Influence of stability of polymer surfactant on oil displacement mechanism

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Abstract: At present, most of the oilfields of China have entered the late stage of high water-cut development, and three oil recovery technique has become the leading technology for improving oil recovery. With the improvement of three oil recovery techniques, the polymer surfactant flooding technology has been widely promoted in oil fields in recent years. But in the actual field experiment, it has been found that the polymer surfactant has chromatographic separation at the extraction end, which indicates that the property of the polymer surfactant has changed during the displacement process. At present, there was few literature about how the stability of polymer surfactant affects the oil displacement mechanism. This paper used HuaDing-I polymer surfactant to conduct a micro photolithography glass flooding experiment, and then compared the oil displacement law of polymer surfactant before and after static setting. Finally, the influence law of stability of polymer surfactant on the oil displacement mechanism is obtained by comprehensive analysis.

1. Introduction

Polymer surfactant flooding technology has been popularized in oil fields in recent years. Polymer surfactant has good anti-viscosity, anti-salt, anti-oxidative degradation, anti-biodegradation, selective water-blocking and other characteristics, so it has attracted the attention of major oilfields. Compared with common polymer molecular structure, the hydrocarbon chain of polyacrylamide of polymer surfactant has functional groups, so the aqueous solution of polymer not only has double characteristics, but also has new characteristics.

At present, the research on polymer surfactant mostly stays in the study of oil displacement mechanism between different polymer surfactant. The contents of the study include: viscoelasticity of polymer surfactant, displacement efficiency, sweep area and distribution of residual oil after displacement, etc. However, there was a lack of in-depth research on “Influence of stability of polymer surfactant on oil displacement mechanism”

In this work, we have used a new method of testing, firstly, the micro photolithography glass flooding experiment was carried out with a newly prepared Huading-I polymer surfactant. Then, the same Huading-I polymer solution was prepared for 30 days. Afterword, we used that solution to carry
out micro photolithography glass flooding experiment. By comparing the two experimental results, the influence law of stability of polymer surfactant on the oil displacement mechanism is obtained.

2. Experimental materials and experimental scheme

2.1. Experimental materials and conditions
Experimental instruments: sample container, micro photolithography glass, constant speed constant pressure pump, camera, microscope, computer.

Experimental conditions: in order to simulate the reservoir state of Daqing oilfield, the experiment was carried out under the condition of 45℃.

Experimental reagents: Simulated formation water in Daqing oilfield with salinity of 6778mg/L, clean water and sewage from first oil production plant in Daqing Oilfield, simulated oil with viscosity of 9.8 mPa·s at 45℃, Huading-I polymer surfactant.

The chemical oil displacement agent is configured with clean water and diluted with sewage

| Table 2-1. Viscosity of different displacement agents (45℃) |
|----------------------------------------------------------|
| Concentration 1000 mg/L | Huading-I | Huading-I static setting for 30 days |
| viscosity (mPa·s) | 53 | 103 |

2.2 Experimental scheme

| Table 2-2. Experimental scheme of microscopic displacement |
|----------------------------------------------------------|
| Scheme Number | Specific scheme |
| NO.1 | Water flooding to water content 98% + Huading-I polymer surfactant 1PV+ Subsequent water flooding |
| NO.1 | Water flooding to water content 98% + Huading-I static setting for 30 days 1PV+ Subsequent water flooding |

2.3 Experimental steps

(1) The microscopic model is vacuumed and saturated water
Pumping a photolithographic glass model into a vacuum, and then saturated water by injecting with Daqing formation water into the micro photolithography glass model. Finally, saturated oil by injecting with simulated oil.

(2) Water flooding stage
We used the one injection and one extraction of well and the constant speed of micro pump to carry out a displacement experiment. Stop the experiment when the outlet does not produce oil. In order to ensure the repeatability and comparative of the experiments, it is required that the main channel between the injection-wells should be formed at the end of the water flooding phase, if not, the experiments need to be repeated, after water flooding experiment meet the requirements for the subsequent chemical flooding.

(3) Chemical flooding stage
Firstly, prepared the liquid of the chemical agent, and then the flow rate of the constant speed trace pump was set to 0.03mL/h for the chemical drive and the injection of 1PV chemical agent. At the same time, taking photos of the whole displacing process at the injection end and the extraction end. Finally, taking a local picture of the remaining oil areas, and then taking the picture of chemical flooding, the purpose is to compare with the full picture after water flooding, so as to observe the effect of chemical flooding.

(4) Subsequent water flooding
Shoot at the end of the well until the oil is not appear. Because the glass is too small to calculate the amount of liquid, the total effluent is used as the index of moisture content of 98%. And then taking
the local picture of the remaining oil area, and then taking the full picture of subsequent water flooding, the purpose is to compare with the chemical flooding, so as to observe the effect of subsequent water flooding.

3. **Comparison of oil displacement mechanism before and after stability change of polymer surfactant**

3.1 **Comparison of overall oil displacement effect of the model**

![Figure 3-1. The concentration of polymer surfactant solution is 1000 mg/L before and after static setting.](image)

The above figure has a Huading-I polymer surfactant before static setting (left in the figure) and a Huading-I polymer surfactant after static setting (right in the figure). We can see from the figure, the solution on the left is clear, the solution color on the right is muddy, and a large number of flocculent substance appeared.

| Scheme                  | Water flooding (%) | Polymer surfactant flooding (%) | Subsequent water flooding (%) | Overall (%) |
|-------------------------|--------------------|---------------------------------|------------------------------|-------------|
| Huading-I before static setting | 25.9               | 54.3                            | 2.1                          | 82.3        |
| Huading-I after static setting | 29.8               | 55.7                            | 1.0                          | 86.5        |

As shown in table 3-1, the polymer surfactant before and after static setting, all of their swept area of the polymer surfactant flooding stage were improved, and the swept area of the polymer surfactant after static setting for 30 days was increased by 1.4% compared with the polymer surfactant before static setting. It can be seen that the change of stability has certain influence on the oil displacement mechanism of the polymer surfactant.

The following is to compare the model of oil displacement effect of polymer surfactant before and after static setting.

![Figure 3-2. Oil and water distribution diagram of Huading-I polymer surfactant before static setting.](image)

![Figure 3-3. Oil and water distribution diagram of Huading-I polymer surfactant after static setting.](image)
As we can see from the two pictures, at the end of displacement, the remaining oil volume of Huading-I polymer surfactant after static setting is lower than the remaining oil volume of Huading-I polymer surfactant before static setting. That is to say, the effect of displacement of Huading-I polymer surfactant after static setting is better than that before static setting.

3.2 Comparison of oil displacement mechanism of polymer surfactant before and after static setting

![Figure 3-4](Image)
**Figure3-4** Entrance of Huading-I polymer surfactant before static setting

![Figure 3-5](Image)
**Figure3-5** Exit of Huading-I polymer surfactant before static setting

![Figure 3-6](Image)
**Figure3-6** Entrance of Huading-I polymer surfactant after static setting

![Figure 3-7](Image)
**Figure3-7** Exit of Huading-I polymer surfactant after static setting

Figure 3-4 and 3-5 can be seen, Huading-I polymer surfactant before static setting, at the entrance not found oil was emulsified into small droplets. At exit, only a small amount of oil was emulsified into small droplets, most of the oil is extracted in the form of oil flow under the displacement of the polymer surfactant.

You can see from the displacement process of Huading-I polymer before static setting:

1) The oil displacement mechanism of Huading-I polymer before static setting is to adjust profile, enlarge swept area, and then drive oil.

2) It mainly uses the viscoelasticity of the polymer surfactant to drag the crude oil in the pore to drive oil. The polymer surfactant before static setting has certain emulsification effect, but it is not strong, it is not the main function of improving oil displacement efficiency.

3) It has no obvious effect on the remaining oil be utilized in the main line and the corner area, mainly by displacing the remaining oil on both sides to improve the oil displacement efficiency.

4) In the process of displacement, the molecular chain of Huading-I polymer surfactant is long, and it is not easy to break, and the deformation ability is generally in the pore.

You can see from the displacement process of Huading-I polymer after static setting:

1) The oil displacement mechanism of Huading-I polymer before static setting is also to adjust profile, enlarge swept area, and then drive oil. But in the middle stage of displacement, however, it can displace the remaining oil in the main line.
2) Polymer surfactant after static setting mainly through emulsification to improve displacement efficiency, and then the emulsified crude oil is extracted by the viscosity of the polymer surfactant.

3) The areas on both sides of the mainstream line are well utilized by Huading-I polymer surfactant after static setting 30 days, and the remaining oil in the corner area and the main line area is well utilized. The effect of oil washing displacement is obviously higher than before.

4) The piston displacement capacity of the polymer surfactant in the pores was higher than that before static setting. We can be concluded that the molecular chain of Huading-I polymer surfactant after static setting is easy to be broken when displacing oil in the pores, and its deformability in the pores is stronger than that before the static setting. And its self-crosslinking of the netted space structure increases the deformation capacity.

4. Conclusions

(1) The oil displacement mechanism of Huading-I polymer surfactant before and after static setting are to adjust profile, enlarge swept area, and then drive oil. But after 30 days of polymer surfactant, the displacement effect of the main line was better than that before the static setting.

(2) Huading-I polymer surfactant has a certain emulsification effect before the static setting, but the effect is not obvious, mainly depends on the viscoelasticity of the polymer surfactant to drive oil. However, after 30 days of Huading-I polymer surfactant, the emulsification effect increased obviously, and the crude oil was mainly emulsified into small oil droplets and then was extracted by displacing.

(3) The molecular chain of Huading-I polymer surfactant after static setting is easy to be broken when displacing oil in the pores, and its deformability in the pores is stronger than that before the static setting. And its self-crosslinking of the netted space structure increases the deformation capacity.

(4) The stability of Huading-I polymer surfactant has obvious influence on the oil displacement mechanism, mainly reflected in the increase of emulsification effect, and the swept area of Huading-I polymer surfactant after static setting 30 days is higher than that before static setting.

Acknowledgments

This work was supported by Natural Science Foundation of Heilongjiang Province " Study on Displacement Mechanism of Polymer Agent under Reservoir Condition "(No. E2016016) and National Natural Science Foundation of China Youth Science Fund Project "The Law and Mechanism of Effects of Base Parameters on CO2 - Crude Oil at Core Scale " (Grant No. 51704075).

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