Study on Variation of Physicochemical Parameters of the Polymer/Surfactant Binary Multisystem in Porous Media

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Abstract. The sulfonate Gemini surfactant and hydrophobic associating polymers were prepared with different ratio in multisystem, and we measured viscosity and interfacial tension of the solution before pour it into the core. The multisystem with different ratio was poured into the core, we measured the produced liquid viscosity, interfacial tension, the concentration of polymer and surfactant at core outlet with different injection stage and at different locations after stable, calculated the dynamic adsorption capacity of the binary multisystem, and measured the static adsorption capacity of binary multisystem with different ratio on natural oil sand in Suizhong 36-1 Oilfield. Experimental results show that the stable viscosity of the produced liquid of multisystem increased with increase of polymer concentration, and decreased with the increase of the distance flowed through the core, and these changes concentrated on the first 1/3 of core; the interfacial tension decreased with the increase of mass fraction of surfactant, the stable interfacial tension value after passed through the core was about 7-10 times before solution injected; Multisystem has the chromatographic fractionation in rock.

1. Introduction

Chemical flooding is an effective method to enhance oil recovery, including polymer flooding, surfactant/polymer flooding, alkaline/surfactant/polymer flooding and so on. The effects of surfactant/polymer (SP) flooding and alkali/surfactant/polymer (ASP) flooding are similar, but the surfactant/polymer (SP) flooding has no alkali, weakening the negative effects of the scaling, so the SP flooding technology will become the main research direction of chemical flooding enhanced oil recovery technology [1].

Bohai Suizhong 36-1 oilfield is typical of China's offshore heavy oil field, it has some characteristic such as high viscosity, high porosity and permeability, the high degree of mineralization etc. With the continuous water flooding, the oilfield has gradually entered the medium and high water cut stage. Then apply polymer flooding, but it is restricted by the offshore oil reservoir, environment and engineering condition, polymer flooding technology faces challenges on offshore heavy oil field [2]. In order to apply polymer/surfactant binary combination flooding at offshore oil field after polymer flooding, the actual changing patterns of physicochemical parameters of binary multisystem in Bohai Suizhong 36-1 oilfield reservoir porous medium should be learnt [3].
At present, there are many the experiments of performance analysis of chemical displacing agent in porous media, Zhao Qinghui etc. studied the rheological characteristics of ternary multisystem in porous media through the laboratory experiment [4]; There are researches on solution of partially hydrolyzed polyacrylamide passed through the core, the viscosity of produced fluid at different time and pressure difference of polymer solution passing through core [5]. There are also a lot of researches, through the core experiment, analyzed the actual viscosity and viscosity loss factor of polymer solution in porous media in polymer flooding [6-7]. Although there is the study on surfactant adsorption of chemical flooding [8] and the study on interfacial tension of surfactant [9], but study on changing patterns of interfacial tension and adsorption properties of binary multisystem in porous media is less [10].

This paper designed that by the use of TEXAS-500 spinning drop interfacial tension meter and Brookfield viscometer, we can measured and contrasted interfacial tension, viscosity concentration of binary multisystem at the static condition and after passed through the artificial core of different length, measured and calculated dynamic and static adsorption capacity of the binary multisystem on natural oil sand, and then study the actual changing patterns of physicochemical parameters of binary multisystem in porous media, it provides a reference to binary multisystem performance in the seepage of actual reservoir[11].

2. The experimental conditions

2.1. Simulated water
Total salinity of simulated water which used for experiments is 9374.13mg/L, ionic contents of simulated water are shown in Table 1.

| Ionic composition | Na⁺ | K⁺ | Ca²⁺ | Mg²⁺ | Cl⁻ | CO₃²⁻ | HCO₃⁻ | SO₄²⁻ | Total salinity |
|------------------|-----|----|------|------|-----|--------|--------|--------|---------------|
| Ionic contents /mg·L⁻¹ | 3091.96 | 276.17 | 158.68 | 5436.34 | 14.21 | 311.48 | 85.29 | 9374.13 |

2.2. The experimental agent
Polymers in binary multisystem are hydrophobic associating polymer HNT300 provided by CNOOC Research Institute, the molecular weight is about 1600×10⁴[12]; surface active agent is sulfonate Gemini surfactant BH-M2 provided by Southwest Petroleum University [13].

2.3. The experimental oil
Simulated oil used in experiment is prepared by the mixture of crude oil and kerosene oil provided by oil field according to a certain proportion, and its viscosity is 70mPa·s at temperature of 65℃.

2.4. The cores
The gas permeability of artificial cores which used in experiment is about 2500×10⁻³ m², and length is 0.9m, the cores opened the receiving port in the distance of 0.1m, 0.2m, 0.3m and 0.6m of the entrance.

2.5. The experimental instrument
The experimental instrument of physicochemical performance evaluation of binary multisystem include BROOKFIELD DV-III Digital Viscometer, Model TX500C interfacial tension instrument [14];
test equipment of physicochemical parameters of binary multisystem in porous media include advection pump, pressure gauge, core holder and the piston container etc. In experiment, expect advection pump, other instruments should be placed in the constant temperature box of 65°C.

3. The experimental method

3.1. Determination of static viscosity and interfacial tension of binary multisystem

(1) Measurement of viscosity: determine the viscosity of the solution using BROOKFIELD DV-III viscometer, first using the No.0 rotor shear 30s with the speed of 100rpm, then set aside and preheating 90s, after that began to test the apparent viscosity; Determination conditions: No.0 rotor, 6r/min, the shear rate is 7.35s⁻¹, a constant temperature of 65°C.

(2) Measurement of interfacial tension of oil–binary multisystem: determining interfacial tension of binary multisystem and simulated oil (viscosity of 70mPa.s) using Model TX500C interfacial tension meter; Determination conditions: temperature of 65°C, the speed of 6000r/min.

3.2. The steps of the experiment

(1) According to the ratio prepared binary multisystem with target concentration, determining interfacial tension and viscosity at the static condition;

(2) Using vacuum pump for vacuum pumping the core 4-8 hours, and then saturate the simulated water into the core, pore volume of the core would be obtained by the amount of saturated water;

(3) Driving the binary multisystem solution pass through core by pump, every 0.3PV determining viscosity, interfacial tension and concentration of produced liquid at the 0.9m outlet, until two consecutive sample determinations of viscosity, interfacial tension, and concentration value are stable;

(4) After steady, orderly taking samples from the receiving port respectively at 0.6m, 0.3m, 0.2m and 0.1m of the core, determining interfacial tension, viscosity and concentration of the produced liquid;

(5) Driving formation water pass through the core by pump about 4PV, and the experiment is end.

3.3. The experimental scheme

In order to contrast effects of the concentration of polymer and surfactant in binary multisystem on physicochemical parameters, making the following seven kinds of experimental schemes, see Table 2.

| Scheme  | Polymer concentration /mg·L⁻¹ | Surfactant mass fraction /% |
|---------|------------------------------|-----------------------------|
| Scheme 1| 500                          | 0.20                        |
| Scheme 2| 1250                         | 0.20                        |
| Scheme 3| 1750                         | 0.20                        |
| Scheme 4| 2000                         | 0.20                        |
| Scheme 5| 1750                         | 0.05                        |
| Scheme 6| 1750                         | 0.10                        |
| Scheme 7| 1750                         | 0.15                        |

4. Experimental results and analysis

4.1. The variation of viscosity of binary multisystem in the porous media

(1) The variation of viscosity and polymer concentration of binary multisystem after passed through the core with injecting PV number.

When the binary multisystem with polymer concentration of 1750mg/L and surfactant mass fraction of 0.2% passed through a 90cm long core, the variation of viscosity and polymer concentration of produced liquid with the injecting PV number can be shown in the figure below.
Figure 1. The variation curve of viscosity and concentration of binary multisystem with injecting PV number after passed through the core

As shown in Figure 1, the trend of the viscosity and polymer concentration of produced liquid with the injecting PV number is very similar, which indicates that the viscosity of produced liquid is mainly affected by the polymer concentration, it also proves the correctness that the viscosity changes with the injecting PV number. With the increase of injecting PV number, at the beginning, the viscosity of produced liquid is not changed, and it is close to that of water. When the injection volume comes to about 1PV, the viscosity of produced liquid begins to increase. And when the injection volume comes to about 1.8PV, the viscosity reaches a stable value, then the viscosity has a small fluctuation around the stable value.

From the analysis, we can know that in the core the viscosity loss of binary multisystem mainly comes from the following aspects: 1) The decrease of polymer concentration in binary multisystem; 2) The shear action on the polymer macromolecule of binary multisystem from the core pore[15].

(2) The variation of viscosity of binary multisystem in the different position of the core

When the binary multisystem reaches a flow balance in a 0.9m long core, the following figure shows the viscosity experiment results of binary multisystem in 0.1m, 0.2m, 0.3m or 0.6m from the entrance of the core.

Figure 2. The variation curve of viscosity of produced liquid in different position of the long core

As shown in Figure 2, when the binary multisystem reaches a flowing balance in the core, the viscosity of the binary multisystem decreases with the increase of the distance flowed through the core, and the variation of viscosity is mainly concentrated on the first 1/3 of the core.

(3) The variation of viscosity of binary multisystem of different polymer concentration after passed through core.
We compared the different viscosity and viscosity retention of the binary composite system with different polymer concentration after passed through the core, we get the following results.

![Figure 3](image)

**Figure 3.** The relationship between the viscosity, viscosity retention and polymer concentration of binary multisystem

As found in Figure 3, the viscosity of binary multisystem increases with the increase of the polymer concentration: The higher the polymer concentration of the binary multisystem, the lower the viscosity retention after passed through the core.

5. Conclusion

(1) The trend of the viscosity and polymer concentration of produced liquid of binary multisystem with the injecting PV number is very similar, which indicates that the viscosity of produced liquid is mainly affected by the polymer concentration. With the increase of injecting PV number, at the beginning, the viscosity of produced liquid is not changed, and it is close to that of water. When the injection volume comes to about 1PV, the viscosity of produced liquid begins to increase, and when the injection volume comes to about 1.8PV, the viscosity reaches a stable value, then the viscosity has a small fluctuation around the stable value.

(2) The viscosity of binary multisystem in porous medium decreases with increasing distance it passed through the core, and the change of viscosity is mainly concentrated on the first 1/3 of core. And the higher the concentration of polymer in binary multisystem, the lower the viscosity retention rate after it passed through core.

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