Evaluation of Development Effect of Weak Base ASP Flooding In Secondary Oil Reservoirs

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Abstract: A set of EOR technologies have been formed in a development area after the exploitation of ASP pilot zone and industrial demonstration zone. Since 2015, the industrialization promotion of weak base ASP flooding has been realized. At present, 4 blocks have been invested and all of them have achieved good development effect. In order to better understand the rule of ASP flooding, further broaden the EOR potential and guide oilfield development more efficiently, this paper will evaluate the ASP flooding development effect and summarize the dynamic change law based on an existing block. The results show that after entering in low water period, the injection pressure rises above 25%, the inhaled index falls to 45% above, the liquid producing index falls 36.3% on average, comprehensive water cut largest decline reaches 12.36%, oil increase letter number reaches one time above. At the end, the paper gives the classification response characteristics of well group, and provides a basis for other weak base ASP flooding blocks.

1. Basic introduction
Taking two ternary blocks A and B as the example, this paper carries out the evaluation of development effects. The off-take target of these two blocks is Sa II10-16 ~ III10. Block A with 278 oil-water wells, adopts 150m×150m five-spot areal well pattern for exploitation. The average effective thickness of single-well perforated well in Block A is 10.7m and its permeability is 0.392μm². Block A was injected by polymer front plug in January 2015, injected by ternary main slug in June 2015, and injected by ternary auxiliary slug in November 2017. Until March 2019, the injection pressure of Block A is 11.7MPa, the injection rate is 0.13PV/a, the injection pore volume is 0.654PV, the comprehensive water cut is 86.03%, and the oil recovery is increased by 13.6%, which is 1.18% higher than that of the digital model. With 226 oil-water wells, Block B employs 150m×150m five-spot areal well pattern for exploitation. The average effective thickness of single-well perforated well in Block B is 14.1m, whose permeability is 0.403μm². Block B was injected by polymer front plug in December 2015, injected by ternary main slug in June 2016, and injected by ternary auxiliary slug in March 2018. Until March 2019, the injection pressure of Block B is 11.0MPa, the injection speed is 0.21PV/a, the injection pore volume is 0.721PV and the comprehensive water cut is 88.61%. In addition, the oil recovery in Block B is increased by 14.00%, which is 1.20% higher than that of the digital model.

2. Geologic characteristic

2.1 Depositional environment of oil layer
Block A and B have developed 18 sedimentary units, mainly including delta plain distributary subfacies and delta front subfacies. The drilling rate of microphase in each sedimentary unit is different, which reflects the characteristics of fast plane phase transition in the second type oil reservoir.

2.2 Developmental situation of oil layer
From the aspect of the developmental situation of oil layer, the average mono-layer effective thickness in Block A and B are 1.1m and 1.0m respectively, which is lower than the pilot site with the thickness of 1.1m. From the situation of sand drilling in the river, the sand drilling rates of Block A and B are 25% and 29% respectively, which is obviously lower than that of the experimental area by more than 10%. From control degree, the chemical flooding control degrees of Block A and B are 62.2% and 70.6% respectively, which is lower than the average level of experimental area. In conclusion, compared with the experimental area, the thickness of oil layer in industrial zone becomes thinner, the permeability becomes worse, the heterogeneity is strengthened, and the continuity of sand body becomes poorer. Therefore, the developmental situation of industrial area is obviously worse than that of experimental area [1].

2.3 Watered-out state of oil layer
Based on the statistical results of water flooding interpretation data in new wells, the high watered-out thickness percentages of Block A and B are 38.7% and 27.3% respectively. The low and end watered-out thickness percentages are 22.4% and 20.4% respectively, which has certain residual oil potential. Different sandstone has different watered-out situation. The river sand and the inter-river sand are mainly flooded by medium water, but the high watered-out ratio of river sand is higher than that of inter-river sand.

2.4 Anisotropy of oil layer
There are some differences in the degree of heterogeneity between plane and longitudinal direction since there are many sedimentary units developed in industrial extension blocks and the sedimentary types of each unit in the second type of reservoir are different. From the aspect of plane variable coefficient, the average variable coefficient each unit in Block A and B are 0.78 and 0.75 respectively, which shows that the plane heterogeneity is strong. From the perforated situation of oil layer, the effective thickness of each small layer in Block A and B is generally thin and the permeability varies continuously. Therefore, the longitudinal heterogeneity is strong.

2.5 Quantifying classification criteria
The difference between wells and layers is large due to the strong heterogeneity of second type oil layers. Therefore, according to geological characteristics, the key indexes are selected and the classification standard of single well is established to improve the effectiveness of injection well scheme and measure adjustment, and to enhance the accuracy of the analysis of production well effectiveness characteristics. The injection wells and production wells are divided into four types. The first type of well has multiple river channels with many replace layers and good connection; the second type of well is dominated by the development of river channel, and its connection of river channel becomes worse; the third type of well only has single river channel with less replace layers and poor connection; the fourth type of well has poor development of oil layer. The detailed standards are shown in Table 1.
Table 1. Single well classification criteria

| Well group classification | Effective thickness (m) | Channel sand thickness ratio (%) | Ratio of first class channel communication thickness (%) | First class multidirectional channel communication thickness ratio (%) | Permeability ≥0.3μm² thickness ratio (%) | Degree of chemical drive control (%) |
|---------------------------|------------------------|---------------------------------|---------------------------------|---------------------------------|-----------------------------------|-----------------------------------|
| The first type            | ≥10                    | ≥60                             | ≥50                             | ≥30                             | ≥60                               | ≥60                               |
| The second type           | ≥8                     | ≥30                             | ≥20                             | ≥25                             | ≥40                               | ≥45                               |
| The third type            | ≥6                     | ≥20                             | ≥10                             | ≥10                             | ≥20                               | ≥30                               |
| The fourth type           |                        |                                 |                                 |                                 |                                   |                                   |

3. Evaluation of development effects

3.1 Evaluation of injection effects

The viscosity of each ternary block is above 20mPa·s and the viscosity of Block A is lower than Block B since the oil development of Block A is poorer than that of Block B. The injection speed is within the range of 0.15~0.25PV/a. The injection speed of Block A is slower (the injection speed of Block A is about 0.15PV/a while other areas are above 0.20PV/a) since its injector producer distance is 150m and its development is poor [2-3].

From the aspect of injection pressure, the increased rule of each block is basically the same. The pressure increases quickly in the early period of injection, then increases slowly and becomes stable. Due to the later breakthrough of chemical agent slug, the injection pressure declines in pilot and demonstration areas. The biggest increase of the injection pressure in Block A is 28.0%, which is 49.1% lower than that in inhalation index. The biggest increase of the injection pressure in Block B reaches 75.0%, which is 54.5% lower than that in inhalation index, as shown in Figure 1. The reason for those differences is that the injection pressure of Block A before injection is 2.8MPa higher than in Block B. However, when the injection pressure reaches the highest, their allowable injection pressure difference is basically the same, all within 1MPa. (allowable injection pressure difference = bursting pressure - injection pressure).

![Figure 1. Comparison of injection indexes of different ASP flooding blocks](image)

From the injection pressure of classified well, it is seen that the injection pressure of Block A and B tends to increase regularly since the personalized classification and optimization are adopted based on the development characteristics and dynamic changes of each well. The deep profile control is used mainly in class I and class II well; the main measures to increase injection is employed in class III and class V well; the scale injection is adopted in class I, class II and Class III well. From the aspect of the increase of injection pressure, there are some differences between Block A and Block B. The injection pressure of class V in Block A increases by about 2MPa, which is more than 40% lower than that of inhalation index. The injection pressure of class V in Block B increases by about 4MPa, which is more than 50% lower than that of inhalation index.
3.2 Evaluation of use condition
After injection, the injectivity profile of Block A and B is improved greatly and the inhalation thickness percentage of oil layer continuously increases. Compared with 2015, the inhalation thickness percentage increases by 10%, the inhalation thickness percentage of lower permeability layer with the permeability less than 300×10⁻³μm² increases by more than 10%. The inhalation thickness percentage of high permeability layer with the permeability more than 500×10⁻³μm² declines by more than 5%.

3.3 Evaluation of pressure system
After injection, the formation pressure of Block A and B gradually recovers and keeps near the original formation pressure, and the total pressure difference is kept within a reasonable range (±0.5MPa). At the same time, with the continuous effect of the block, the injection-production pressure difference, the driving pressure difference and the production pressure difference increase gradually, which indicates that the middle and low permeability layer can be effectively used and the formation energy is fully released.

3.4 Effect evaluation of recovery
From the variation of production fluid index, the comprehensive decline law is basically the same. The biggest decline of industrial area is 36.3%, which is obviously lower than that of experimental area, as shown in Figure 2. By the changing curve of water cut, the decline rule of water cut is basically the same. In the early state of injection, the water cut declines slowly; when being injected 0.1PV, the water cut declines sharply; when the stable operation time exceeds 0.35PV in the low-value period of water cut, the maximum drop amplitude of water cut in the industrial area reaches 12.36%, and the maximum oil increase ratio is more than double, which is lower than the level of experimental area, as shown in Figure 3. As the experimental blocks, the chemical drive development effect of experimental area and demonstration area is better than that of industrial area due to their single mining horizon, small inter-layer interference and better development [5-6].

![Figure 2. Comparison of specific liquid production index of different ASP flooding blocks](image1)

![Figure 3. Comparison of comprehensive water cut of different ASP flooding blocks](image2)

From the effect characteristics of classified well group, the largest drop of comprehensive water cut of class I well is 12.3% and the day average oil enhancement of single well reaches 8.4t; The largest drop of comprehensive water cut of class II is 11.5% and the day average oil enhancement of single well reaches 7.2t; the largest drop of comprehensive water cut of class III is 10.9% and the day average oil enhancement of single well reaches 5.8t. The largest drop of comprehensive water cut of class V is 10.4% and the day average oil enhancement of single well reaches 5.1t. Therefore, the effect of the class I and class II is better than that of class III and class V.

4. Conclusions
4.1 This paper not only selects five key indexes, such as effectiveness thickness, thickness percentages of channel sand and chemical flooding control degree, but also establishes quantitative classification
standard for single well. Additionally, injection wells and production wells in the block are divided into four categories, the effectiveness of classified development and adjustment of injection wells is improved, and the accuracy of the analysis of production well effectiveness characteristics is enhanced.

4.2 The increasing rule of injection pressure is basically the same. The increase of injection pressure of industrial area is 28~75% with great difference and the decrease of inhalation index is 45~55%. The comprehensive decline law of composite water cut is basically the same. The biggest decrease of composite water cut in industrial area is 12.36% and the maximum oil increase multiple is more than double, which is obviously lower than the level in experimental area.

4.3 The effect characters of classified well group shows that the biggest composite water cut and average oil enhancement of single well in one and second-class well are higher than that in the third and fourth-class well. Therefore, the effect of one and second-class well is better than that of third and fourth-class well.

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