 meters, a main shaft length of 1406.6 meters, nine sidetracks (334–1006 meters long), and a reservoir depression of 5 atm. The oil-saturated thickness is 14.4 meters. The primary challenge is determining the optimal location in the gas-oil-water zone. Wells placed too close to the gas-oil contact (GOC) are prone to early gas breakthroughs, leading to well shutdowns and reduced production. Conversely, wells located too close to the oil-water contact (OWC) may experience water breakthroughs, resulting in rapid watering of the produced oil. Due to the high salinity of reservoir waters, water breakthrough is less of a concern than gas breakthrough in the SBNGKM field. Hydrodynamic modeling, using the Tempest MORE simulator, was employed to identify the optimal well placement. The sector model consisted of 112,746 cells, with dimensions of 1425×901×23 meters. The gas-oil contact was at an absolute depth of 1562 meters, and the water-oil contact at 1573 meters. The study simulated the performance of a multilateral fishbone well over 50 years, analyzing key indicators like cumulative production of oil, gas, and liquids, as well as flow rates and the gas factor.

Results and Discussion: The sector model simulations explored various well placements within the oil-saturated zone, ranging from 1 to 10 meters from the GOC. The study aimed to find the location that maximized cumulative oil production while minimizing the risks of gas and water breakthrough. The study's novelty lies in its application of hydrodynamic modeling to optimize the placement of a multilateral fishbone well with nine branches, totaling 5050 meters of horizontal wellbore, in a thin oil rim under challenging geological conditions at the SBNGKM field. This study highlights the importance of well placement optimization in complex reservoirs like those found at the Srednebotuobinskoye field, where multilateral wells can provide significant production advantages if positioned correctly.

Figure 2 illustrates the relative phase permeability of the fluids incorporated into the model. The key pressure-volume-temperature (PVT) properties of the fluid, as well as the reservoir's porosity and permeability, are as follows: oil density is 864.2 kg/m³, molecular weight is 1000 kg/m³, gas density is 0.822 kg/m³, and reservoir water density under reservoir conditions is 1236 kg/m³. Additionally, water compressibility is 0.255 atm⁻¹, reduced pressure is 140.1 atm, viscosity is 8.0 cPs, critical water saturation is 0.23,

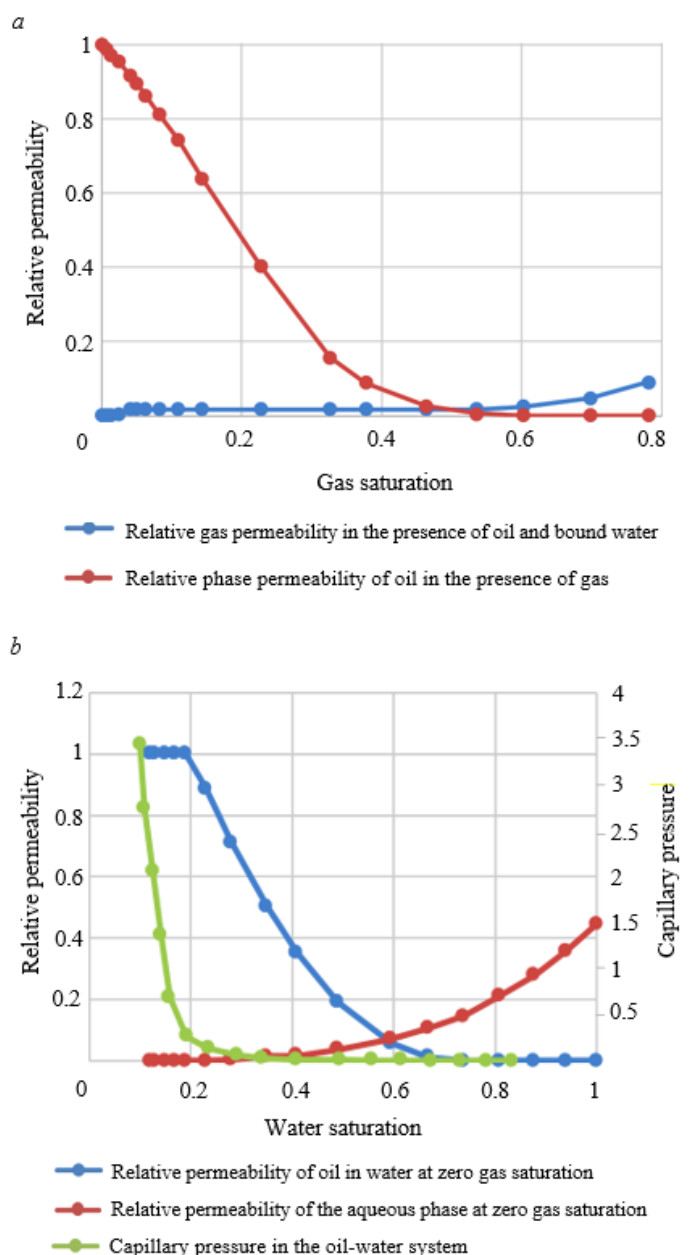


Fig.2. Relative gas-oil (a) and water-oil (b) phase permeabilities

critical gas saturation is 0.05, residual oil saturation in water is 0.31, residual oil saturation for gas is 0.43, residual water saturation is 0.08, permeability is 369.3 mD, and porosity is 0.16.

Discussion of the Results: The simulation produced several significant findings. Figure 3 presents the oil production dynamics for different well placement depths, ranging from 1563 m (closest to the gas-oil contact, GOC) to 1572 m (furthest from the GOC). By analyzing Figure 3, we can observe how the well flow rate changes over the 50-year development period. A maximum liquid flow rate of 60 m³/day was set as a limitation in the Tempest software for the simulation. Additionally, a gas-oil ratio (GOR) limit of 2400 m³/m³ was imposed for the field, indicating gas breakthrough (Figure 4). The stepwise decrease in flow rate, visible in Figure 4, reflects the limitation set to control gas inflow, as the GOR approaches its limit. The GOR data analysis reveals the timeline for gas breakthrough from the gas cap into the well, which effectively stops production for the SBNGKM conditions. Due to the constraints of the Tempest simulator, a reduction in flow rate occurs when the maximum GOR value is reached. For wells drilled at 1572 m from the GOC, gas breakthrough is expected by 2031, while wells at 1571 m and 1570 m will experience gas breakthrough by 2030 and 2029, respectively.

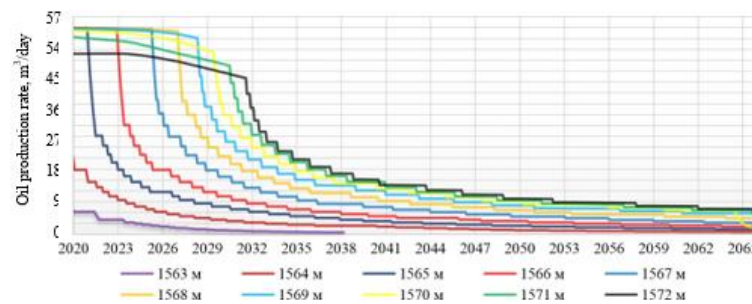


Fig.3. Dynamics of oil production at different depths of MGZS location

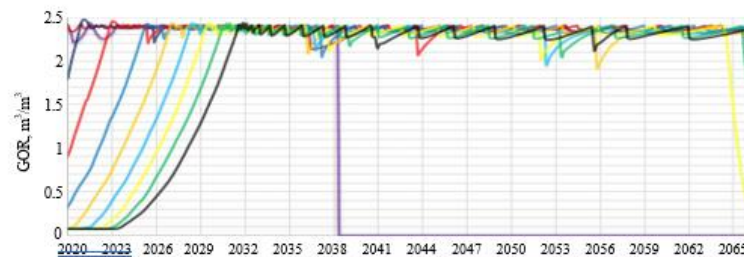


Fig.4. GOR dynamics at different depths of MGZS location
Symbols see in Fig.3

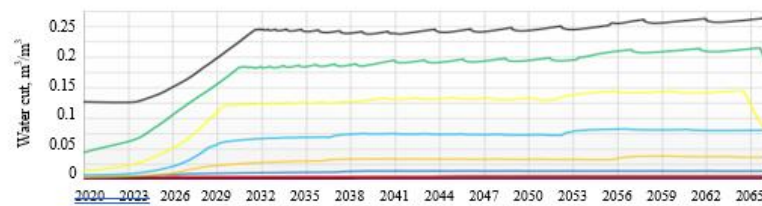


Fig.5. Dynamics of water cut at different depths of MGZS location
Symbols see in Fig.3

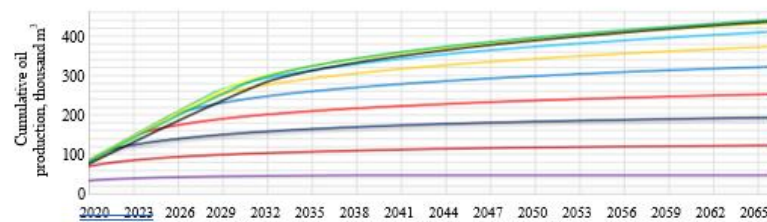


Fig.6. Dynamics of cumulative oil production at different depths of MGZS location
Symbols see in Fig.3

Figure 5 presents the water cut results at various well depths. For a well located 1 m above the oil-water contact (OWC), the water cut reaches $0.24 \text{ m}^3/\text{m}^3$ at the point of gas breakthrough. Wells drilled to depths of 1567 m exhibit a slight water cut increase to 0.01, while those at 1568, 1569, 1570, 1571, and 1572 m show water cuts of 0.02, 0.07, 0.13, 0.18, and $0.24 \text{ m}^3/\text{m}^3$, respectively, up until gas breakthrough.

Finally, Figure 6 illustrates the cumulative oil production for different fishbone well depths. Based on the results of calculating key technological indicators for various placements of the fishbone well within the oil-saturated layer, it can be concluded that positioning the multilateral well at a depth of 1571 m (9 m from the gas-oil contact, GOC) is optimal for cumulative oil production. After 50 years of operation, this location is projected to yield 440,000 m^3 of oil. However, cumulative oil production leading up to gas breakthrough—equivalent to shutting down the well—carries more significance. With this consideration, the well at 1571 m again shows the best performance. By 2031, the cumulative production from a well at 1572 m is expected to be 274,000 m^3 , while by 2030, the well at 1571 m will reach 280,000 m^3 , and by 2029, the well at 1570 m will yield 267,000 m^3 . The optimal placement of wells in the gas-oil-water zones at the SBNGKM, based on the model, corresponds to a position 2-3 m from the oil-water contact (OWC). However, due to variations in the oil-saturated layer's thickness and the size of the gas cap across the field, individual well placements must be tailored to specific sections of the reservoir, depending on local constraints.

An important factor when drilling at the SBNGKM is the presence of an inclined oil-water contact. Based on well data, it is possible to map this sloped contact, which also shows an oil layer with increased viscosity in the transition zone. This non-horizontal OWC is likely due to relatively recent tectonic movements, the effects of which have not yet been fully balanced by gravitational forces because of the high viscosity of the oil in the lower part of the deposit and low water-phase permeability. It is an established fact that inclined oil-water contacts are often present in ancient deposits, and attempts to explain this phenomenon remain debated. At SBNGKM, between the depths of 1564 m and 1580 m, the OWC is slightly inclined southeastward. According to well logs, core studies, and reservoir sample analysis, an oil layer with higher viscosity exists in this zone. This is confirmed by field and laboratory studies, which show an increase in oil viscosity from 6.5-9 cP in the upper sections to 24-28 cP near the water contact, with the high-viscosity zone being 1-1.5 m thick.

Thus, wells can potentially be drilled closer to the OWC, as this high-viscosity oil zone can act as a barrier against water breakthrough, allowing drilling to occur even within 2 m of the OWC and maximizing oil production.

Overall:

1. Hydrodynamic modeling using the sector model of SBNGKM determined that the optimal location for the fishbone well is at a depth of 1571 m, which is 9 m from the GOC and 2 m from the OWC. This placement offers the highest cumulative oil production both before gas breakthrough (observed after 10 years) and over the estimated 50-year period.
2. An individualized approach to well drilling is necessary, considering variations in the oil-saturated layer's thickness, the gas cap, and high-viscosity oil zones. Given these factors, well drilling can be justified at minimal distances from the OWC to optimize oil recovery.

Conclusion: This study used hydrodynamic modeling to determine the optimal location for a multilateral fishbone well with nine branches, totaling 5050 m of horizontal wellbore, in an 11 m thick oil rim under challenging geological conditions at the SBNGKM. Further investigation is required to better understand the zones of high-viscosity oils, and refinements should be made to the filtration model. Additionally, justifying the drilling of wells closer to the OWC in certain areas will improve the oil recovery factor in this field.

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