Study on Polymer Flooding Objects and Utilization Limits of Three Types of Oil Layers in Daqing Oilfield

Min Wang *
Daqing Oilfield Co., Ltd. Third Oil Production Plant, Daqing 163000, China.

*Corresponding author: 10530537@qq.com

Abstract. In the Daqing Oilfield, the oil flooding of one type of oil layer was transferred to the subsequent water flooding, and the third oil recovery object gradually transferred to the thinner and worse two or three oil layers. Although the three types of oil layers are thinner and have lower physical properties, their reserves are large, reaching 1.86 billion tons, accounting for 44.6% of the total reserves of the Lamadian Oilfield, Sarto Oilfield, Xingshugang Oilfield. It is the sustainable development potential of the oilfields after the second type of oil layers. Aiming at the characteristics of three types of oil layers, such as thin oil layer, poor physical property and scattered distribution, it is determined that it is suitable for polymer flooding to develop reservoir objects and their utilization limits. It is one of the difficult problems for the three types of oil layers to further improve oil recovery.

Key words: Three types of oil layers, polymer flooding, injection target.

1. Introduction
At present, the old district of Daqing Oilfield has entered the mining stage of ultra-high water cut. Faced with the severe situation of ultra-high water cut, imbalance of storage and production, it is urgent to explore new technologies for increasing recoverable reserves and controlling the rate of water cut in the ultra-high water cut period of old oilfields. As the mature technology for enhancing oil recovery, the main oil layer polymer flooding has been widely used in Daqing Oilfield. The second type of oil layer polymer flooding has also entered the stage of industrialization promotion. The remaining thin oil layer and off-surface reservoir are not yet available. A mature technology that greatly enhances oil recovery. Therefore, it is urgent to verify the feasibility and technical and economic effects of the three types of oil layer polymer flooding, which are mainly based on the development of thin oil layers and surface layers, and to explore the technical methods for greatly improving oil recovery in the three types of oil layers [1].

2. Three types of reservoir characteristics

2.1. Geological Features
Compared with the main oil layers, the three types of oil layers are mainly composed of the inner and outer fronts of the delta. The general characteristics of the three types of oil layers are that the development of the river sand is small, the small layer is small, the thickness of the single layer is thin,
and the permeability is low. The longitudinal heterogeneity is serious and the phase transition is complicated. The main body shape, non-main body mat sand and extra-surface sand body are distributed alternately. According to the thickness and distribution characteristics of the mat sand, it is divided into thick and stable type, thin and stable type, poor and stable type, thin and unstable type.

### 2.2. Three types of oil layer microscopic characteristics

Compared with the first and second oil layers, the three types of oil layers have small pore throat radius and poor connectivity, and the permeability is low. It is difficult for crude oil to enter the small pore throat occupied by water, and the irreducible water saturation is obviously increased [2]. The three types of oil layer clay and mud content are high, the capillary resistance is large, more crude oil cannot be driven out, the residual oil saturation is high, and the discharge pressure is high. At the same time, the clay content is high and the reservoir properties are poor, resulting in a low relative permeability of the water phase.

![Comparison of oil and water infiltration curves with oils in the second type.](image)

**Table 1.** Statistics of pore structure and clay content of different types of oil layers.

| Serial number | Total clay (%) | Number of samples (block) | Average pore throat radius (μm) | Discharge pressure (MPa) |
|---------------|----------------|----------------------------|--------------------------------|-------------------------|
| 1             | 4.66           | 2624                       | 9.35                           | 0.052                   |
| 2             | 5.20           | 1006                       | 6.49                           | 0.090                   |
| 3             | 11.71          | 681                        | 4.59                           | 0.156                   |

### 3. Three-class oil layer polymer flooding indoor evaluation

#### 3.1. The better the relative molecular weight of the polymer matches the oil layer, the better the development effect

According to the relationship between the median value of the pore radius of the oil layer and the permeability, the polymer of a certain molecular weight can only pass through the porous medium which is compatible with it. Therefore, when selecting the molecular weight of the polymer, the permeability
value of the oil layer into which the polymer molecule can enter is taken into consideration. When the molecular weight of the polymer matches the permeability of the oil layer, the more pores the polymer solution can enter, the higher the degree of polymer flooding control, and the better the polymer flooding effect [3]. At the same time, the higher the molecular weight of the polymer, the greater the viscosity of the polymer solution, the better the oil-water mobility ratio, and the greater the recovery factor. Laboratory studies have shown that oil layers with a permeability of less than 50 x 10^{-3} \text{μm}^2 are suitable for polymers below 8 million molecular weight.

![Figure 2.](image1)

**Figure 2.** The relationship between the median pore radius and permeability of the oil development zone in the northern part of Sarto.

![Figure 3.](image2)

**Figure 3.** Polymer molecular weight and oil layer permeability curve.
3.2. Indoor flooding experiment

Using the 4 million, 6 million, and 8 million molecular weight polymers produced by Daqing Refining & Chemical Company, the same concentration of polymer solution was prepared, and the oil displacement experiments were carried out in different permeability cores. The results show that the ultimate recovery factor of the three types of oil layer polymer flooding is 4-8 percentage points. At the same time, the lower the oil layer permeability, the lower the relative molecular mass of the injectable polymer, and the worse the polymer flooding effect. Therefore, when selecting the relative molecular mass of the polymer, the polymer with a higher relative molecular mass should be selected as much as possible while matching the oil layer, and the oil displacement effect is good under the same conditions.

| Injection molecular weight (million) | Viscosity (mPa.s) | Effective permeability (mD) | Original oil saturation (%) | Water recovery ultimate recovery (%) | Polymer flooding ultimate recovery (%) |
|-------------------------------------|------------------|-----------------------------|-----------------------------|-------------------------------------|---------------------------------------|
| 400                                 | 30               | 11.70                       | 67.92                       | 36.41                               | 4.1                                   |
| 600                                 | 30               | 23.60                       | 66.81                       | 37.23                               | 5.9                                   |
| 800                                 | 30               | 69.20                       | 65.33                       | 39.86                               | 8.8                                   |

3.3. Establish a graph of polymer molecular weight, viscosity, and permeability

The relationship between polymer molecular weight, viscosity and permeability shows that when the oil layer permeability and the relative molecular weight match and the suitable injection viscosity, the polymer solution can be smoothly injected into the oil layer to expand the volume and improve the oil displacement efficiency. On the contrary, it will inject difficulties or block the oil layer, and the oil displacement effect is poor. Reasonable injection parameters are an important prerequisite for the development of three types of oil layers. Indoor results table, reasonable oil-mixing parameters of the third-class oil layer: permeability greater than 0.05μm² oil layer suitable for polymer molecular weight 8 million, viscosity 30mPa·s or more; permeability less than 0.05μm² oil layer suitable for polymer molecular weight 6 million, viscosity 20-30mPa · s; the surface oil layer with a sandstone thickness greater than 1 m is suitable for a polymer molecular weight of 4 million and a viscosity of 30 mPa·s or less.
4. Field application

In 2004, Daqing Oilfield carried out three types of oil layer field tests in the Gaotaizi oil layer in the eastern part of the North 2nd District. The test area is a thin oil layer with an effective thickness of less than 0.5m and a permeability of less than 0.05µm² in various leading-edge sedimentary types. The oil layer, the test proves that the three types of oil layer low-dispersion polymer flooding is feasible, and the oil displacement objects of the three types of oil layer low-dispersion polymer flooding are clarified, and the reasonable injection parameters of the three types of oil layer low-dispersion polymer flooding are determined. Increased oil recovery by 5.2 percentage points [4].

During the test, during the 4 million molecular weight polymer flooding, the water cut of the production well was small. Compared with the water flooding, the minimum water cut only decreased by 2.5%, which was equivalent to the enhanced oil recovery by water flooding; Although the initial stage showed the effect of increasing oil and precipitation, the inhalation profile showed a significant reversal phenomenon in less than half a year. The proportion of inhaled thickness in the surface and off-surface oil layers decreased by 10.0 and 3.0 percentage points respectively, and the water content of the production well rose by 2 percentage points; After the conversion of 6 million molecular weight, the production well appeared twice effective. After the water content decreased by 2%, the low value period was stabilized for another 10 months, the suction profile became better, and the ratio of the in- and out-of-surface oil layer suction thickness increased respectively compared with the 8 million molecular weight period. At 6.0 and 3.0 percentage points, this stage is also the period with the largest increase in recovery rate. The comprehensive analysis shows that the suitable polycondensation parameters of the oil layer with effective thickness less than 0.5m and permeability less than 0.05mm² are polymer molecular weight of 6 million and injection viscosity of 20-30mPa·s.
The inhalation conditions of different types of sand bodies in the four million-merging stages of 4 million, 8 million and 6 million indicate that the main sand with effective thickness greater than 0.5 m has good inhalation conditions during the injection process, and the sandstone multiple suction thickness ratio is above 70%. The effective thickness of less than 0.5 m non-main body sand during the injection of 400 million to 6 million molecular weight multiple inhalation thickness ratio of about 60%, which indicates that the effective thickness of less than 0.5 m non-main body sand is suitable for 4-6 million molecular weight polymers.

Figure 6. Statistical table of continuous inhalation status at different molecular weight stages in the test area.

In the injection wells with pure surface oil layer development, under the condition that no injection measures are taken, the suitable injection polymerization parameters are polymer molecular weight of 4...
million and injection viscosity of less than 20 mPa • s. The north 2-5-more water 74 well in the test area is mainly open to the outside, and the whole well is shot at 10 layers, with 9 outer layers and a sandstone thickness of 10.1m. The well has a molecular injection frequency of 4-6 MPa, an average injection pressure of 13.6 MPa, an injection concentration of 1000 mg/L, and an injection viscosity of 20 mPa • s. The injection pressure is 2.4 MPa higher than that before injection, and is 0.4 MPa lower than the fracture pressure. The utilization ratio reached 46.8%, which was 27.8% higher than the whole region. After transferring 8 million molecular weight, only one oil layer in the watch absorbs liquid, and the outer layer of the watch does not move \[5,6\]. The relationship between the degree of stage production and the injection time shows that the molecular weight of 4 million by polymer flooding is equivalent to that of water flooding, but the input cost is higher than that of water flooding. From the perspective of economic benefits, the oil layer outside the surface is not suitable for polymer flooding development.

5. Conclusion
The three types of oil layer polymer flooding oils, which are mainly composed of thin and extra-layer reservoirs, are the oil layers in the surface, and the off-surface reservoirs are not suitable for polymer flooding development.

Suitable for the polymerization parameter is the premise of ensuring the effect of polymer flooding. The effective thickness is less than 0.5m, the thin layer and the outer oil layer with permeability less than 50mD are suitable for injecting parameters of 400-600 million molecular weight, viscosity 20-30mPa•s polymer. Blockage will occur, the overall utilization ratio of the oil layer is high, and the oil displacement effect is good.

Acknowledgments
Wang Min was born in 1983, female, Anda City, Heilongjiang Province, who is engineer in Daqing Oilfield Co., Ltd. Third Oil Production Plant and is mainly engaged in tertiary oil recovery in three types of oil layers.

References
[1] Li Yang, Cao Gang. Development technology of low permeability sandstone reservoir in Shengli Oilfield. Petroleum Exploration and Development, (32 January 2005) pp. 123-126.
[2] Liao Guangzhi, Niu Jingang, Shao Zhenbo, et al. Industrial polymer flooding effect and main practices in Daqing Oilfield. Daqing Petroleum Geology and Development, (23 January 2004) pp. 48-50.
[3] Shen Pingping, Yuan Shiyi, Deng Baorong, et al. Influencing factors of chemical flooding efficiency and displacement efficiency. Petroleum Exploration and Development, (31 May 2004) pp. 1-4.
[4] Lu Xiangguo, Wang Keliang, Gao Shusen, et al. The optimal range of polymer relative molecular mass selection. Journal of Daqing Petroleum Institute, (22 March 1998) pp. 18-20.
[5] Zhang Xiaojin, Guan Heng. Development and practice of polymer flooding in three types of oil layers in Daqing Oilfield. Petroleum Exploration and Development, (33 March 2006) pp. 374-377.
[6] Fujin Jiang, Zeng Hongmei. Three types of oil layer periodic mass spectrometry objects and layer system optimization combination. Daqing Petroleum Geology and Development, (26 January 2007) pp. 100-103.