Study on adjustment technology of infilled horizontal wells in low abundance Putaohua reservoir of Daqing Changyuan peripheral oilfield

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Abstract. With the deepening of infilling adjustment in Daqing Changyuan peripheral oilfields, some low permeability and low abundance Putaohua reservoir blocks have low oil production and poor economic benefits. Therefore, exploring the adjustment technology of infilled horizontal wells has certain guiding significance for the joint development of vertical wells and horizontal wells in unused blocks.

1. Introduction
Putaohua reservoir with low permeability and low abundance has thin single well thickness, low production of infilled vertical wells and poor economic benefit. Compared with vertical well development, infilled horizontal well development has the advantages of increasing well pattern control reserves, reducing seepage resistance, enlarging sweep volume and oil displacement efficiency, and has a significant effect on improving reserves production, oil well production, oil recovery rate and recovery factor.

2. Fine description method of target reservoir in infilled horizontal well
Based on the fine processing and interpretation of seismic data in encrypted blocks, the micro-amplitude structure and sand body distribution pattern of target formation are delineated by using well-seismic combined prediction method, thus forming a fine description method of top surface control of reservoir group and micro-amplitude structure of target formation.

Compared with the results of micro-amplitude structure before and after seismic constraints, the error after seismic constraints is significantly lower than that before seismic constraints, and the error is significantly reduced, which can greatly improve the design accuracy of infilled horizontal wells. This method is applied to infill horizontal wells in peripheral oilfields of Daqing placanticline to improve sandstone drilling rate.

3. "Two-Step" Three-Dimensional Geological Modeling and Numerical Simulation Method

3.1. "two-step" three-dimensional geological modeling method for whole and target layer models
According to the need of horizontal well design, two geological models of reservoir whole model and target layer model are established. According to the top structure of reservoir, the whole model is established, including structural model, sedimentary facies model and reservoir attribute model (Fig. 1).
According to the results of well and earthquake combined with the micro-amplitude structure on the top of sand body, the construction model of target layer model is established, the vertical mesh of target layer model is subdivided, and the sedimentary facies model and attribute model of target layer model are established. Compared with the overall model, the target layer model can fully reflect the development of the reservoir in the main reservoir, and the vertical model can better characterize the changes of physical properties and oil-bearing properties in the reservoir, thus providing a quantitative geological basis for the trajectory design of horizontal wells.

![Fig. 1](image)

**Fig. 1 Result Diagram of Three-dimensional Geological Modeling Integral Model and Target Layer Model**

3.2. *Two-step numerical simulation method for whole and target layers*

The first step is to fit and split the whole model, input the dynamic data of actual production wells, fit the whole numerical model historically, output the dynamic data of single well and single layer, and get the distribution results of single layer remaining oil of the whole model.

The second step is to fit the target layer model precisely. Using the numerical simulation software to split the output of single well and single layer, then the whole model single layer splitting results, combined with test data, input the target layer model, and fit the history of the target layer model. According to the result of remaining oil distribution in target formation model, the design parameters of infilled horizontal wells are optimized, which can delineate the production status of target formation and guide the design of infilled horizontal wells, and has good applicability.

4. **Optimum design method of infill horizontal well pattern**

According to the well pattern form of the unencrypted block in the peripheral oilfield of Daqing Changyuan, the original well pattern takes a low permeability block in the form of reverse nine-point well pattern as an example. Using the actual geological parameters of the block, two infilling modes of infilling vertical wells and infilling horizontal wells are designed respectively. The development effects of different infilling wells are compared by numerical simulation method, and the infilling effect of horizontal wells between wells is determined by combining the economic benefit evaluation method. OK.

Through comprehensive comparison and analysis of the encryption effect of various schemes, it is considered that the effect of infilled horizontal well is better than that of infilled vertical well. At the end of 10 years, cumulative oil production of infilled horizontal well block is high, daily oil production of infilled horizontal well is high at the beginning, recovery of infilled horizontal well is high, and internal yield of infilled horizontal well is high.

5. **Optimum design method of infill horizontal well parameters**

5.1. **Optimum Design of Horizontal Section Length of Encrypted Horizontal Well**

With the increase of recovery degree, the economic benefit of infilled horizontal wells becomes worse. With the increase of horizontal section length, the economic benefit increases slowly. When the length of horizontal section is 400-700 m, the economic benefit is the best. In order to determine the length of horizontal section of infilled horizontal well, it is necessary to determine the size of sand body and the pattern of well pattern in combination with the actual field situation.
5.2. **Optimization of Track Extension Direction of Horizontal Wells**

Low and ultra-low permeability reservoirs have poor physical properties and low natural productivity. Fracturing transformation is needed to obtain economic benefits. Fracture strikes generally follow the direction of maximum principal stress. In this way, the action force on the fracture surface is the minimum horizontal principal stress. When designing the extension direction of horizontal wells, it is consistent with the minimum horizontal principal stress as far as possible. During fracturing, multiple transverse fractures perpendicular to horizontal wellbore can be formed at different positions of horizontal wellbore (Fig. 2). Communication between artificial fracture and natural fracture can increase sweep volume and productivity of oil wells.

![Fig. 2](image)

*Fig. 2 Design sketch of angle between wellbore and fracture in different horizontal wells*

The angle between wellbore and fracture is designed by numerical simulation research method. The angle is 15 degrees, 30 degrees, 45 degrees, 60 degrees, 75 degrees and 90 degrees respectively. It can be seen from the graph that the angle of fracture has a great influence on the production of fractured horizontal wells. The production increases with the increase of the angle of fracture. When the angle of fracture is 90 degrees, the production reaches the maximum value (fig.3), so the horizontal wells are fractured. In order to obtain the maximum fracturing effect, vertical horizontal wellbore in fracture extension direction should be used as far as possible.

![Fig. 3](image)

*Fig. 3 Variation of single well production in horizontal wells with different fracture angles*

5.3. **Vertical position optimization of infilled horizontal wells**

The numerical simulation results show that the cumulative oil production of infilled horizontal wells is the highest and the water cut is relatively low at 1/3 of the drilling distance of horizontal wells. The specific determination of different parts combined with actual flooding conditions and lithology can effectively reduce the initial water cut of horizontal wells, improve the oil production of single wells and obtain better economic benefits.
6. Application examples and effects

Taking Aonan oilfield as an example, the detailed description of target reservoir in infilled horizontal wells and two-step modeling method are applied to study. It is concluded that the water drive between wells and near faults in some areas of Aonan oilfield is low, the remaining oil is enriched, and it has infilling adjustment potential. Interwell infill horizontal well adjustment was carried out in N210-S272 well area of Mao 733 block in 2014.

The oil-bearing area of N210-S272 well area is 1.26 km², and the geological reserves are 29.98*10⁴t. The average porosity is 15.8%, and the average air permeability is 1.01 *10⁻³ um². The drilling rate of sandstone in Putaohua formation is 95.8% and the effective drilling rate is 79.2%. Among them, the effective thickness of P₁-P₃ layers is above 90%, the average effective thickness of single well is 3.6m, and the average effective thickness of P13 layers is 1.5m.

The infill horizontal well adjustment technology is applied to design and infill three horizontal wells. The length of horizontal section is 600 m and the target layer is P₃. After infilling, the injection-production well spacing is reduced from 300 m to 150 m. The horizontal section orientation is vertical to the original well row direction. The perforation 10 segments are designed by using the perforation fracturing technology. According to the relationship between injection and production wells, the injection-production wells are not perforated within 100 m. Hole.

The actual length of horizontal section is 656 m and the drilling rate of oil-bearing sandstone is 83.5%. Homogeneous fracturing is put into operation. In September 2014, infill wells were put into operation, with an average daily oil production of 6.9 t per well in the initial stage, which is 6.9 times higher than that of surrounding vertical infill wells. By the end of December 2018, the average daily oil production of single well was 2.0t, the cumulative oil production of three infilled wells was 12973t, and the average cumulative oil production of single well was 4324t.

7. Conclusion

(1) Fine description of target reservoir in infilled horizontal wells, two-step modeling and numerical simulation method lay the foundation for quantifying the distribution of residual oil in target formation and designing the trajectory of horizontal wells.

(2) Infiltration horizontal well pattern and optimization technology of technological parameters effectively guide the determination of different original pattern and non-location infilling mode, improve the reliability of infilling horizontal well design, and provide technical support for infilling horizontal well design.

(3) The method of determining the boundary of infilled horizontal wells realizes the comprehensive design of geology, development degree and investment environment of infilled horizontal wells. It can directly judge whether the wellbore area is suitable for infilled horizontal wells and provide basis for the design of infilled horizontal wells.

(4) The infill horizontal well is applied to infill adjustment in the periphery of Changyuan oilfield. The initial daily output of infill horizontal well is 4.2 times that of infill vertical well, and good results have been achieved.

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