

# The oil displacement effect evaluation of Different Displacing systems

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**Abstract.** During the chemical flooding, the surfactant and the alkali play an emulsifying role. The emulsification can not only improve the displacement efficiency, but also expand the swept volume by the mechanism of emulsifying trapping. We select some chemical flooding systems including different kinds of surfactants, alkali/alkali-free and different emulsion degrees to make the comparative experiment and draw the conclusion that it is an effective way to enhance the recovery by increasing the emulsion stability without having to pursue the ultra-low interfacial tension.

## 1. Introduction

There are three important factors involved in the oil displacement process including the porosity, the emulsifying power and the interfacial tension. It plays an important role in the study of the crude oil distribution, the flow characteristics and the recovery [1]. So choose the chemical flooding system with the certain emulsifying power and interfacial tension has great significance to improve the oil displacement effect of the binary and the ternary systems. It is also of great significance to improve the recovery technological progress [2].

During the chemical flooding, the surfactant can emulsify the crude oil and the emulsified crude oil not only improve the oil displacement efficiency, but also expand the swept volume by the emulsion trapping mechanism [3,5]. The choice of surfactant is an important factor about the emulsification during the chemical flooding. In this study, the different surfactant composite flooding systems actual function were evaluated by comparing the emulsification and displacement characteristics, based on Berea sandstone core flooding experiment and the interfacial tension measurement and emulsion water separating proportion analysis.

## 2. Experimental materials and conditions

- Water: filtered sewage from the Daqing fourth oilfield.
- Oil: the simulated oil was made from crude oil from the Daqing oilfield with a viscosity of 10 mPa·s.
- Chemical slug: a total of 0.5 PV, protected by 0.3PV main slug (strong alkali/weak alkali ternary, alkali-free binary, 0.3% surfactant, 40mPa·s) + 0.2PV protective polymer slug (40mPa·s).
- Injection rate: 0.35mL/min
- Berea core: specifications for the 4.5×4.5×30cm.
- Texas-500 spinning drop interfacial tension meter and the configured emulsion.



### 3. The process

#### 3.1 Experimental details

- select the core.
- The core is evacuated for 4 hours, saturated formation water, measuring the pore volume.
- Heating the core in a 45°C incubator for 15 hours.
- The core is saturated crude oil and placed in a 45°C incubator for 20 hours.
- When the moisture content reach 98%, stop the water flooding and calculate the water flooding recovery.
- The chemical slug is injected by 0.5PV, continue the water flooding to the exit and end when the water content reach 98% and calculate the chemical recovery.

#### 3.2 Measurement of interfacial tension

- open the interface tension meter power, preheat the instrument, set the experimental temperature for the test temperature
- Wash the measuring tube with distilled water and rinse it with the surfactant solution, then fill the measuring solution with surfactant solution to be measured
- Draw the oil sample with a micro-syringe, inject the measuring tube and form the appropriate size of the oil droplets; remove the measurement tube bubbles. The measuring tube install in the rotating cylinder and preheat 5min.
- Set the speed to the test speed and adjust the camera to observe the location of oil droplets so that the oil droplets in the middle of the screen is easy to observe.
- Observe the oil droplet width at 2h and record the interfacial tension value.

#### 3.3 Emulsion stability test

Prepare the different emulsion systems of 10mL. the oil to water ratio is 1:9 and record the Separation of water that the emulsion has changed over time in a 45°C incubator.

### 4. Results and analysis

#### 4.1 The effect of emulsibility on recovery

Table 1 shows the oil displacement experiments results in different composite flooding systems, where in the weak alkali ternary contains 0.3% mahogany sulfonate+1.2% weak alkali and strong alkali ternary contains 0.3% heavy alkali-benzene sulfonate+1.2% strong alkali. The remaining four systems are alkali-free binary systems from the Daqing oilfield

**Table 1.** the oil displacement test results

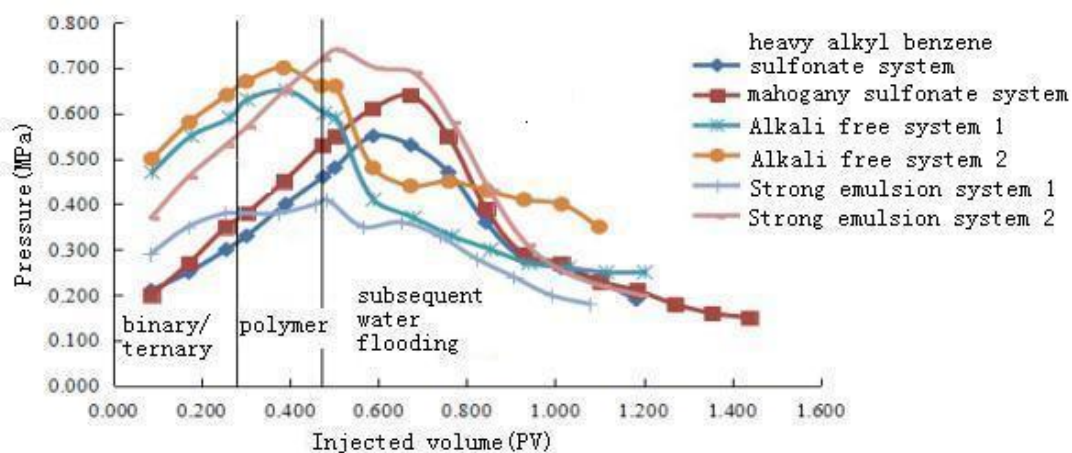
Core water Permeability (MD)	The Oil Displacement system	The total recovery (%)	Water displacement recovery (%)	the injection phase (%)	the subsequent water flooding phase (%)	The subsequent water flooding /the chemical flooding recovery (%)	The Chemical flooding recovery (%)	The emulsion degree of extraction (tube)
126	heavy alkali-benzene sulfonate system	66.76	35.14	16.89	14.73	46.58	31.62	9
166	mahogany sulfonate system	65.13	35.53	16.02	13.59	45.89	29.61	5
150	Alkali-free system 1	61.22	37.41	15.51	8.30	34.86	23.81	3
167	Alkali-free system 2	62.80	38.00	16.40	8.40	33.87	24.80	3
159	Strong emulsion system 1	62.30	34.46	17.40	10.44	37.50	27.84	3

188	Strong emulsion system 2	68.55	38.82	17.37	12.37	41.59	28.74	5
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From the results of the oil displacement test in table1, the chemical flooding recovery of the weak alkali ternary, strong alkali ternary and strong emulsified alkali free binary are higher than that of other systems. In the process of alkali free system flooding. The reserve recovery degree from a high to low order is strong emulsification system, alkali free system. The subsequent water flooding recovery degree of chemical flooding total recovery ratio is strong emulsification system2, strong emulsification system1, alkali-free system1, alkali-free system2 from a high to low order. the main reason for the the sorting results is due to the difference in the surfactant displacement efficiency and the the resulting emulsion stability. The polymer viscosity in the composite system used in the experiment is consistent, so the emulsion stability produced by the displacement agent and the oil phase depend primarily on the performance of the surfactant. The surfactant used in the ternary composite system and the strong emulsification system have a strong ability to reduce the interfacial tension, the emulsifying ability and the oil displacement efficiency are higher so that the chemical flooding recovery efficiency is improved. The formed emulsion stability is high, the subsequent water flooding stage can effectively plug the high relative permeability position in the core. Which shows that the subsequent water flooding recovery degree of chemical flooding total recovery ratio is higher. Therefore, from the two sort can be seen in the injection system viscosity of certain circumstances, the surfactant displacement efficiency and the emulsion stability co-determine the effect of displacement characteristics.

#### 4.2 Injection pressure analysis

Summarize the pressure curves , as shown in Figure 1.



**Figure 1.** The relationship curves between injection pressure and injection volume in different systems

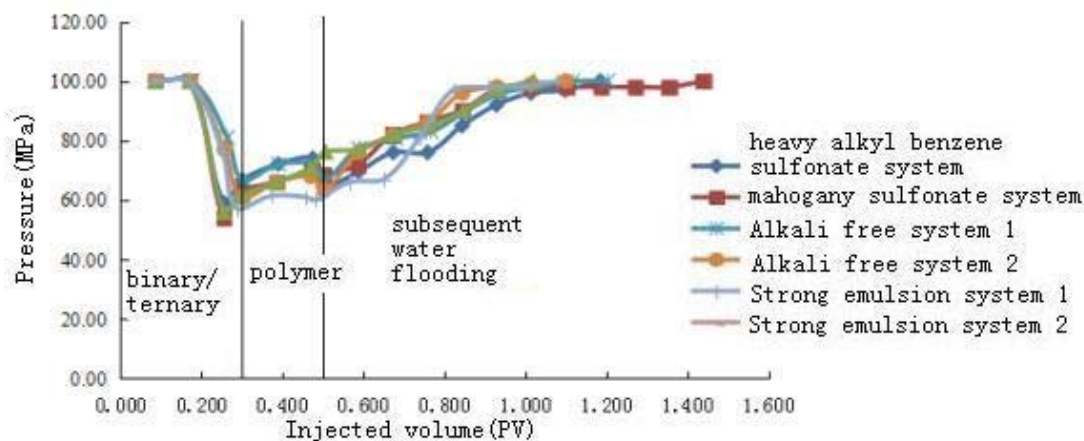
From figure1 we can see that the curve is roughly divided into three forms:

(1) The initial pressure is lower and the subsequent water flooding phase pressure is increased first and then descends, including mahogany sulfonate and heavy alkali benzene sulfonate. (2) The initial pressure is higher and the subsequent water flooding phase pressure is directly decreased, including the alkali-free system 1, alkali-free system 2. (3) The initial pressure is medium and the subsequent water flooding phase pressure is decreased slowly, including strong emulsification system 1, strong emulsification system 2.

The reason for this phenomenon is that the interfacial tension of mahogany sulfonate and heavy alkali benzene sulfonate is low and the emulsion droplet size is small after mixing with the crude oil in the porous media. The capillary pressure difference produced by droplet is low and the shut-off capacity is weak. It shows that the initial injection pressure is low and the latter stage due to the higher

stability of the emulsion, can continue to plug the pore throat, so that the subsequent water flooding phase pressure has increased. There are higher interface tension in the Alkali-free system 1, alkali-free system 2, strong emulsification system 1 and strong emulsion system 2. after the initial contact with the crude oil, the emulsion droplet size is larger and the capillary pressure is higher and the initial injection pressure increases rapidly. But the alkali-free system 1, alkali-free system 2 in the injection phase to the end of the subsequent water flooding pressure has been declining, indicating that the initial injection of the emulsion occurred significant demulsification, the emulsion stability is lower than the strong emulsification system 1 and strong emulsification system 2.

#### 4.3 The variation of the water cut



**Figure 2.** The Relationship curve between water cut and Injection Volume in Different oil displacement Systems

As can be seen from figure 2, the water content ratio is rapidly reduced from 100% to the lowest point in the chemical injection stage. It began to recover in the polymer flooding stage and the subsequent water flooding phase kept the trend. The recovery trend has slowed down until the water content ratio reaches 90% and gradually recovered to 100%.

#### 4.4 The effects of interfacial tension and emulsion stability on recovery

The interfacial tension of different emulsification systems and the water separating proportion at oil/water ratio of 1:9 were tested. The emulsion stability was evaluated by the water separating proportion, the results are shown in table 2.

**Table 2.** the effects of the interfacial tension and emulsion water separating proportion on recovery in different systems

The Oil Displacement system	The Chemical flooding total recovery (%)	Interfacial tension (mN/m)	The degree of emulsion extraction (tube)	The water separated proportion after 2 hours (%)
Heavy alkali - benzene sulfonate system	31.62	$1.8 \times 10^{-3}$	9	75
Mahogany sulfonate system	29.61	$2.3 \times 10^{-3}$	5	76
Alkali-free system 1	23.81	$8.7 \times 10^{-3}$	3	98
Alkali-free system 2	24.80	$6.8 \times 10^{-3}$	3	98
Strong emulsion	27.84	$9.0 \times 10^{-3}$	3	86

system 1				
Strong emulsion	28.74	$7.5 \times 10^{-3}$	5	84
system 2				

From the above experimental results, reducing the interfacial tension and improving the emulsion stability can effectively enhance the chemical flooding recovery. According to the chemical flooding effect of the field, the ternary composite system interfacial tension is lower, the emulsion stability is better and the chemical recovery is higher. the scaling phenomenon is serious while the alkali free system has not the question. Compared with the ternary composite system, it is difficult to reduce the interfacial tension in the alkali free system. But it is relatively simple to enhance the emulsifying ability by improving its system. Therefore, there is no need to pursue ultra-low interfacial tension in the alkali-free system. It is an effective way to improve the alkali free system by enhancing the emulsion stability.

## 5. Conclusions

The polymer concentration in the composite system used in the experiment is consistent, so the emulsion stability is produced by the displacing agent and the oil phase depends primarily on the surfactant. Some surfactants have the stronger ability that reduce the interfacial tension, the ability to produce emulsion and oil displacement efficiency are also stronger so that the chemical flooding recovery is enhanced. In the case of a certain amount of polymer, the surfactants displacement efficiency and the formed emulsion stability co-determine the effect of the oil displacement.

In improving the alkali-free system formation, it is an effective way to enhance the recovery by increasing the emulsion stability without having to pursue the ultra-low interfacial tension.

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