Potential analysis of class II reservoirs after water flooding based on core

Xie Xiao Jing

Address: Geological Brigade, No. 3 Oil Production Plant, Daqing Oilfield Co., Ltd., Saertu District, Daqing City, Heilongjiang Province, 163113

Author brief introduction Xie Xiao Jing, engineer, graduated from Northeast Petroleum University in 2011, majoring in geological engineering, engaged in tertiary oil recovery and development. E-mail: 281779074@qq.com

Abstract. With the deepening of oilfield development, residual oil distribution has become an important reference for evaluation of oilfield development effect and selection of measures to improve oil recovery. Based on core data of coring wells, through core analysis and comparison between coring wells of different layers in single well and different coring wells in adjacent blocks at the same layer and different coring wells, combined with sedimentary facies zones and dynamic production and development data, this paper analyses and studies the exploitation situation of class II reservoir a II 1-9 in western S oilfield, in order to provide basis for searching for potential remaining oil and formulate more suitable potential tapping measures.

1. Introduction

The western block of S oilfield has an oil-bearing area of 8.1 km² and a geological reserve of 6422.1×10⁴t. Since the basic well pattern was put into development in 1964, it has undergone three major adjustments. At present, there are seven well patterns: basic well pattern; primary, secondary and tertiary well pattern; the polymer flooding well pattern of the main reservoir bl1-4 in reservoir b in 1994 and the polymer flooding well pattern of the second class reservoirs aII13+14-aIII10 in reservoir a in 2004-2014.

2. Core analysis of reservoir production

2.1 Coring Well 533

Coring well 533, located in the western block of S oilfield, was drilled in 2014. Coring horizon is designated as aI top to bottom. Core analysis coring wells show the degree of recovery of various reservoirs as shown in Table 1.

The effective thickness of the class I reservoirs is 4.9m, and the proportion of wash thickness reaches 100%, of which the proportion of strong wash thickness is 86.5%, the proportion of medium wash thickness is 13.5%, the displacement efficiency is 63.9%, and the recovery degree is 63.9%.

The effective thickness of the class II reservoirs (aII13+14-aIII10) is 18.2m, the wash thickness is 16.32m, the ratio of strong wash thickness is 46.9%, the ratio of medium wash thickness is 38.7%, and the ratio of weak wash thickness is only 14.40%. After polymer flooding, the displacement efficiency is 56.9%, and the recovery degree is 51%. 

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The effective thickness of class II reservoirs (aII1-9) is 14.1m, the washing thickness is 9.16m, and the washing thickness ratio is 65.0%. Among them, the strong washing thickness ratio is 18.4%, the medium washing thickness ratio is 29.3%, and the weak non-washing thickness ratio is 52.3%. The oil displacement efficiency is 45.5% and the recovery degree is 29.5%.

The effective thickness of class III reservoirs bII+G is 10.2m, the wash thickness is 7.56m and the wash thickness ratio is 74.1%. The strong wash ratio is 10.3%, the medium wash ratio is 55.3%, and the weak wash ratio is 34.3%. The oil displacement efficiency is 44.1% and the recovery degree is 32.7%.

According to the core analysis results of various reservoirs in core well 533 reservoirs, it is calculated that the weak non-wash thickness of class II reservoirs (aII1-9) after wash is 52.3%, the displacement efficiency is 15.9%, and the recovery degree is 29.5%. The weak non-wash thickness of class II reservoirs (aII13+14-aIII10) accounts for 14.4%, the displacement efficiency is 45.5%, and the recovery degree is 51.0%. The recovery degree of class II reservoirs (aII1-9) is not only much lower than that of class II reservoirs (aII13+14-aIII10), but also 32.7% lower than that of class III reservoirs (bII+G).

### Table 1. Core Analysis Results of Various Reservoirs in Well 533

| Reservoirs | Wash Thickness % | Strong Wash % | Medium Wash % | Weak Non-Wash % | Displacement Efficiency % | Recovery Degree % |
|------------|------------------|---------------|---------------|-----------------|----------------------------|------------------|
| Class I reservoirs | 100.0 | 86.5 | 13.5 | 0.0 | 63.9 | 63.9 |
| Class II reservoirs | 89.7 | 46.9 | 38.7 | 14.4 | 45.5 | 51.0 |
| Class II reservoirs | 65.0 | 18.4 | 29.3 | 52.3 | 15.9 | 29.5 |
| Class III reservoirs | 74.1 | 10.3 | 55.3 | 34.3 | 44.1 | 32.7 |

According to the core analysis results of various reservoirs in coring well 533 reservoirs, it is calculated that the weak non-wash thickness of class II reservoirs (aII1-9) after wash is 52.3%, the displacement efficiency is 15.9%, and the recovery degree is 29.5%. The weak non-wash thickness of class II reservoirs (aII13+14-aIII10) accounts for 14.4%, the displacement efficiency is 45.5%, and the recovery degree is 51.0%. The recovery degree of class II reservoirs (aII1-9) is not only much lower than that of class II reservoirs (aII13+14-aIII10), but also 32.7% lower than that of class III reservoirs (bII+G).

### 2.2 Four coring wells in eastern block of western S Oilfield

Four coring wells: 60, P59, P60 and P61, in the eastern block of Western S oilfield, were drilled in 2008, and sealed coring was carried out for a and b reservoirs respectively. Core analysis data of four coring wells are as follows (Table 2):

### Table 2. Core Analysis Results of Four Coring Wells in eastern block of western S Oilfield

| Well Number | Core Analysis | Effective Thickness (m) | Wash Thickness (m) | Displacement Efficiency (%) | Recovery Degree (%) | Average |
|-------------|---------------|-------------------------|--------------------|----------------------------|---------------------|---------|
| 60well (aII7+8) | 3.1 | 2.9 | 49.3 | 46.6 | 36.34% |
| P59well (aII1-3) | 7.6 | 7.5 | 43.4 | 42.6 | |
| P60well (aII3) | 6.9 | 5.2 | 43.5 | 32.57 | |
| P61well (aII7+8) | 3.6 | 3.4 | 43.6 | 23.6 | |

According to production and development data, the recovery degree of water flooding in class II reservoirs is basically 37% - 38%. The average oil displacement efficiency of four coring wells is 42.96% and the average recovery degree is 36.34%. According to the recovery degree data of all I-9 formation of four coring wells in the eastern block of western S Oilfield, the recovery rate of core well 533 in western Block is only 29.5% in aII1-9 formation, which is lower than the average level of water flooding in class II reservoirs.
3. Analysis of remaining oil potential

Through comprehensive analysis of data from 5 coring wells in western and eastern blocks of S oilfield, it is found that the recovery degree of class II reservoirs (aII1-9) in western block is relatively low, even lower than that of class III reservoirs. The reasons are as follows:

3.1 Well pattern can not be controlled

Since the main reservoirs of basic well pattern a and b were put into development in 1964, the western block of S oilfield has undergone three major adjustments. At present, there are seven sets of well patterns: the basic well pattern for exploiting the main reservoirs a and b; the first infilling adjustment well pattern; the second infilling adjustment well pattern; the third infilling well pattern; and the polymer flooding well pattern. In the third development adjustment, the infill well pattern were not perforated in the class II reservoirs(aII1-9), only the basic well pattern have been perforated in this layer, and the perforation horizon is less.

   The western part of S oilfield (class II reservoirs aII1-9) only covers the basic well pattern. The cutting distance of the basic well pattern is 2.1 km. The first row of production wells is 500 m in the north, 600 m in the South and 500 m in the well spacing; the row spacing of the second production well is 500m, and the well spacing is 500m; the production wells are staggered and the injection wells are 300m apart. The arrangement of three rows of production wells between two rows of water injection wells results in poor water injection efficiency of two and three rows of production wells far away from the rows of water injection wells, forming remaining oil retention zone.

3.2 injection-production relationship

Mainstream line and diversion line of injection and production

    In the injection-production relationship between oil wells and water wells, there is a widespread gap between the recovery degree of mainstream line and diversion line. Oil wells on the mainstream line of water injection have good results, while water injection effect on the diversion line is relatively poor.

    The aII1+2b layer of coring well 533 is located in the middle of the connection of two production wells, which is at a disadvantage in the injection-production relationship and at the blind spot of the injection route, resulting in poor water drive effect and remaining oil retention zone.

    Imperfect relationship between injection and production

    The water injection wells of the basic well pattern for water supply of well 533 were shut down in 1993, and the newly injected updated wells were put into operation in 2000. There was a 7-year time lag between the shutdown of the original water injection wells and the production of the renewed wells, which resulted in the lack of water inflow direction, imperfect injection-production system, and reduced control degree of water drive well pattern and poor efficiency of water injection.

    In addition, the difference between the perforation thickness of each layer of the newly injected renewal well and that of the original injection well is also an important reason for the difference of injection effectiveness.

    There are 10 sub-layers in the aII1-9 layer in the western block of S oilfield. One of them is undeveloped, and the other three sub-layer water injection wells, 34 wells and Geng 34 wells, are not perforated in this layer. Of the other six sub-layers, only two sub-layer renewal wells have larger perforation thickness than the original water injection wells, as shown in Table 3. Statistics show that the total perforation thickness of the original injection wells is 17.5m, and that of the renewal wells is 12.8m, with a difference of 4.7m. For example, in layer aII1+2b, the perforation thickness of the original injection well is 5.8m, and that of the renewal well is only 0.7m. The injection effect becomes worse with thin injection and thick production. In layer aII4, the injection thickness of the original water injection well is 2m, and the renewal well is not opened, and there is no injection thickness production, so the injection effect becomes worse.

    The poor effect of water injection on injection-production diversion line caused by imperfect injection-production relationship, and the fact that the original well pattern has well-point drilling, but
it can not perforate due to the reasons of interlayer, cementing quality and so on, resulting in injection-no production or no injection-production or no injection-no production, are the important reasons for the formation of uncontrollable remaining oil in the well pattern.

Table 3. Comparisons of perforation thickness between old and new wells

| Thickness | aI1+2b | aI2+3a | aI2+3b | aI4 | aI7+8a | aI7+8b |
|-----------|--------|--------|--------|-----|--------|--------|
| 34well    | 5.8    | 1.0    | 1.4    | 2.5 | 4.2    | 2.6    |
| Geng34well| 0.7    | 5.8    | 0.8    | 0.0 | 4.4    | 1.1    |

3.3 Areal heterogeneity

There are differences between the new injection well coordinate (Geng 34) and the original well coordinate, which may lead to the difference of sedimentary facies zones between new wells and old wells, thus affecting the connectivity of oil and water wells.

The aI7+8a layer of coring well 533 and well 34 are first class of connectivity in the channel, and the water injection effect of oil well is good. Renewal well Geng 34 and coring well 533 are both channel deposits, but there is abandoned channel shielding between the two wells, which leads to poor connectivity between oil and water wells. The aI7+8b layer of coring well 533 and the original injection well are first class of connectivity in the channel, and the water injection effect of oil well is good. After the injection of renewal wells, the connectivity of reservoirs is poor due to the blocking of the river edge, which leads to the decrease of reservoir productivity.

Generally speaking, only aI2+3a in each sedimentary unit of aI1-9 is shut down in the original water injection well casing, and the injection effect of the renewal well becomes better after the injection production, while the water injection effect of the other sedimentary units becomes worse in varying degrees, resulting in worse water flooding effect and lower recovery degree in a large area of this block.

The shielding caused by the difference of plane heterogeneity is an important factor for the formation of shielding remaining oil.

4. Tapping the Potential

According to the statistics of control degree of formation combination under different well spacing conditions, the control degree of polymer flooding in 250m well spacing is 58.4%, 67.4% in 175m well spacing, 75.4% in 150m well spacing and 82.7% in 125m well spacing for the first class of reservoirs, which indicates that the control degree of polymer flooding increases with the decrease of well spacing.

The second class reservoirs aI1-9 has 10 sub-layers, which is more than the current target reservoir aI10-12. However, cutting well pattern with lower well pattern density has been used for water injection in this reservoir. Under the condition of original well pattern, channel sand drilling rate and polymer flooding control degree are lower, only 38.2% and 58.4% respectively. It is suggested that the aI1-9 layer should be exploited by polymer flooding. It is predicted that the sand drilling rate can reach 75.5% and the degree of polymer flooding control can reach 82.7%.

5. conclusion

By using the method of core analysis and comparison, it is found that there may be remaining oil in class II reservoirs (aI1-9) in western block of S oilfield.

At present, there are three classes of remaining oil in class II reservoirs (aI1-9) in western block of S oilfield, which are remaining oil in detention zone, uncontrollable remaining oil in well pattern and shielding remaining oil.

In view of the distribution of remaining oil, it is suggested that the reservoir be exploited by polymer flooding. It is predicted that the sand drilling rate can reach 75.5% and the degree of polymer
flooding control can reach 82.7%.

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