Study On Water Injection Effect of New Reservoir For Petroleum Energy Development

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Abstract. Oilfield has gone through the stages of self injection production, water injection development and three times of chemical agent injection development. At present, it has entered the late development stage of high water cut, and the production and new exploration reserves have decreased significantly. As a potential resource of high water cut later development, SA0 formation reservoir has a certain oil and gas abundance. However, because of its poor physical properties and strong water sensitivity, SA0 formation reservoir in Oilfield has great difficulties in water injection development. This set of reservoir was not developed in the early development of Oilfield. With the improvement of development technology and the increasing demand of recoverable reserves, the development of SA0 formation reservoir becomes more and more important. However, there is no in-depth study on the specific characteristic parameters of the reservoir and the feasibility of water injection development, which restricts the development of this set of reservoir. Therefore, this paper explores the feasibility of waterflooding development of lithologic and physical properties of SA0 formation reservoir in Development Zone. Laboratory experiments and field practice show that SA0 formation reservoir is a low permeability and highly sensitive reservoir. 3% concentration of anti swelling agent can effectively inhibit the expansion and migration of clay minerals, and play the purpose of protecting the reservoir. In the field test, through adding clay stabilizer to perforate and complete the well with flow limiting method, a high liquid production capacity has been achieved. At the initial stage, the average daily oil production of a single well is more than 1.50t. The production performance of oil wells is quite different, the liquid production layers are concentrated, and most of them are dry layers. A certain understanding has been obtained in the waterflooding development of SA0 formation in development zone of Oilfield.

1. Introduction
Because of the poor physical properties and strong water sensitivity, the reservoir of SA0 formation in Oilfield is very difficult to be developed by water injection. With the improvement of development technology and the increasing demand of recoverable reserves, the development of SA0 formation reservoir becomes more and more important. However, there is no in-depth study on the specific characteristic parameters of the reservoir and the feasibility of water injection development, which restricts the development of this set of reservoir. As a part of the oil-bearing combination in the middle part of placanticline, the oil-bearing layer of SA0 formation in Development Zone belongs to the inactive oil-bearing layer. Several years of research shows that the characteristics of SA0 oil layer are quite different from those of conventional oil layer. The specific performance is that the reservoir sensitivity is serious and the diagenesis is weak. It is very difficult to develop and transform SA0 oil layer by conventional means. Therefore, we have studied the lithology, physical properties and the
feasibility of water flooding development of the reservoir of the SA0 formation in the Development Zone, and obtained some understanding on the water flooding development of the reservoir of the SA0 formation in the Development Zone.

2. General Situation of The Experimental Area
The test area is located in team of the northern transition zone, with an oil-bearing area of 1.47 square kilometre and controlled geological reserves of 396700 tons. There are 35 newly drilled test wells in the test area, including 29 production wells and 6 water injection wells. The injection production well spacing is 175 meters. The average thickness of sandstone is 4.6 meters, the effective thickness is 2.4 meters (Table 1).

| Entry Name                   | Experimental area |
|------------------------------|-------------------|
| Oil-bearing area, km²        | 1.47              |
| Controlled geological reserves, 10⁴t | 39.67          |
| Average thickness of sandstone, m | 4.6             |
| Effective thickness, m       | 2.4               |

3. Reservoir Properties in Test Area
The oil layer of SA0 formation belongs to the first member of Nen formation. The first member of Nen formation includes two sets of oil layers of SA1 formation and SA0 formation. It is in the transitional stage of the lake basin from depression to rising stage. The overall sedimentary characteristics show that the scale of lake transgression is expanded. After the short-term deposition of the SA1 formation, the lake water began to expand, and a set of thick mudstone deposits, namely the interlayer between the SA0 formation and the SA1 formation, were formed. During the next two lake regressions, the oil layer of the SA0 formation was deposited, during which a large area of lake transgression period was experienced, and a mudstone interlayer with a thickness of about 8m was formed in the middle of the SA0 formation. The stratum thickness is about 35m. According to the sedimentary cyclicity, standard layer and electrical characteristics, the oil layer of SA0 formation is divided into two sandstone formations and eight small layers by using the correlation method of lacustrine sedimentary oil layers. In recent years, with the increasing of drilling data, the research on the reservoir of SA0 formation in Development Zone is more and more in-depth. The reservoir of SA0 formation is located in the upper part of SA0, PU and Gao oil layers. Through the study of geological characteristics and systematic comparative analysis of SA0 formation, it is divided into 2 sandstone formations and 8 small layers. From top to bottom, they are named as SA01 to SA08 successively. The mudstone interlayer with a thickness of about 8m between SA03 and SA04 is divided into two sandstone formations, namely, SA0 upper and SA0 lower sandstone formations. According to the development characteristics and distribution of sand bodies, the oil layers of the SA0 formation can be divided into three distribution types: one is the overall distribution type, the SA06, SA07 and SA08 sub layers are the products of the first stage Lake regression, and the sand bodies are developed in a large area, in which the SA07 sub layer can further divide the boundary between the inner and outer front facies of the Delta near the fault west of the north area 1; the other is the local distribution type, the scale of the second stage Lake regression is much smaller than that of the first stage Lake regression, the sand body of SA02 is only locally developed; the third is the scattered distribution type, SA03 is the product of the early stage of the second stage Lake regression, and the sand body is sporadically developed; SA04 and SA05 are the products of Lake progradation, and the sand body is also sporadically developed.

3.1. Lithologic characteristics of reservoir
The oil layer of SA0 formation in northern Saertu oilfield is mainly siltstone or argillaceous siltstone, with an average clay content of 27.31%. The reservoir is rich in clay minerals, in which
montmorillonite, illite and kaolinite are the main clay minerals. Montmorillonite and illite are water sensitive minerals, montmorillonite is the most serious expansion and dispersion, and kaolinite is a strong speed sensitive mineral.

3.2. Physical properties of reservoir
The average porosity of SA0 formation is 21.1%, in which 71.4% of the total porosity samples are more than 20%, 9.5% of the total porosity samples are 18% - 20%, and 19.1% of the total porosity samples are less than 18%. It can be seen that the SA0 formation in this area is a medium low porosity reservoir. The average permeability is 17.1 millidarcy, 6.25% of the total samples are more than $50 \times 10^{-3}$ μm², 40.63% of the total samples are 10 millidarcy - 50 millidarcy, and 53.12% of the total samples are less than 10 millidarcy. From the perspective of permeability, the reservoir of SA0 formation in this area belongs to low permeability reservoir.

3.3. Reservoir sensitivity
Sensitivity test: the reservoir protection should be fully considered in the process of oilfield development, and the degree of damage to the reservoir is the sensitivity of the reservoir. The results of laboratory experiments are as follows: the reservoir of SA0 formation is highly water sensitive, highly salt sensitive, moderately strong velocity sensitive and strongly acid sensitive. From the reservoir itself, it is difficult to develop by water injection, so it is necessary to consider taking measures (viscosity stabilizing agent) to restrain the formation damage caused by injected water[1][2].

Performance evaluation of clay stabilizer: because the reservoir of SA0 formation is a strong water sensitive reservoir, clay minerals are easy to expand and migrate in the process of water injection development, blocking the pore throat, resulting in the decline of permeability. Therefore, in order to control the formation damage caused by injected water, the existing clay stabilizer was optimized in the laboratory, and the performance of clay stabilizer was evaluated. The long-term flushing experiment of clay stabilizer injection water shows that the core permeability decline rate can be stabilized at about 30% in the long-term injection process of clay stabilizer, which indicates that clay stabilizer can effectively inhibit the expansion and migration of clay minerals in the reservoir, and achieve the purpose of reservoir protection.

There is no effective thickness interpretation standard for SA0 formation in Development Zone of Oilfield. Based on the existing study of formation characteristics of SA0 formation, the effective thickness physical property standard of SA0 formation is formulated by using empirical statistical method and oil yield method based on the relationship among lithology, physical property, oil-bearing property and electrical property of SA0 formation, and the multi-dimensional spatial information of logging, oil testing and core is proposed Methods to establish the electrical standard of effective thickness. The standard has been applied to the thickness interpretation of production wells in Development Zone, and it has been proved by the actual production situation[3][4].

4. Field Test Injection Status
The indoor velocity sensitive experiment shows that the reservoir has strong velocity sensitivity. When the injection rate is more than 1 ml per minute, the permeability damage of the reservoir begins to increase. In order to protect the permeability of the reservoir and avoid the damage to the reservoir caused by too high injection rate, we calculated that the maximum injection intensity of the well is no more than 5.3 cubic meters per day under the thickness of each meter. At the same time, according to the reasonable injection production ratio and the field test experience of the first oil production plant, we finally determined that the average injection intensity of a single well is 5 cubic meters per day under the thickness of each meter.

In the initial stage of injection, the average injection pressure of 6 water injection wells is 11.20MPa, the daily injection volume is 66m³, the daily actual injection volume is 64m³, and the daily injection volume is 5m³ under the water injection intensity per meter thickness; at present, the injection pressure is still about 11MPa, and the water absorption capacity is stable compared with the
initial stage of injection. The stability of water injection shows that the selected anti-swelling agent can effectively inhibit the expansion and migration of clay minerals under the condition of 3% concentration, which has played the purpose of protecting the reservoir[5].

5. Oil Production in Field Test

Based on the understanding of the reservoir characteristics of the SA0 formation, the main problems in the fracturing of the SA0 formation are to solve the reservoir sensitivity problem and proppant inlay problem. Through improving fracturing fluid formula, optimizing proppant suitable for SA0 formation reservoir and innovating fracturing technology, better fracturing effect is ensured. Referring to the development experience of SA0 oilfield in No.1 oil production plant, 25 production wells in the experimental area of SA0 formation were fractured and put into production in June 2008. At the initial stage of production, the average daily fluid production of a single well was 2.5t, the daily oil production was 1.5t, and the comprehensive water cut was 38.91%.

Among the 29 production wells in the test area, there are 22 oil wells. The sandstone thickness of single well is 5.0m, the effective thickness is 2.7m, the permeability is 0.147 Darcy, the average daily liquid production of single well is 1.8t, the daily oil production is 1.2t, and the comprehensive water cut is 30.50%. The highest oil production of 22 wells is 7.77t, and the lowest is only 0.02t. The average daily water production of each well is 0.4t, the thickness of the injected sandstone is 2.7m, the effective thickness is 1.1 m, and the permeability is 0.071 Darcy.

The results of 1 coring well in the test area show that the reservoirs with oil-bearing occurrence are mainly distributed in SA05 and SA06 layers; the sidewall coring of 15 wells in the test area shows that the cores with oil-gas indication are mainly distributed in SA04, SA06, SA07 and SA08; the oil test results show that only two wells have industrial oil flow in SA06 layer, and the other six test layers have no oil-gas indication; the production profile shows that the liquid producing layers are SA06, SA07 and SA08. According to the analysis of the above data, most of the layers in the test area are dry layers and have no liquid production capacity, and the liquid production layers are mainly SA06 and SA07.

In order to reduce the formation damage, it is necessary to add a certain concentration of anti-swelling agent to restrain the expansion of clay minerals during water injection development of SA0 formation. By means of X-ray method and core flow method, the potassium chloride type clay stabilizer is selected by systematically evaluating the lattice spacing, core damage rate, anti-swelling rate, dissolution rate and other indicators characterizing the performance of clay stabilizer. The optimal injection concentration is 3%, which has a certain guiding significance for the optimization of anti-swelling agent for similar low permeability and strong water sensitive reservoirs.

At the same time, the hot washing fluid is optimized to ensure that under the condition of high temperature hot washing, the damage rate of the hot washing fluid to the reservoir is close to that of the injected water, and the hot washing measures can be adopted for the production wells with serious wax deposition. The solid paraffin inhibitor has an effective paraffin control effect in the production wells of SA0 formation, and its validity period is more than 2 years. The hot washing fluid can eliminate the wax deposition and false liquid level in the production wells of SA0 formation, and has a good protective effect on the oil layer.

6. Conclusion and understanding

At present, Development Zone of Oilfield has entered the period of ultra-high water cut development, and all oil layers have been injected with water or polymer. Because the oil layer of SA0 formation is a low permeability oil layer with strong sensitivity and certain particularity, it is very difficult to develop. The oil field has never been used in nearly 50 years, and it is the reserve reserve of Development Zone. The experimental study on water injection development of SA0 formation reservoir in Development Zone is carried out to effectively develop SA0 formation and provide important reference for later development. The main understanding is as follows:
(1) The reservoir of SA0 formation is medium low porosity and permeability, strong water sensitivity, strong salt sensitivity, medium to strong velocity sensitivity and strong acid sensitivity.

(2) The reservoir of SA0 formation has low water injection ability and high injection pressure.

(3) The results show that the 3% concentration of viscosity stabilizer can protect the reservoir and achieve better injection under the current well pattern and well spacing conditions.

(4) The reservoir of SA0 formation has good productivity after fracturing with anti swelling and flow limiting method.

(5) The dynamic response of the test area is quite different, the liquid producing layers are concentrated, and most of them are dry layers.

**Author brief introduction**

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**Reference**

[1] Shi Junlian, Cao Weizheng, Bai Yaming, Li Jiafen; Water injection development test of SA0 formation reservoir in Sazhong Oilfield. Petroleum Geology and development in Daqing, 2005.

[2] Zhang Fan, Wang Dawei, Fu Zhiguo; Reservoir characteristics of SA0 formation in LaSaXing area of Daqing Oilfield. Petroleum Geology and development in Daqing, 2001.

[3] Wu Fengqin, Sui Xinguang; Experimental study on reservoir development of SA0 formation in Sazhong Development Zone. Petroleum Geology and development in Daqing, 2007.

[4] Wang Wei, Wang Yingbin. The potential tapping method of water flooding in the ultra-high water cut period is "two-three combination". Petroleum Geology and development in Daqing, 2012.

[5] Wu Wenyou, Wang Luchun, Zhang Jifeng. The main influencing factors of oil recovery rate in oilfields during the ultra-high water cut period. Petroleum Geology and development in Daqing, 2012.