Analysis of water control effect in Sabei water flooding Development Area

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Abstract: The structure analysis method has been used to analyze the effect of the structure change on water cut in Sabei water flooding development area. The results show that structural adjustment plays an important role in water control, various adjustment measures have gradually weakened the effect of water control, improving the utilization rate of water injection is an important safeguard measure for water control. With the gradual increase of water flooding, the low efficiency and invalid circulation is serious and the water control is difficult. Three methods are proposed to improve the water control effect.

1. The rising rate of water cut in of water flooding is obviously slowed down

In the period of “11th Five-Year”, Sabei development area was adjusted by optimizing the water injection structure, increasing the measures of oil and water wells and improving the utilization rate of water injected. The rising rate of water flooding was effectively controlled. The annual water cut of water flooding decreased from 0.36% in “15th Five-Year” to 0.14% in 2010, and the increase rate of water cut decreased from 1.59% to 0.50% in 2010. The water control effect of the base well pattern is particularly obvious. The annual water cut in 2010 is 95.69%, and only 0.88 percentage point’s rise in five years. The annual average water cut of first infill well increases by 0.49 percentage points during the “fifteen” period, and slows down to 0.35 percentage points during the period of “11th Five-Year”, and for the second infill wells with fast rising speed of water cut, the annual average of the water cut rising rate dropped from 1.02 percentage points to 0.31 percentage points. It can be seen that the water cut rising rate of each set of reservoir layers is obviously slowed down.

2. Structural adjustment plays an important role in water control

The factors that affect the rise of water cut can be divided into two types of geological factors and development factors, among which the influence of geological factors is the inherent property of oil layer in the law of water cut rise, which is not analyzed in detail here. The development factor is the influence of some adjustment methods and adjustment measures adopted in the process of development and adjustment on the rising law of water cut. In the very high water cut period of the oil field, the adjustment method and adjustment measure play a decisive role in controlling the rising speed of water cut.

2.1 Structural water cut

It is defined by the definition of water content； $f_w = \sum_{i=1}^{n} \frac{Q_{Li}}{Q_L} f_{wi} = \sum_{i=1}^{n} a_i f_{wi}$

Where, f_w——Water content in whole area of oil field，%； a_i——The produce structure coefficient

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of each prediction structure; f_{wi} ——water cut of each prediction structure, %。

2.2 Change trend of water control effect of structural adjustment

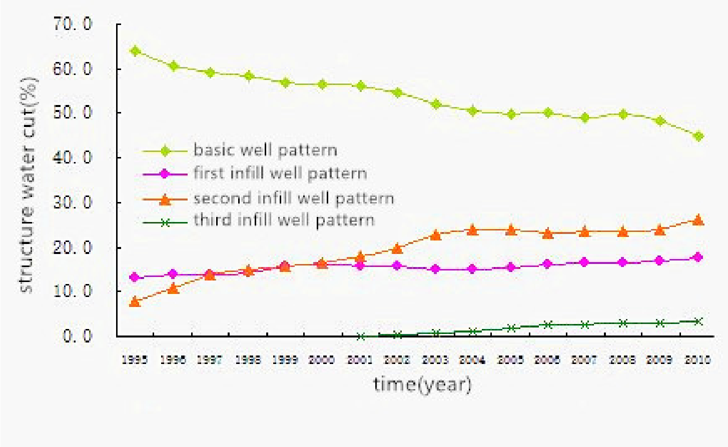

Fig.1 Structure water cut of various wells in Sabei development area changes with time

In order to analyze the effect of structural adjustment on water cut, we set the classification well as the basic unit. The structure analysis method was used to analyze the effect of the structure change on water cut. The results show that the water cut in the whole reservoir is mainly affected by two factors: the structural coefficient of the classification well and the change of water cut.

That is $\Delta f_w = \sum_{i=1}^{n}(a_i \Delta f_{w0i} + \Delta a_i f_{w0i} + \Delta a_i \Delta f_{w0i})$

Where， $a_i = \frac{Q_{Li}}{Q_L}$ is structural coefficient； $f_{w0i} = a_i f_{wi}$ is structure water cut;

$\Delta f_{w0i} = a_i \Delta f_{w0i} + \Delta a_i f_{w0i} + \Delta a_i \Delta f_{w0i}$

The contribution value of the variation of water cut in various well structures to the variation range of water cut in the whole oilfield.

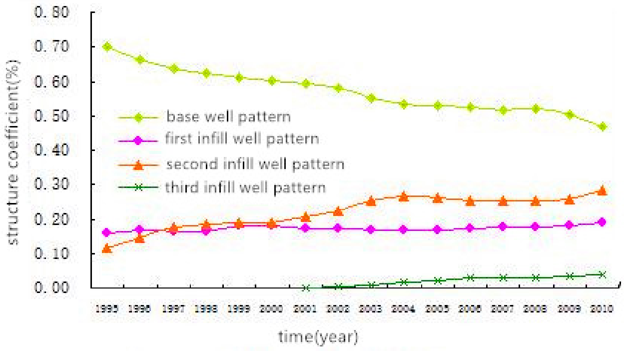

Fig.2 Structure coefficient of various wells in Sabei development area changes with time

By applying the above methods, we have analyzed the structural adjustment effect of the Sabei development area. The analysis results show that, since the water flooding development entered “15th five year”.The structure coefficient of the second and third infill wells increases and the structure water cut rises, making water flooding water cut increase from 91.36% to 93.14% in five years, only up 1.78 percentage points, , and the water cut rising rate of “11th Five-Year” continues to slow down, and only rises 1.17 percentage points in the five years. Structure of water drive is only 1.17 percentage points up in five years. The effect of structural adjusting water control is obvious.

3.Various adjustment measures have gradually weakened the effect of water control

Drawing on the concept of structural water cut, we use the contribution value analysis method. The water control effect of new well put into production, oil well fracturing, liquid extraction and water plugging are studied. The results show that the effect of measures on controlling water cut in the whole area is mainly affected by the difference between the water cut of the measures and the natural water cut, and the rate of liquid increased in the whole area. That is: the absolute contribution of item i to the control of water cut in the whole area is $\Delta f_{wi} = \frac{Q_{Li}}{Q_L}(f_w - f_{wi})$

Where, f_w natural water cut, %; f_{wi} water cut of more liquid produced by all measures, %。

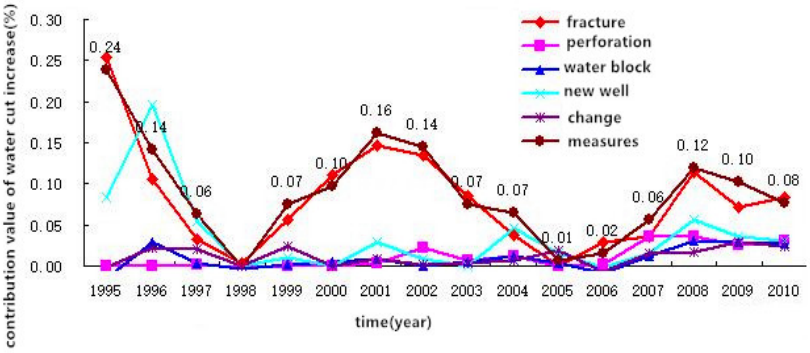

Fig.3 Changing curves of contribution value of water cur increase caused by various measures

The influence of measures on the water cut change of the oilfield since 1995 has been analyzed by the above methods. The analysis results show that since 1996, the water control function of various measures has been gradually weakened, and oil well fracturing has always been the main measure of water control.

4.Improving the utilization rate of water injection is an important safeguard measure for water control.

In 1999, the comprehensive water content of the water drive in the Sabei development area was 90.41%, and entered the super high water cut stage. By the end of 2010, the water injection efficiency had reached 94.32%. According to the statistical law, when the water cut increases, the ratio of wells and layers with water content greater than 98% increases rapidly after entering the high water cut stage. The proportion of oil wells with water content greater than 98% is the main object of water control.

Although structural adjustment and various adjustment measures play an important role in water control, it is an important guarantee for water control to strengthen the treatment of inefficient and invalid circulation and increase the utilization rate of water injection. During the period of "11th Five-Year", the adjustment of injection and production adaptability, measures of injection well, adjustment and extension of water injection technology were strengthened with "injection of enough water and injection of good water" as the main line. All measures and adjustments have achieved good results and effectively controlled the rising rate of water cut.

4.1 Strengthening the adaptability of injection production system to ensure enough water injection.

During the "11th Five-Year", the injection production system was adjusted, oil well transfer to injection well, drill new well, injection well overhaul, perforation and so on so as to further improve the injection production relationship, which laid the foundation for the adjustment of water injection structure and the guarantee of "injection enough water".

The first step is to carry out the oil well transfer to injection well and improve the injection and production system. There are 53 wells transferred into injection wells in the western of the Beisan area, in the early stage the average single well injection layers were 2.7 sections. The daily water injection is 2014m3, and the cumulative injection is 74.34 × 104m3, which effectively reduces the burden of the old water injection wells. Compared with 2007 before the transfer, the thickness of the reservoir sandstone and thickness of effective thickness increased by 9.12 and 11.28 percentage points, and the formation pressure restored 0.26MPa in year, 138 non measures oil wells around the injection wells area produced 290t more liquid, 54t more oil and water cut dropped 0.52 percentage points.

Second is to fill the new well and increase the direction of water injection. At the end of "10th Five-Year ", 23 new water injection wells were drilled in the third infilling adjustment layers in the west of Beier area, and the initial daily water injection was 731m3, and the total water injection increased by 139.87 × 104m3.

Third is to increase the intensity of overhaul, upgrading and inclined shaft, and improve the relationship between injection and production in local wells. During the "11th Five-Year" period, 74 injection wells were overhauled, 7 were updated, and 19 inclined shafts to restore water injection 6302m3/d. for 300 affect wells around, the average daily recovery of single well was 3.32t, recovery of oil was 0.31t, water cut dropped by 0.20 percentage points.

The forth is to increase the strength of well perforation and further improve the relationship between injection and production of single sand body. During the period of "11th Five-Year", 24 water injection well were perforated, and the water injection was increased by 590m3/d. There were 81 oil wells without measures in the surrounding area. The average daily increase of oil of single well was 0.71t, and the water cut decreased by 1.11 percentage points.

4.2 Increase the intensity of comprehensive adjustment of injection wells to ensure water injection

4.2.1 Strengthening fine adjustment of injection well to improve water injection quality

During the "11th Five-Year" period, 1620 injection well schemes were adjusted, the injection increased 6975m3/d, and the real injection increased 6767m3/d. The average surrounding 4371 wells average production increased by 0.18t, and the water cut decreased by 0.25 percentage points.

First, increase the intensity of subdivision adjustment of water injection wells and slow down the contradiction between layers. During the "11th Five-Year" period, 269 wells were divided into subdivision wells, and the average number of single well water injection layers increased from 3.52 to 4.79, and the water injection volume increased by 1359m3/d. Statistics showed that 676 surrounding wells without measures taken. The average daily increase in single well was 0.48t, the daily oil increased by 0.18t, and the water cut decreased by 0.23 percentage points.

The second is to match the water injection quantity of new and old wells with the corresponding relationship of new and old wells. The reasonable transfer of water injection between the new and old injection wells on the plane promotes the direction change of liquid flow and further improves the effect of water injection. In which 26 injection wells were adjusted, the water injection intensity increased from 5.85 m3/d·m to 8.55m3/d·m; 18 old injection wells were adjusted, the water injection intensity is reduced from 11.40m3/d·m to 8.92m3/d·m, and water injection pressure dropped 0.4MPa.

Third, we should reasonably restore the injection volume of the long stopping section and tap the remaining oil in the high water cut layers. During the "11th Five-Year" period, by analyzing the remaining oil potential of the long stopping section, a total of 200 long stopping sections of 195 wells were recovered, and the daily recovery injection amount was 3994m3. The surrounding 655 wells average increase 1.19t liquid, 0.12t oil and water cut dropped 0.09 percent point.

The forth is to increase the adjustment of injection wells that keep working for 5 years and improve the water injection condition. Combined with subdivision and recombination of injection wells, 135 wells were adjusted during the "11th Five-Year" period. 89 of them were adjusted in 2010, the daily water injection increased by 45m3, and the water injection pressure dropped from 13.55MPa to 13.00MPa.

4.2.2 Optimizing injection well stimulation measures to improve reservoir water absorption

During the "11th Five-Year" period, by optimizing injection well improvement measures, reducing water injection pressure and controlling layer under injection target, 615 injecting measures were implemented, and the water absorption of the oil layer was effectively improved. The water absorption of the measure well is improved, and the water absorption ratio of sandstone and effective thickness is increased by 7.39 and 7.90 percentage points respectively, and the water absorption ratio of the thin and surface layer of the thin layer with effective thickness less than 0.5m is increased by 6.65 and 4.57 percentage points respectively. Through the treatment of water injection wells, in the end of 11th Five-Year, 369 less injection sections of water flooding accounting for 6.55% of the total number of strata, and 1.06 percentage points lower than that of the end of "10th five-year".

4.2.3 Implement cycle injection to control inefficient and invalid cycle

In 1992, the Sabei development area carried out the periodic water injection test in the transition zone. After ten years' exploration, it was popularized and applied in the whole region. The optimization methods of the parameters and technical boundaries such as well area selection, water injection mode, inter injection cycle and recovery ratio were formed. Since 11th Five-Year, with the development of numerical simulation technology and the application of this field, the theory of periodic water injection has been deepened, and the theory and practice are combined closely. During the "11th Five-Year" period, 836 wells were cycle injected, with a cumulative less water injection of 327.58×104m3, less water production of 40.10×104m3, and an average annual water cut of 0.02 percentage points.

4.3 The utilization rate of water injected is obviously improved

Water storage rate and water flooding index are important indexes for evaluating water injection status and water injection effect in water flooding oilfield. The rate of water storage is an indicator of the utilization rate of water injected, and it refers to the ratio of the amount of water stored in the underground (cumulative water injection volume minus cumulative water production) to the cumulative water injected.

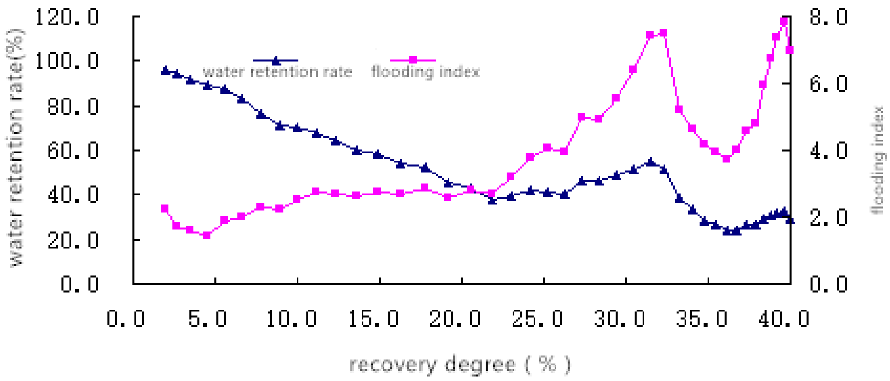

Fig.4 Relationship between Water retention rate and flooding index and recovery degree of Sabei development area

Generally speaking, if the accumulative water storage rate of the oilfield is high, the extraction efficiency is high, and the efficiency of water injected is high, and the development effect is good. Conversely, the cumulative water storage rate is low, and the recovery rate is low, the efficiency of water injected is low, and the development effect is poor. The water drive index is an index to measure the effect of oil displacement, that is, the water quantity stored underground of every 1t underground crude oil displaced. The rate of water retention and water drive index kept up steadily during the period of "11th Five-Year", indicating that the increase of water injection and liquid produced were effectively controlled by the above adjustment, and the effect of water flooding was better. From Fig.4, it can be seen that the change curve of the water retention rate deviated from the early "11th Five-Year" and tended to the water flooding recovery of 45%, indicating that the adjustment effect was better.

5.The direction of water control in the future

Through the above analysis, it can be seen that the water control effect of various adjustment measures during the “11th Five-Year” period is quite obvious, but with the gradual increase of water flooding, the low efficiency and invalid circulation is serious and the water control is difficult. How to improve the water storage rate is the key to control the rising rate of water flooding and the improvement of the oil field development effect.

First, the “three transformations” are gradually realized, that is, the macro adjustment and control between interlayers and interlayers change into the fine adjustment within the interlayer and in the layers. From thin and poor layer tapping potential to both thin layer and thick oil layer tapping the potential and laying equal stress on it. From a single stratified water injection plan adjustment and production increase measures to transform mainly into a variety of adjustment means such as adjustment, control, perforation, block and so on.

Second, we should adjust well the water wells and adjust the liquid production structure. Increase the strength of subdivision and reorganization, retard interlayer contradiction, expand affect volume of injection water, so as to increase the water storage rate of middle and low permeability layer, continue to carry out restore water injection in long stop layers, extracting the remaining oil in high water cut layers, carry out periodic water injection and periodic oil production, reduce inefficient and invalid circulation, carry out deep profile control for high permeability layer, reduce invalid circulation of the pass and the high permeability zone.

The third is to take measures to control the rising of water cut in oil wells. Optimizing the wells and layers selection method to increase the development effect of remaining oil in the thick oil layer. Through accurate perforation, the injection and production relationship of single sand body are improved, the imperfect injection to production residual oil is excavated, the high water cut and strong flooded layer are blocked, the invalid drainage is reduced and underground water storage rate is increased.

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