The study on effect and design of fracture-flooding in Class Ⅲ oil reservoirs

Hongwei Wang [1, 2]

[1]Petroleum Engineering College, Northeast Petroleum University, Daqing, Heilongjiang 163318, China;

[2]No.2 Oil Production Plant, Daqing Oilfield Company Limited, PetroChina, Daqing, Heilongjiang 163000, P R of China

whw0459@petrochina.com.cn

Abstract. The research on the efficient development of Class Ⅲ oil reservoirs in Daqing Oilfield is the key to ensure the stable production of oil fields. This paper analyzed the characteristics of Class Ⅲ oil reservoirs of Sazhong Development Area in Daqing Oilfield, put forward the innovative technology of fracture-flooding, and got preferable development efforts through field tests. The results show that the Class Ⅲ oil reservoirs in Sazhong Development Area have many different types of sand bodies but poor reservoir property. According to the development process, the recovery level is low, the residual oil is scattered, the adsorbed amount is much, and it is difficult to use chemical flooding. So the author innovatively put forward the "fracture-flooding" technology, which made long fractures by fracking, then formed high-speed channels, the efficient oil displacement agent was transported quickly to the enrichment of residual oil through the fractures. Creating artificial fractures and leaking-off along up and down reduces the contact time and contact distance between the chemical agent and strata to which resolved the high linear loss of the performance of chemical agent and low utilization efficiency that affected the flooding effect in the process of injection. According to the results of field tests, the technology of Class Ⅲ oil reservoirs can achieve oil displacing and injecting during fracturing and the researchers did experiments with injector group which showed the flooding effect. That means the fracture-flooding can be applied as a stimulation method for injectors in Class Ⅲ oil reservoirs of Gaotaizi, Saertu and Putaohua in Sazhong Development Area to tap the potential of residual oil in scattered wells.

Keywords: Class Ⅲ oil reservoir; Fracture-flooding; Alkali and surfactant; Residual oil.

1. Introduction

Daqing Oilfield has entered the development stage of the ultra-high water cut stage. The oilfield faces the situation of small potential for increasing storage and unbalanced storage and mining. The Daqing placanticline Class III reservoirs have a geological reserve of 1.86 billion tons, accounting for 44.6% of the total geological reserves of the Lasaxing Oilfield. It is still under flooding development with combined water content of 93% -96% and a recovery of 36%-42%. There are more surplus reserves [1], so the Class III reservoirs are the main target of increasing oil and gas production in the future. The Class III reservoirs are mainly characterized by poor reservoir properties, low flooding degree [2], and scattered residual oil distribution [3]. They can be reformed in a reasonable way to reduce the difference between layers and release residual residual oil. Increasing the proportion of movable reservoirs is the key to the efficient development of Class III reservoirs [4]. Therefore, by analyzing the characteristics of Class Ⅲ oil reservoirs in Sazhong Development Area of Daqing Oilfield, this paper proposes a new technology of "fracture-flooding" based on large-scale fracturing to tap the residual oil of Class Ⅲ oil reservoirs, which provides new technical ideas for efficient development.

2. The development characteristics of Class Ⅲ oil reservoirs in Sazhong Development Area

2.1 The characteristics of property of Class Ⅲ oil reservoirs in Sazhong Development Area

2.1.1 Poor reservoir property

What follows in the passage shows the physical test statistics of 832 rock samples in the Sazhong Development Area. The average effective permeability of reservoirs in the Class Ⅲ oil reservoirs is $175 \times 10^{-3}\mu m^2$, the average pore throat radius is 5.14μm, the average displacement pressure is 0.09MPa, and the average clay content is 11.03%. The average permeability of off-surface reservoirs is only $18.5 \times 10^{-3}\mu m^2$, the average pore throat radius is only 1.35μm, the average displacement pressure is up to 0.22MPa, and the average clay content is 21.13%. Due to the poor reservoir development, the average single well injection strength is only $3.03m^3$ / d · m, so injection and recovery are relatively difficult, resulting in low formation pressure with an average of only 10.03MPa.

2.1.2 The variety of sand bodies and serious cross distribution

The Class Ⅲ oil reservoirs in the Sazhong Development Area are dominated by the inner and outer frontier facies of the delta [5], in which the off-shore part to the frontal near-shore part form the main sheet-shaped on-surface sand; the frontal shore part forms the on-surface non-main body sand; the frontal off-shore part to the prodelta part form the off-surface reservoirs. The results of coring analysis of different oil reservoirs show that the physical properties of on-surface and off-surface reservoirs within the same oil layer are quite different. The average permeability difference is up to 8.75, and the mud content is doubled. The comparison between different reservoirs shows that the best permeability of Putaohua reservoirs is as high as 9.39, the permeability difference of Saertu reservoirs is 9.10, and the difference of permeability of Gaotaizi reservoirs with the worst property is 7.20. Therefore, the better the physical property of Class Ⅲ oil reservoirs in Sazhong Development Area is, the greater the difference in permeability is, the higher the degree of heterogeneity in the reservoirs and the off-surface of the reservoir are interactively distributed.

2.2 The development characteristics of Class Ⅲ oil reservoirs in Sazhong Development Area

2.2.1 Low level of flooding

Due to the existence of sand body types and serious interaction and distribution in the Sazhong Development Area, the current development and classification of the Class Ⅲ oil reservoirs need to be divided into development and subdivision measures [3,6]. Take the Gaotaizi Class Ⅲ oil reservoirs as an example, the current injection wells have been subdivided into an average of 6.2 segments. Even in this subdivision mode, through years of fine tapping potential, integrated water has reached 96.75%, the current mining level of 42 %, lower than the level of development of flooding for the first and second type reservoirs.

2.2.2 The residual oil is scattered

The result of flooding in coring wells shows that the ratio of on-surface non-water-layer is 21.2% and the thickness of it is of 17.2%. The off-shore non-water-layer has a high percentage of 83.1% and a thickness of 70.5%, it has a great oil-generation potential. The results of unswept area in water layer show that the on-surface unwashed thickness is of 28%, off-surface thickness is 57.3%, flooding efficiency is of only 43.9%. In the remaining microscopic classification, the remaining residual oil in the area affected by flooding is mainly the residual oil in clusters, accounting for 72%. The residual oil in the shape of membrane, column, blind end and corner is 28% in total. Therefore, the analysis of residual oil control factors based on viscous force, capillary force and adhesion force shows that the tapping potential of reservoir remaining oil needs to increase the viscous force, reducing the capillary force and reduce the adhesion force, this means that the Class Ⅲ oil reservoirs need to increase the pressure difference between injection and production, and to control the flow and reduce the interfacial tension between oil and water. That is to say, it is more necessary to carry out chemical flooding.

2.3 The characteristics of chemical flooding in analogous Class Ⅲ oil reservoirs

The results of intermediate sampling in chemical flooding show that under the well spacing is of 125m, the main streamline and shunt direction is of, the sampling well near the injection well is of

60m well spacing (1/2 well spacing) can form ultra-low interfacial tension. There is a crude oil emulsification phenomenon. However, the 90m sampling results show that no effective low interfacial tension chemical flooding effect has been achieved. Therefore, assuming a critical point of low interfacial tension at 75m, the area where flooding efficiency is effective is only 0.36PV in the near injection well zone, whereas 0.64PV in the near production well area does not increase the flooding efficiency. It shows that the performance of chemical agent in the process of injection is large, the utilization efficiency is low, and the displacement effect is affected.

3. The proposing of fracture-flooding technology of Class Ⅲ oil reservoirs

3.1 The fracturing fractures description of Class Ⅲ oil reservoirs

The theoretical analysis shows that the principal stress σ_z of the overlying strata in Sazhong Development Area of Daqing Oilfield is less than the principal stress of σ_x and σ_y in the horizontal direction. Therefore, according to the theory of fracture opening [8], the shape of artificial fractures is horizontal seam [18-19]. At the same time, the fracturing is carried out by a single packer with double packer. After that, the monitoring result by 3D microseismic is shown in Fig. 1 and Fig. 2. The monitoring results of cracks show that the hydraulic fractures in the Sazhong Development Area are horizontal fractures. By controlling the direction of fracturing fractures, the intercalated layers are not damaged, and later stratification and adjustment work can be carried out to ensure that the stratified injection can continue after the fracturing construction.

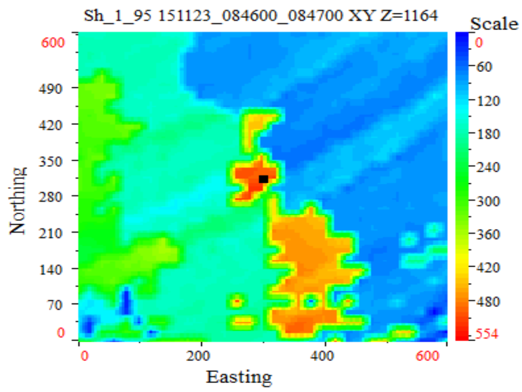

Fig. 1 The schematic diagram of fracturing plane

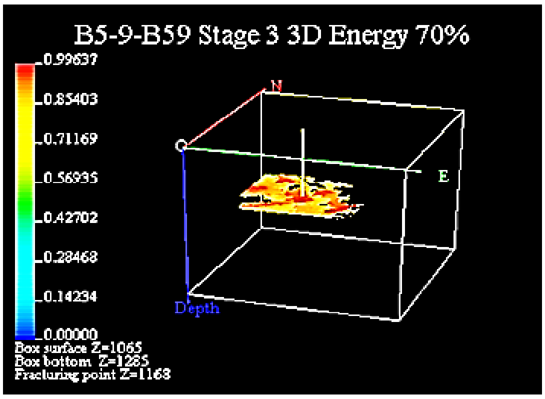

Fig. 2 The results of fracture 3D interpretation

3.2 The putting-forward of fracture-flooding theory in Class Ⅲ oil reservoirs

"Fracture-flooding" means fracturing and fracturing by means of fracturing. Effective flooding agent can be quickly sent to the remaining oil enrichment site through the fracture. The displacer can be used as fracturing fluid. Loss, the drive oil filled quickly into the pores, reducing the contact time and contact distance between chemical agents and formation to address chemical properties of the injection process along the way of loss, low utilization efficiency, the impact of displacement effect. Through the selective fracturing in the interval, the influence of large difference between reservoirs and reservoirs can be improved to solve the problems of multi-section length, serious interlayer heterogeneity, difficulty of matching in injection parameters and difficulty of using thin layer. At the same time, the fracturing and flooding can quickly replenish formation energy to achieve the effect of advanced water injection in low permeability reservoirs, enabling formation energy recovery and achieving the starting pressure of low permeability reservoirs.

4. Field tests of fracturing reservoirs in Class Ⅲ oil reservoirs

4.1 Well selection of fracture-flooding wells

In August 2016, in the test area of the Class Ⅱ oil reservoir in the Three-Dimensional demonstration area of the west of the sewage, one oil well B1-26 and one injection well B1-24 with poor physical properties similar to those of the Class Ⅲ oil reservoirs were selected to carry out fracture-flooding oil test to explore the feasibility of Class Ⅲ oil reservoirs of fracture-flooding efficient development of oil.

According to the subdivision condition of injection well and the condition of production well, according to the current delamination process requirements, the fracture-flooding reservoirs are divided into six sections. Among them, the first and second stages improved the inter-layer difference by fracturing to recover the formation energy, and the fourth and sixth six stages drove the submarine residual oil through fracturing and exploiting submersibles.

4.2 The design of injection of oil agent

Binary liquid alkali and alkali compatibility, and a wide range of interface activity and good oil-washing ability can meet the high displacement efficiency requirements. The injection volume design is based on the calculation of the injection volume and formation pressure rise in accordance with the relationship between the overall pressure rise of the block and injection-production ratio. When 0.05PV is injected, the formation pressure returns to 10.97MPa of original formation pressure, designed to inject 0.05 PV.

4.3 Oil well fracture-flooding effect

After fracture-flooding oil well B1-26 well produced a significant increase in liquid oil to reduce the effect of oil, the effect shown in Fig 3. Daily production of 15t / d, daily output of 0.5t / d, moisture content of 96.6%, the maximum daily output of liquid 65t / d, daily output of 8.5t / d, moisture content of 88.9%. Up to now, the expiration date reaches 429 days, the daily output of liquid is 54t / d, the daily output of oil is 1.6t / d and the water content is 96%. Due to the improvement effect of fracturing on the oil layer, oil 910t, improve oil recovery 1%. Fig 4 shows the results of the concentration of the recovered polymer. The concentration of the polymer in the produced fluid reached a peak value of 499 mg / L at 126 days after fracturing and flooding, which shows that even large-scale fracturing and flooding did not cause a rapid reservoir breakthrough.

The injection rate of conventional chemical flooding in the experimental area is about 50m^3 / d, which can be up to 6480m^3 / d according to the current fracturing and flooding construction speed, and about 100 times of the normal injection can be achieved through the delivery of fractures. At the same time, a one-time injection of 0.05PV plays a decisive role in the rapid recovery of formation pressure in the low permeability layer, and further activation of the formation can be achieved by increasing the formation pressure. Because of the direct transport of cracks, the fissure surface is filtered up and down, so that the performance loss caused by shearing, adsorption and retention along the path can be reduced.

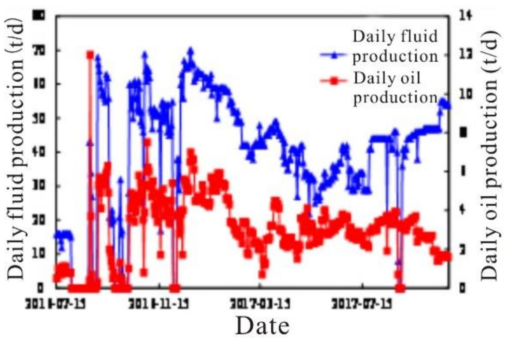

Fig. 3 Oil well production curve

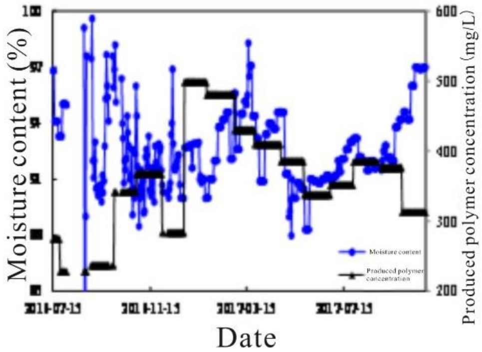

Fig. 4 The analysis of production fluid

4.4 Well fracturing effect of oil well

Injection well flooding after flooding significant increase injection effect, the effect shown in Fig 5. The day before the pressure injection was 40m^3 / d, injection pressure was 13MPa, injection viscosity was 15 MPa · s. In the initial stage of pressure injection is 40m^3 / d, injection pressure is 5MPa, injection viscosity is 15mPa · s, maximum daily injection is 200m^3 / d, injection pressure is 13MPa, injection viscosity is 25mPa · s. Up to now, the expiration date reaches 300 days and accumulates 27,000 m^3 accumulatively. Due to the effect of fracturing on the reservoirs, the production profile is improved accordingly. After the fracturing and flooding, the ratio of the number of layers to use increased from 62.5% to 72.05%, markedly increased, while the standard deviation decreased, indicating that the degree of utilization was more uniform. The results of cumulative water absorption showed that the cumulative water absorption ratio of each layer was more uniform with the standard deviation decreasing from 13.22 to 5.76. The results of marshalling from the down-hole water nozzle show that at present the layers can be used evenly under the conditions of natural pressure distribution. Fig 6 shows the results of daily production and moisture content changes in the production wells around the well. The daily production rate rises $40m^3$ / d after fracturing and flooding, and it is stable. Meanwhile, the recovery rate of moisture content is extremely effective.

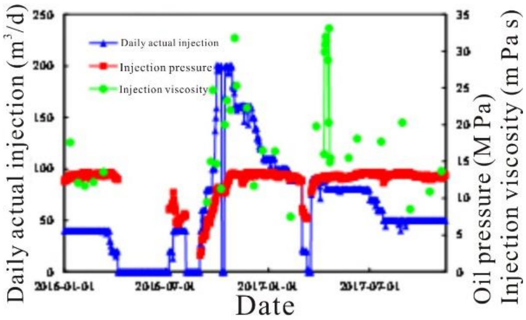

Fig. 5 The water well injection curve

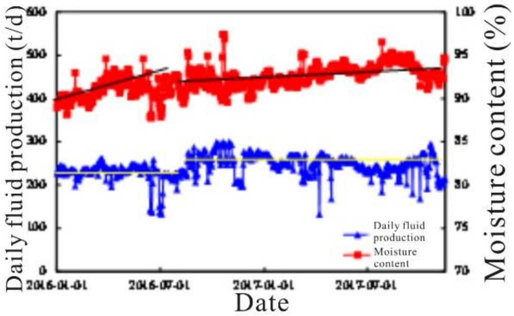

Fig. 6 The comprehensive curve of production of oil wells around well

5. Conclusion

(1) The physical properties of the main reservoirs of the Class Ⅲ oil reservoirs in Sazhong Development Area are characterized by poor reservoir physical properties and multi-types of sand bodies, resulting in the development features of low recovery and residual oil fragmentation in the development process, and the chemical flooding is difficult.

(2) "Fracture-flooding" means to form a high-speed channel by fracturing the long seam to send the high efficient flooding agent through the crack to the residual oil enrichment site quickly, using the flooding agent as fracturing fluid and fracturing The upper edge and the lower edge of the seam lost filter will be filled quickly displacing agent into the pores, reducing the contact time and contact distance between chemical agents and formation to address chemical properties of the injection process along the loss of large, low utilization efficiency, the impact oil displacement effect of the problem.

(3) Class Ⅲ oil reservoirs of fracture-flooding in the third type of well should select isolated well points. Usually, there is no relationship between injection and production, or the relationship between injection and production is very imperfect, or the formation of serious energy deficit wells.

(4) The field test results show that it is possible to realize the fracture-flooding injection of the Class Ⅲ oil reservoirs in the process, and the well flooding effect is found in the test injection well group, which can be widely applied to the Class Ⅲ oil reservoirs in the Sazhong Development Area, rapid tapping of potential technology scattered wells residual oil.

Acknowledgements

Fund Project: National oil and gas major projects (Item Number: 2009ZX05009-004-01).

About the Author: Wang Hong-wei, male, PhD student, senior engineer, engaged in enhanced oil recovery and reservoir numerical simulation research.

References

[1] Wang Y., Song K. P., Yang E. L., et al., The evaluation of remaining oil potential and producing condition in Sazhong area. Journal of Daqing Petroleum Institute [J], 2009, 33 (2): 48-52.

[2] Liu J. Y., Liu M. Y., Xu H., Analysis and quantitative calculation on influencing factors of recovery percent at the high water cut stage- a case study of Sazhong Development Area, Daqing Oilfield. Petroleum Geology and Recovery Efficiency [J], 2010, 17 (1): 62-67.

[3] Miao H. C., Kan C. L., The practice and cognition of accurate potential tapping of flooding in Sazhong Development Area, Daqing Oilfield. Journal of Yangtze University (Natural Science Edition) [J], 2013, 26 (10): 134-136.

[4] Wang Q. M., The study and development of off-surface reservoirs in oilfields. Foreign Oilfield Engineering [J], 1998, 1 (1): 5-8.

[5] LI A., Chen S. M., Zhang E. H., The description technology of seismic prestack in low permeable reservoirs in Fuyu reservoirs in Gaotaizi region of Daqing placaticline. China Petroleum Exploration [J], 2011, 139-147.

[6] Li D. W., Study on the method of subdivision water injection in Gaotaizi reservoirs. Science and Technology Innovation Herald [J], 2014.

[8] Li J. B., Lu S. F., Chen G. H., et al., Friability evaluation for the mud shale reservoirs based on the mineralogy and rock mechanics, Petroleum Geology & Oilfield Development in Daqing [J], 2015, 34 (6): 159-164.

[9] Xie C. Y., Li Z., Luo M. E., et al., Fracturing and tapping potential technology of thin difference reservoirs in Daqing Oilfield, FAULT BLOCK OIL & GAS FIELD [J], 1997, 4 (4): 53-56.

[10] Biao F. J., Liu H., Zhang S. C., et al., A numerical study of parameter influences on horizontal hydraulic fracture, ENGINEERING MECHANICS [J], 2011, 28 (10): 228-235.

[11] Xie C. Y., Li Z., Luo M. E., et al., Fracturing and tapping potential technology of thin difference reservoirs in Daqing Oilfield, FAULT BLOCK OIL & GAS FIELD [J], 1997, 4 (4): 53-56.

[12] Liu Y. K., Yu Q. N., Liang S., et al., Optimization of the well-layers for fracturing in Chaoyang Oilfield, Petroleum Geology & Oilfield Development in Daqing [J], 2013, 32 (2): 136-140.

[13] Tao J. W., S K. P., H J. G., et al., Experiment of the influence factors of the advanced water injection in extra low permeability oil reservoirs, Petroleum Geology & Oilfield Development in Daqing [J], 2015, 26 (3): 156-160.

[14] Wen A. Z., Pu C. S., Study on the influence of starting pressure gradient on productivity of fracturing wells, Journal of Xian Shiyou University [J], 2009, 24 (4): 50-53