Understanding of the Tracking and Adjusting Effect of Deep Profile Control and Flooding Expansion Application Blocks in Pubei Oilfield

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Abstract: In order to explore the development technology of enhancing oil recovery during the ultra-high water cut period in the Pubei Oilfield, deep profile control pilot tests and expanded application tests have been carried out in the Pubei Oilfield. This article mainly starts from the actual production performance of the deep profile control and flooding expansion application test, analyzes the main tracking and adjustment methods and the understanding of the results obtained in the development process of deep profile control and flooding, laying the foundation for the establishment of deep profile control and flooding matching tracking and adjustment technology in Pubei Oilfield.

Keywords: Deep profile control and flooding; Track and adjust; Effect recognition.

1. Introduction
The on-site testing of oil and water wells in the expanded application block of deep profile control and flooding in Pubei Oilfield was successively put into operation and injected in January 2018, and is currently in the late stage of main slug injection. In order to fully leverage the effectiveness of deep profile control and flooding oil production development, and explore the matching methods for tracking and adjusting deep profile control and flooding in Pubei Oilfield, a full process tracking and adjustment method has been developed during the implementation of deep profile control and flooding plans to ensure the effectiveness of profile control and flooding development; Classify and optimize injection plans to maintain a stable increase in injection pressure; Develop parameter adjustment technical boundaries to ensure smooth injection; Classify and optimize measures to reduce pressure and increase injection capacity; Timely adjustment work in oil well fracturing transformation, improving the development effect of profile control and flooding, etc. By summarizing the results and understanding, a set of deep profile control and flooding matching adjustment technologies suitable for the northern region of Portugal is formed to guide the production of the block and provide technical support for the stable production of the oilfield.

2. Overview of Block
The experimental area for expanding the application of deep profile control and flooding is located in the middle of the third fault block in the Pubei Oilfield. The development layer is the PuI Formation oil layer, divided into 11 small layers and 26 sedimentary units. The experimental area has an oil bearing area of 1.45 km² and a geological reserve of 132.77 × 10⁴ t, average air permeability 298 × 10⁻³ μm², pore volume 271.48 × 10⁴ m³, with a total of 43 wells, including 15 injection wells and 28 production wells. The average single well sandstone thickness is 12.9m, and the effective thickness is 7.9m. The scheme selects composite ion polymer gel system for injection, and the designed injection pore volume is 0.30PV. The test entered the blank water drive stage in January 2018. In September 2018, the pre slug injection of deep profile control and drive system was implemented. In January 2019, the main slug injection of deep profile control and drive system was started. By June 2023, 69.33 profile control and drive agent had been accumulatively injected × 10⁴ m³, injected into underground pore volume of 0.255PV, with a cumulative oil increase of 5.67 in stages × 10⁴ t, increased oil recovery by 4.28 percentage points.

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3. Main methods for tracking and adjusting

3.1 Strengthen dynamic tracking and adjustment to improve the effect of displacement control

3.1.1 Develop a full process tracking and adjustment method to ensure the effectiveness of profile control and flooding development

Drawing on the experience gained from the Pu125 pilot test of deep profile control and flooding in Pubei Oilfield, this study explores the tracking and adjustment methods for the entire process of deep profile control and flooding. Based on different water bearing stages of profile control and flooding, adjustment goals and methods are formulated and optimized to ensure the development effect of deep profile control and flooding. Regarding the ineffective period: due to the rapid increase in injection pressure, the oil well is not significantly affected. Therefore, high concentration and low speed injection should be maintained appropriately to achieve the goal of increasing injection pressure and expanding the affected volume; For the period of water cut decrease: the injection pressure steadily increases, and the oil well begins to take effect. Timely adjustment of well group parameters, timely stimulation of oil well fracturing, and well measures to reduce pressure and increase injection are carried out to achieve the goal of balanced effect and water cut reduction; For the low water content period: individual wells have increased injection pressure and maintained low water content, optimizing injection and production parameters, increasing oil well fracturing efficiency, and reducing water well pressure measures to achieve the goal of maintaining injection and production balance and extending the low water content period; In response to the recovery period of water content: the overall injection pressure is high, and the water content slowly rises. Adhere to the combination of improvement and control, plane adjustment, and well group potential tapping and governance to achieve the goal of maintaining effective injection and controlling the recovery of water content; For subsequent water flooding: the injection pressure is basically stable, and the water content gradually rises. Stratified water injection is carried out in an orderly manner, and the injection production structure adjustment is optimized to achieve the goal of controlling interlayer and plane contradictions.

3.1.2 Classify and optimize injection plans to maintain a stable increase in injection pressure

Personalize injection plans based on reservoir development characteristics and production dynamics, guide optimization and adjustment of injection parameters, and ensure effective injection of the system. In the early and middle stages of injection, injection wells are divided into two categories: Class I wells with large reservoir development thickness, relatively high permeability and connectivity ratio, and large injection pressure rise space adopt the adjustment method of "maintaining concentration and stable injection"; Wells with relatively small reservoir development thickness, low permeability and connectivity ratio, and high injection pressure in Class II wells adopt the adjustment method of "low concentration and low speed injection".

3.1.3 Develop parameter adjustment technical boundaries to ensure smooth injection

Based on the experience of mathematical model prediction and parameter adjustment for different water bearing stages, the control principles and boundaries of injection rate, concentration, and flow pressure parameters are formulated to guide the optimization and adjustment of injection production parameters, ensuring smooth injection.

During the non effective period and water cut decreasing period, the adjustment principle of "low speed and high concentration injection, high water cut and high flow pressure, and low water cut and low flow pressure" is adopted to promote balanced efficiency of the reservoir and maintain a stable increase in pressure.

During the low water content period, the adjustment principle of "maintaining concentration and velocity injection, and producing at low flow pressure" is adopted to ensure balanced injection and production, and improve the effect of profile control and flooding.

3.2 Carry out measures to finely tap potential and expand the development effect of profile control and flooding

3.2.1 Classification optimization of depressurization and injection increase measures to improve injection capacity

In the process of deep profile control and flooding, wells with large fluctuations in injection volume should be washed with high displacement to timely remove blockages in the wellbore and near wellbore areas, and maintain stable injection; For wells with poor reservoir development, poor depressurization effect of conventional measures, allowable injection pressure difference less than 0.5MPa, high initial injection pressure, and poor later well flushing effect, large-scale fracturing methods such as deep penetration fracturing and multi fracture fracturing are adopted to improve reservoir conditions and improve injection capacity. A total of 163 well renovations were implemented, including 153 well washes and 10 well fracturing.
3.2.2 Timely oil well fracturing transformation to improve the development effect of profile control and flooding

In the process of deep profile control and flooding, it is recommended to select effective wells or trend wells with a water content reduction of more than 3%, a liquid production reduction of more than 20%, a profile control and flooding thickness of more than 4.0m, and an effective thickness greater than 1.0m in the main reservoir. Timely oil well fracturing and efficiency enhancement are carried out to further improve the effectiveness of deep profile control and flooding.

A total of 13 oil well fracturing operations were carried out, with an average daily increase of 37.7 tons of fluid and 5.2 tons of oil per day in the initial stage. The water content decreased by 3.1 percentage points. As of now, the average single well measure has increased oil by 1939 tons, with an effective period of 532 days. Based on the actual results of fracturing and summarizing experience and understanding, the requirements for deep profile control and flooding oil well fracturing technology have been formed.

4. Achieve stage test results and understanding

4.1 Maintain good injection and production capacity

In the initial stage of injection, adhere to low-speed injection, and maintain the apparent suction index at around $0.44 \text{m}^3/(d \cdot m \cdot \text{MPa})$, a decrease of 21.4% in injection capacity compared to before profile control. In the middle and later stages of injection, through optimization of injection parameters adjustment and fracturing modification, the injection capacity remains basically stable, with a slight decrease.

Since the deep profile control and flooding experiment, the daily liquid production has been relatively low in the initial stage. In the middle and later stages, supporting treatment measures such as optimizing parameter adjustments and fracturing measures have gradually improved the liquid production capacity of the experimental area. Currently, the daily liquid production capacity is maintained at around 750t, the liquid production index is maintained at around $0.80 \text{t}/(d \cdot m \cdot \text{MPa})$, and the liquid production capacity is basically stable.

4.2 Improvement of oil reservoir utilization degree

The utilization of oil layers has been significantly improved after deep profile control and flooding. According to the analysis of continuous injection profile data from 15 injection wells, the effective utilization ratio of the oil layer in the initial injection stage has increased to 72.8%, which is 9.7 percentage points higher than before deep profile control and flooding. Currently, the effective utilization ratio of the oil layer is stable at around 80.2%, and reservoirs with different permeability levels have been utilized. Among them, $150 \times 10^{-3} \mu \text{m}^2$ The utilization degree of medium and high permeability reservoirs above is significantly higher than $150 \times 10^{-3} \mu \text{m}^2$ Low permeability reservoirs below, and high permeability reservoirs have reduced relative liquid absorption, transferring to medium and low permeability reservoirs, and the proportion of utilization in medium and low permeability reservoirs has increased significantly.

4.3 Significant effect of increasing oil and reducing precipitation

After the measures were taken, the daily oil production of the entire region increased by 24.0 tons, and the water content decreased by 1.9 percentage points, with a cumulative increase of 5.67% during the stage $\times 104t$, increased oil recovery by 4.28 percentage points, and had a significant effect on increasing oil and precipitation. The proportion of effective wells is high, with a total of 27 produced wells in the entire area showing significant results, with an effective rate of 96.4%. Compared with before the effectiveness, the average daily oil production of a single well in the entire area increased by 0.5t, and the water content decreased by 2.0 percentage points.

4.4 Phase effect better than expected in the plan

Currently, the cumulative oil increase in the experimental area is $5.67 \times 104t$, with a stage increase of 4.28 percentage points in oil recovery rate. Overall, the stage effect is better than the plan’s expectation, with a recovery degree of 0.05 percentage points higher than the plan’s expectation, and an additional 0.07 percentage points of oil increase $\times 104t$, with a water content lower than the expected 0.57 percentage points in the plan.

5. Conclusion

(1) Dynamic tracking adjustment is an effective way to improve the effectiveness of deep profile control and flooding. Timely carry out the development of full process tracking and adjustment methods, classify and optimize injection plans, develop parameter adjustment technical boundaries, establish dynamic tracking and adjustment charts, and other adjustment work, in order to seize favorable opportunities and maximize the role of deep water flooding.

(2) Measures to tap potential are a powerful guarantee for expanding the effectiveness of profile control and flooding development. In the process of deep profile control and flooding, high displacement flushing and fracturing of injection wells are effective means to improve injection capacity; Timely implementation of fracturing transformation on the produced wells can significantly improve the effectiveness of deep profile control and flooding.

(3) Deep profile control and flooding is an effective means to tap the potential of remaining oil during the ultra-high water cut development period. Since the deep profile control and flooding, the injection and production capacity of the experimental area has remained good, the
degree of oil reservoir utilization has increased, and the effect of increasing oil and precipitation is obvious. The stage increase in oil recovery rate is 4.28 percentage points, and the stage effect is better than the expected plan.

References


