Application of Chemical Flooding in Increasing Yield of Tertiary Oil Recovery

Xun Wang *
Geological Team of No.1 Oil Production Plant, Daqing Oilfield Limited Liability Company, Daqing 163000, China

*Corresponding author e-mail: Wangxun@Petrochina.Com.Cn

Abstract. This paper mainly explores the application measures of chemical flooding in increasing yield of tertiary oil recovery to. In the research process, taking the overview of tertiary oil recovery as the starting point, analyze that oil extraction can be divided into three stages, tertiary oil recovery as the last link, and the crude oil recovery rate needs to be improved. On the basis of this research, the application mechanisms of polymer flooding, alkaline flooding, surfactant flooding, and ASP flooding are proposed, make actual application measures are clear, so as to provide references for related workers.

Keywords: chemical flooding; tertiary oil recovery; recovery ratio; application.

1. Introduction
Petroleum as a non-renewable energy, the process of developing the oil field can be divided into three stages, tertiary oil recovery is to use natural energy extract and supplement traditional artificial energy, develop mine tailings by chemical, physical and other means, transform the displacing phase and oil-water interface nature by steam injection, chemical injection, microbial injection, etc., it can also be called enhanced oil recovery. Among the tertiary oil recovery technologies, the chemical drive can be used to improve the recovery ratio of crude oil; it is consistent with China's national conditions, can be applied on a large scale, which obtain good results in developing oil fields.

2. Overview of Tertiary Oil Recovery
Oil is not only a common industrial energy source, but also a kind of energy source in daily life, which can be used in all aspects of life. As the exploration of oil resources in the world gradually increase, shallow oil decreases with it, in order to promote the economic development of the country, the detailed analysis should be carried out in the practical management in combination with of the extraction technology and oil reserves, make clear that oil extraction can be divided into three stages (as shown in Table.1) [1].
Table 1. Recovery ratio of tertiary oil recovery

| flooding methods         | primary oil recovery | secondary oil recovery | tertiary oil recovery |
|--------------------------|----------------------|------------------------|----------------------|
| natural water flooding, dissolved gas flooding, gravity flooding, elastic energy flooding, etc. | 5-10%                | 30-35%                 | 45-50%               |
| gas cap flooding, water flooding |                      |                        |                      |
| thermal oil recovery, gas mixed-phase flooding, chemical flooding |                      |                        |                      |

Primary oil recovery is based on the original pressure of the bottom layer, and directly presses the crude oil to the surface; the recovery ratio is only 5-10% due to the primitive process and technology in this process. Moreover, under the theory of seepage, the reduction of formation pressure and oil recovery will also affect the actual well recovery.

Secondary oil recovery is to inject high-pressure water into the underground, use the injected water to drive the original role of the underground to achieve secondary oil recovery, with the deepening of the exploration project; the recovery ratio can reach about 30%. However, under the promotion of secondary oil recovery, the available original reserves gradually decreases, and the oil content after liquid production is less than 10%, which cannot improve the recovery quality of crude oil[2]. In the secondary oil recovery, 40-60% crude oil can be recovered, and part of the crude oil is still in the rock fracture.

Tertiary oil recovery is a way to develop tailings oil by chemical, physical and other technologies.

3. Application of Chemical Flooding in Increasing Yield of Tertiary Oil Recovery

On the basis of secondary oil recovery, tertiary oil recovery project uses optimized measures for flooding operations, ensures the crude oil recovery ratio and the effectiveness of the operating mechanism, and increases the crude oil recovery ratio by 20%. According to the analysis, chemical flooding technology can improve the oil yield while improving oil recovery quality; it can be divided into polymer flooding, alkaline flooding, surfactant flooding, and ASP.

1. Polymer flooding

When the injected water affects the oil layer, under the effect of capillary fluid resistance and wettability on the rock surface, there are still many residual oils after water flooding, they stay in the porous medium in the form of columns, clusters, membranes, islands, blinds and rings. In polyacrylamide flooding, high molecular weight and a certain amount of polyacrylamide are mainly added to the injection water to increase the viscosity of the injected water and improve the oil-water mobility ratio [3]. The viscosity of the polyacrylamide solution is higher after injection, and its viscoelastic effect and residual resistance coefficient can be improved by passing through the oil layer. In addition, the retention of polyacrylamide in the rock can reduce the water phase permeability, and the residual resistance coefficient exceeds 1, and reduces the water-oil mobility ratio, thereby displacing the clustered residual oil and residual oil that cannot be affected by water flooding. The higher the viscosity, the larger the residual resistance coefficient, the displacement phase mobility is reduced, the mobility ratio of the displaced phase and the displacing phase is reduced; polyacrylamide flooding to expand the microscopic and macroscopic sweep efficiency is increased, and improves the recovery ratio value.

2. Alkaline flooding

The mechanism of alkaline flooding in tertiary oil recovery is more complicated, and there are mainly the following mechanisms in application: one is low interfacial tension. The acidic components of crude oil can react with alkali to produce active substances, the optimal salt concentration can reduce the oil-water interfacial tension $\leq 10^{-2}\text{mN/m}$ to the lowest value, this can promote alkaline flooding to obtain the same effect as surfactant flooding. Therefore, underground crude oil has higher acid value can be used for alkaline flooding, and the acidity of the crude oil can be converted into active substances, such as naphthenic acid [4]; the second is to change the wettability. When the alkali concentration is 1-5%, there are oil-soluble active substances on the rock surface, alkaline flooding can be used to change the
solubility of the substances, and then desorb them, restore the hydrophilism of the rock surface, and make the rock change from oil wetting to water wetting, promote the improvement of displacement efficiency; the third is emulsification. The acidic substances in crude oil can react with alkali to produce surface active substances and reduce the oil-water interfacial tension; therefore, the alkali solution in the formation can form the oil-in-water emulsion with the crude oil. After the emulsion is formed, it can not only increase sweep coefficient by the fluid resistance effect, the emulsified oil will no longer stick to the rock surface, thereby increasing the displacement efficiency.

3. Surfactant flooding

In tertiary oil recovery, surfactant flooding is to add appropriate surfactants to the water injection to reduce the oil-water interfacial tension, displace the residual oil in water flooding, and reduce the oil saturation. This efficiency is described by the capillary number of overall efficiency parameter:

\[ N = \frac{v}{\gamma_{ow} \mu} \]  

N is the capillary number; v is the displacement speed; \( \mu \) is the viscosity of the displacement fluid; \( \gamma_{ow} \) is the interfacial tension between the displacement fluid and the oil. In order to reduce the residual oil saturation, the capillary number needs to be increased by 4 orders of magnitude, the oil layer pressure and injection volume are limited, only increasing \( \mu \) and v is not enough, and \( \gamma_{ow} \) can be reduced by 3 orders of magnitude or more to increase the capillary number.

After analyzing the stress and characteristic effects of surfactant molecules in the water-flooding residual oil at the oil-water interface, it is believed that the surfactants in the enhanced oil recovery also include the following mechanisms:

1. The coalescence and formation oil belt mechanism, wash more and more oil droplets on the rock surface, and merge with other oil droplets after forming oil belts to drive residual oil to production wells.

2. Emulsification mechanism, emulsification capacity is strong for surfactants of crude oil, can quickly strip and disperse the oil on the rock surface, form the oil-in-water emulsion, improve the water-oil two-phase mobility ratio, and increase the sweep coefficient. In addition, the surfactant is adsorbed on the surface of the oil droplets, and the oil droplets are not easy to stick to the layer and can flow to the production well with the active water.

3. Increase the surface charge density, oil displacement uses anionic surfactants, which can be adsorbed on the surface of rocks and oil droplets, increase the surface charge density, thereby increasing the electrostatic repulsion between rocks and oil droplets.

4. Change the oil wettability of the rock surface, the proper surfactant can change the rock surface from oil wettability to water wettability, thereby reducing the adhesion of oil droplets on the rock surface [5].

5. Change the rheological incentives of crude oil, the nature of crude oil is like the non-Newtonian fluid, surfactant is used to expand the oil displacement, part of it is integrated into the oil and adsorbed on the asphalt mass points, which can enhance the firmness of the solvated shell, reduce the interaction of asphalt mass points, and weaken the macromolecular grid structure of crude oil.

4. ASP

ASP technology improves oil recovery by injecting mobility control agent and interfacial tension reducer at the same time, the equation of recovery ratio is as follows:

\[ N_p = \frac{E_v E_p V_p S_{oi}}{B_o} \]

\( N_p \) is the total volume of crude oil produced; \( E_v \) is the volume sweep coefficient; \( E_p \) is the oil washing efficiency coefficient; \( B_o \) is the formation volume coefficient; \( V_p \) is the pore volume; \( S_{oi} \) is the original oil saturation.

The combination of surfactant and alkali changes the relative permeability characteristics, increases \( E_p \), and the mechanism is to change the wettability, solubilize oil, and reduces the interfacial tension, the last one is the main mechanism, and it improves recovery ratio by increasing the capillary number (capillary number=viscous force/capillary force). The capillary number can be controlled by increasing...
the Darcy velocity of the injected fluid, fluid viscosity or reducing the interfacial tension between the crude oil and the injected fluid. The control effect of capillary number of interfacial tension in the reservoir is significant, and the residual oil capillary number needs to be increased by at least 100 times after water flooding. Reducing the oil saturation will increase the effective water permeability and increase the mobility ratio; only adding the interfacial tension reducer to the injected water may increase the viscous fingering and reduce the sweep coefficient.

The addition of polyacrylamide in the injected fluid can improve the mobility ratio, eliminate and reduce the reservoir sweep coefficient via combination flooding, and the addition of polymer polyacrylamide in the injected water can also improve the mobility control. Combination flooding mainly improves the original recovery ratio by reducing the interfacial tension, increases the viscosity of the injected fluid, reduces the viscous fingering, reduces the relative permeability of the water phase, causes the fluid special project and promotes the expansion of the sweep coefficient [6]. Increasing the two coefficients simultaneously will synergistically increase the original recovery ratio; it is not a simple addition, the residual oil produced by single polymer flooding can produce 10-18%, and the interfacial tension reducer can produce 6-17% of the residual oil after injection, injecting polymer and alkali simultaneously can obtain 73-95% of residual oil.

4. Example Applications
A crude oil development area is divided into oil layer sedimentary units (as shown in Table 2).

| Sedimentary sand body parameters | Table 2. Sedimentary sand body parameters |
|---------------------------------|------------------------------------------|
| sedimentation type              | foreland phase                           | foreland phase |
|                                 | Class I | class II | class III1 | Class III2 | Class IV |
| number of layers                | 6       | 19       | 14         | 14         | 23       | 16       |
| sandstone (m)                   | 10.82   | 25.93    | 14.36      | 9.39       | 10.46    | 3.04     |
| effective (m)                   | 4.88    | 9.32     | 3.97       | 1.96       | 1.41     | 0.55     |
| untabulated thickness (m)       | 2.10    | 7.45     | 6.00       | 5.40       | 7.67     | 2.08     |

The lithology of the thin effective layer is mostly siltstone and fine rock, the average air permeability is 0.267 µm², the average porosity is 25.5%, and the oil saturation is 62.4%. In the untabulated reservoirs, there are poor sand and mud separation, high shale content, fine sandstone particles, low oil saturation and porosity and permeability performance, the lithology is mostly muddy siltstone, the mud content is 14.1% and the sand content is 65.4%. The average air permeability is 0.020 µm², the average porosity is 21.5%, the oil saturation is 42.1%, the oil spots are the main, and the oil stains and oil immersion are about 27%. This development zone is a high-freezing point, low-sulfur paraffin base crude oil its carbon element is 86.06%, the medium and low molecular polyacrylamide is used for oil displacement, it seeps in the pore medium of the oil layer, is affected by chemical adsorption, mechanical trapping and retention, can retain part of the polyacrylamide molecules in the pore medium of the oil layer, reduce the pore permeability of the oil layer, and increase the fluid flow resistance. Under the same mass concentration of polyacrylamide, the higher the relative molecular mass, then the viscosity increasing effect will increase, if the limit is exceeded, the injection may not be successful or the formation may be blocked. By analyzing the permeability of the oil layer in the development zone, the polyacrylamide with 6 million molecular weights is selected as the main, the concentration is 1900 mg/L, the recovery ratio in natural core flooding is increased by 8.78%, and has a good recovery effect.

On the basis of the original price of RMB 1040/t, the calculated project incremental financial indicators are 28.3% of pre-tax internal income; net present value is 48.02 million Yuan, pre-tax investment payback period is 4.7 years, the incremental financial indicators conforms to industry requirements, and it has strong anti-risk ability and high economy.
5. Summary
In summary, the rapid development of oil exploration projects in China in recent years has not only promoted the advancement of oil extraction technology, but also made oil displacement effect more economical. Therefore, it is necessary to select the best oil displacement technology in combination with the actual situation, follow the idea of green development and environmental protection, and carry out detailed treatments for different oil displacement mechanisms, so as to increase the recovery ratio based on reducing costs and promote the sustainability development of oil projects.

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