Study on potential and distribution of remaining oil after polymer flooding in XX Oilfield

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Abstract. XX oilfield has been put into polymer flooding development for 24 years, with cumulative oil production reaching XX million tons. Since 2005, the first-class reservoirs of early polymer flooding have been transferred to subsequent water flooding. After long-term water flooding, polymer flooding and subsequent water flooding, these reservoirs are in the development stage of "double extra high", with high reservoir production degree, serious ineffective circulation and highly dispersed remaining oil, which makes it difficult to further tap potential. Therefore, the remaining oil potential and distribution law are studied in the first class oil layer in XX area of oilfield, which provides geological basis for further development and adjustment of EOR.

Keywords: After polymer flooding, Double extra high, Remaining oil, Enhanced oil recovery.

1. Introduction

Table 1. Basic information table of coring wells and new drilling in different periods in the study area

| Water washing data of coring well | Flooding data of new drilling wells |
|-----------------------------------|------------------------------------|
| Stage | Number of wells | Drilling time | Stage | Classification | Number of wells | Drilling time |
|-------|----------------|---------------|-------|----------------|----------------|---------------|
| Before polymer injection | 2 | 199X years | Before polymer injection | New drilling of polymer flooding in a class of oil layers | 141 | 199X years |
| End of polymer injection | 1 | 200X years | Five years after polymer flooding | New drilling in ternary test area of second-class reservoir | 107 | 200X years |
| 14 years after polymer flooding | 1 | 201X year | 12 years after polymer flooding | The first set of new drilling wells for polymer flooding in class II reservoirs | 198 | 201X year |
| | 1 | 201X year | 16 years after polymer flooding | Two sets of new drilling wells for polymer flooding in second-class reservoirs | 208 | 201X year |
The research area is located in the south of the north east block of the oilfield, and the production horizon is Pu I1-2 oil layer, with oil-bearing area of 6.2Km2 and probable geological reserves of 1181.0×104t. Polymer injection was carried out in July 1996, and polymer flooding ended in October 2001. By the end of 2019, after 18 years of subsequent water flooding development, the oil recovery was enhanced by 13.4 percentage points and the recovery ratio was 56.1%. In order to find out the macroscopic remaining oil potential and distribution after polymer flooding, the water washing and flooding data of coring wells and new wells in different periods are used, combined with the whole process numerical simulation of the block.

2. Study on macroscopic remaining oil potential by using coring well data

According to the statistics of water washing data of coring wells at different stages before and after polymer injection, the production status of Pu I1-2 reservoir after polymer flooding has been greatly improved, and the remaining potential has been obviously reduced. In 14 years after polymer flooding, the water-washed thickness ratio reached 99.0%, increasing by 19.2 percentage points, the oil displacement efficiency reached 57.2%, increasing by 16.1 percentage points, the unwashed thickness ratio was only 1.0%, and the remaining oil was more scattered.

According to the water washing status of each unit in 14 years after polymer flooding, Pu I2a, Pu I2b, and Pu I2c are used well, the oil displacement efficiency reaches about 61%, and the proportion of low unwashed thickness drops below 4.0%. The four units Pu I1, Pu I2a, Pu I2b, and Pu I2c are poorly used, with oil displacement efficiency of about 53% and low unwashed thickness of over 5.0%, which are mainly distributed at the top of structural units.

According to the change of water washing status in different periods after polymer flooding, the reservoir production status is further improved in the subsequent water flooding stage, and the distribution characteristics of remaining oil have little change. The four units, Pu I1, Pu I2a, Pu I2b, and Pu I2c, have lower oil displacement efficiency and higher proportion of low unwashed thickness, which are controlled by rhythm characteristics and structural interface, and are mainly located at the top of structural units.

3. Study on macroscopic remaining oil potential by using interpretation data of newly drilled watered-out zone

According to the statistical results of water-flooded data, the production status of oil layers is greatly improved and the remaining potential is obviously reduced after polymer flooding. In the 16 years after polymer flooding, the flooded thickness ratio increased to 99.4%, the recovery ratio reached 57.28%, the oil saturation decreased to 32.3%, and the unwatered thickness ratio decreased to 0.6%, thus the remaining oil potential was more dispersed.

According to the distribution of residual potential of different sand body types, the river sand body is the best after polymer flooding, and the non-main sheet sand is the worst. River channel sand body: the recovery rate reaches 58.6%, the oil saturation decreases to 31.8%, and the proportion of unwatered thickness is only 0.5%; Main sheet sand: the recovery degree is 45.5%, the oil saturation is reduced to 37.2%, and the proportion of unwatered thickness is 1.6%; Non-main sheet sand: the recovery degree is 34.1%, the oil saturation is reduced to 44.5%, and the proportion of unwatered thickness is 14.1%.

From the distribution of remaining potential of reservoirs with different thicknesses, the reservoirs with a thickness of 1.5~1.9m are produced best after polymer flooding, while the reservoirs with a thickness of less than 1.0m are produced worst. In the oil layer with thickness of 1.5~1.9m, the recovery rate reaches 58.7%, the oil saturation drops to 31.8%, and all the oil layers are flooded. The oil layer with thickness greater than 2.0 has a recovery rate of 58.6%, an oil saturation of 31.8%, and an unwatered thickness ratio of 0.5%. The oil layer with thickness less than 1.0 has 34.7% recovery, 44.0% oil saturation and 4.7% unwatered thickness. After polymer flooding, with the extension of subsequent water flooding time, the production status of oil layers with different thickness grades is further improved, and the.
4. Main types of remaining oil after polymer flooding
According to the statistical analysis of water washing and flooding data and numerical simulation, the remaining oil in the study area mainly has the following five types. One is the residual oil at the top of the structural unit. Controlled by rhythmic characteristics and structural interface, the top of the structural unit is poorly used, and there is residual oil, but the unused thickness is further reduced; Second, the interlayer interferes with the formation of residual oil in thin and poor reservoirs. Affected by the difference of permeability between layers, interlayer interference forms residual oil in thin and poor layers, mainly oil layers with thickness less than 1.0; Third, the connectivity becomes worse to form residual oil. The deterioration of sand body between wells or injection-production wells leads to the deterioration of communication relationship and the formation of local remaining oil; Fourth, the development of sand bodies at the edge of the main river channel deteriorates to form residual oil. In crevasse channel, crevasse fan and abandoned channel, the development of sand body becomes worse, forming local residual oil; Fifth, residual oil is formed at the injection-production shunt line. The injection-production shunt line is blocked by the sand body deterioration part, forming local residual oil.

According to the above analysis, the production degree of Pu I1 is 67.4%, which is low, and the remaining geological reserves are 137.4×10⁴ t; the utilization degree of non-channel structural unit is poorly used, and there is residual oil, but the unused thickness is further reduced; Second, the interlayer interferes with the formation of residual oil in thin and poor reservoirs. Affected by the difference of permeability between layers, interlayer interference forms residual oil in thin and poor layers, mainly oil layers with thickness less than 1.0; Third, the connectivity becomes worse to form residual oil. The deterioration of sand body between wells or injection-production wells leads to the deterioration of communication relationship and the formation of local remaining oil; Fourth, the development of sand bodies at the edge of the main river channel deteriorates to form residual oil. In crevasse channel, crevasse fan and abandoned channel, the development of sand body becomes worse, forming local residual oil; Fifth, residual oil is formed at the injection-production shunt line. The injection-production shunt line is blocked by the sand body deterioration part, forming local residual oil.

According to the statistical analysis of water washing and flooding data and numerical simulation, the utilization degree of non-channel sand body is 45.0%, which is low, and the remaining geological reserves are 637.9×10⁴ t. The utilization degree of Pu I1, Pu I2a, and Pu I 2b is about 50%, and the utilization degree is low, with the remaining geological reserves of 241.0×10⁴ t.

Table 2. Distribution of Remaining Geological Reserves in the Study Area

| Construction unit | River sand body | Non-riverway sand body | Total |
|-------------------|-----------------|------------------------|-------|
|                   | Geology reserves (10⁴t) | Recovery degree (%) | Remaining geological reserves (10⁴t) | Recovery degree (%) | Remaining geological reserves (10⁴t) | Recovery degree (%) | Remaining geological reserves (10⁴t) | Recovery degree (%) | Remaining geological reserves (10⁴t) | Recovery degree (%) | Remaining geological reserves (10⁴t) | Recovery degree (%) | Remaining geological reserves (10⁴t) |
| Pu 1  | 67 | 47 | 35.5 | 39.5 | 44.3 | 22 | 3.7 | 32.8 | 2.5 | 43.2 | 43.3 | 24.5 | 110.2 | 45.6 | 60 |
| Pu 2  | 136 | 46.2 | 73.2 | 40.3 | 46 | 21.8 | 2.3 | 30.3 | 1.6 | 42.6 | 45.2 | 23.3 | 178.6 | 46 | 96.5 |
| Pu 3  | 193.8 | 61.6 | 74.4 | 39.7 | 47.9 | 20.7 | 3.5 | 36.9 | 2.2 | 43.3 | 47 | 22.9 | 237 | 58.9 | 97.3 |
| Pu 4  | 156.7 | 54.6 | 71.1 | 21 | 46.7 | 11.2 | 3.4 | 34.8 | 2.2 | 24.3 | 45.1 | 13.4 | 181.1 | 53.3 | 84.5 |
| Pu 5  | 168.6 | 62.3 | 63.5 | 26.4 | 44.3 | 14.7 | 2.1 | 38.8 | 1.3 | 28.5 | 43.9 | 16 | 197 | 59.6 | 79.5 |
| Pu 6  | 269.5 | 58.4 | 112.1 | 31.2 | 47.3 | 16.4 | 1.3 | 31.3 | 0.9 | 32.4 | 46.7 | 17.3 | 301.9 | 57.1 | 129.4 |
| Pu 7  | 226.2 | 68.8 | 70.6 | 35.1 | 43.7 | 19.7 | 0.5 | 35.8 | 0.5 | 35.5 | 43.6 | 20 | 261.8 | 65.4 | 90.6 |
| Total | 121.7 | 8 | 500.5 | 233.2 | 45.7 | 126.5 | 16.6 | 34.4 | 10.9 | 249.8 | 45 | 137.4 | 1467.6 | 56.5 | 637.9 |

5. Conclusion and understanding
(1) Using water washing data of coring wells, water flooding data of new drilling wells and research results of numerical simulation, it is possible to analyze and study the oil layer production in each stage of oilfield development, thus guiding the implementation of remaining oil distribution.
(2) Pu II-2 reservoir has been developed by long-term water injection and polymer injection, and its overall production degree is relatively high. However, different sedimentary types in the plane and different structural units in the longitudinal direction are quite different, and there is a certain residual potential.

(3) The remaining oil distribution in the study area mainly includes five types: the remaining oil at the top of structural unit, the remaining oil in thin oil layer with poor interlayer interference, the remaining oil with poor connectivity, the remaining oil with poor sand body development at the edge of main channel and the remaining oil in injection-production shunt line.

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