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Effect of the Surfactant Type on the Demulsification of the W/O Crude Oil Emulsion Produced by Surfactant−Polymer Flooding

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ABSTRACT: At present, there are many works on the influences of partially hydrolyzed polyacrylamide (HPAM) and surfactant on the stability and treatment of O/W emulsion produced by surfactant−polymer (SP) flooding. However, there are few related reports on the effects of HPAM and surfactant on the demulsification of W/O crude oil emulsion produced by SP flooding. Especially, there is no report on the effect of the surfactant type. In this paper, sodium dodecyl sulfate (SDS), octylphenol polyoxyethylene ether (OP-10), and alkyl C16−18 hydroxypropyl sulfobetaine (HSB1618) were selected as representatives of the anionic surfactant, nonionic surfactant, and zwitterionic surfactant, respectively. Demulsification experiments and interface behavior experiments were conducted to investigate their influences on the demulsification performance of a demulsifier D1. The results showed that the order of the negative effect of the surfactant type on dehydration speed and the dehydration rate of D1 was HPAM + OP-10 > HPAM + HSB1618 > HPAM + SDS. There is no difference in the effect of three surfactants on the conformation adjustment of D1 at the W/O interface, but the properties of the composite W/O interface formed by them and D1 were different. The coalescence time was longest when there were HPAM and OP-10 in water, while the $\lg(G_1'/G_{\text{demulsifier}}')/\lg G_1'$ was the smallest, which led to the most difficult demulsification of W/O emulsion. This work can guide surfactant selection during SP flooding from the perspective of produced fluid treatment.
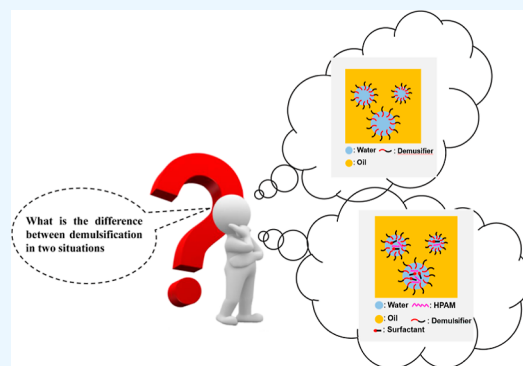
1. INTRODUCTION

Surfactant polymer (SP) flooding, a kind of enhanced oil recovery technology, has shown great potential in oil recovery.[1] SP flooding can achieve ultralow interfacial tension and increase oil displacement efficiency, which could enhance oil displacement efficiency by 20% and decrease the injection pressure in low permeability reservoirs.[2,3] It has been widely used in many oilfields, such as Daqing, Xinjiang, Henan, and Bohai in China.[4−6] Usually, the most used polymer in SP flooding is partially hydrolyzed polyacrylamide (HPAM), and the most used surfactants include anionic surfactants, nonionic surfactants, and zwitterionic surfactants.[7,8]

Produced fluid treatment is an important task that must be considered in SP flooding applications. Especially for offshore platforms, the limited space leads to a short produced fluid treatment time, so the impacts of polymers and surfactants on the produced fluid treatment difficulty are particularly important.[9,10] The produced liquid of SP flooding is usually a mixture of a W/O and an O/W emulsion. As for the O/W emulsion (usually also known as produced water), the oil−water separation characteristics have been extensively addressed by many researchers. It is generally believed that the surfactant is mainly responsible for the stability of oil droplets in SP flooding

produced water compared with the polymer, decreasing oil−water interfacial tension, and zeta potential on the surface of the oil droplets.[11] There also have been many reports on the treatment of SP flooding-produced water.[12,13] However, there are few works on the influences of polymers and surfactants on the stability and treatment of W/O crude oil emulsions in SP flooding applications. Dong et al.[14] studied the influence of surfactant on the stability of crude oil emulsion. They found that, compared with petroleum sulfonate, the anionic-nonionic composite surfactant was more interfacially active and able to enhance the strength of the interfacial film between oil and water; hence, the stability of the W/O emulsion containing anionic-nonionic composite surfactant was much higher. Yang et al.[5] found a composite demulsifier YH-1, which showed a promising demulsification effect for W/O emulsion produced by SP flooding. When the dosage of YH-1 was 20 mg/L, its
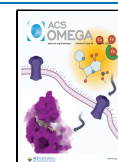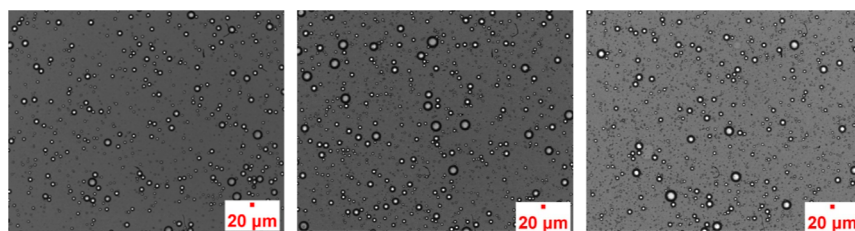
Figure 1. Some typical microscopic photos of the W/O emulsion (from left to right, the water contained SDS, OP-10, and HSB1618).
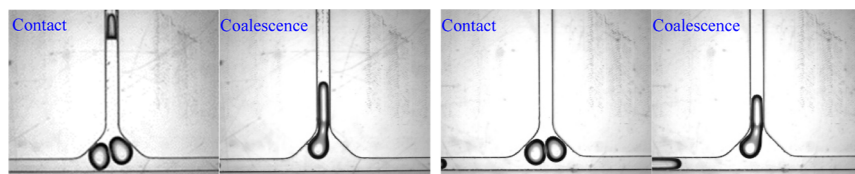

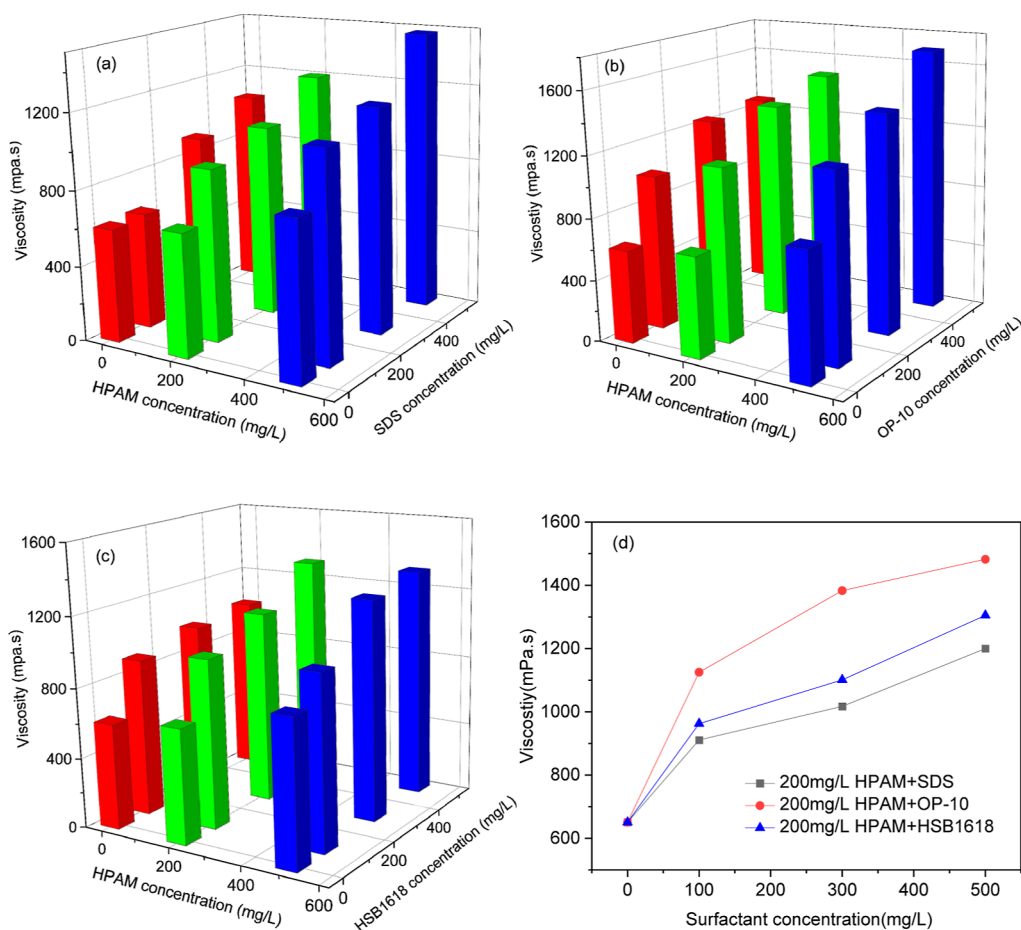**Figure 2.** Two sets of photos of water droplets in contact and coalescence.

Figure 3. Emulsion viscosity of (a) HPAM + SDS; (b) HPAM + OP-10; (c) HPAM + HSB1618; (d) viscosity comparison when the surfactant was different.

dewatering efficiency at 323 K was higher than 72%, when even both surfactant (petroleum sulfonate) and polymer (HPAM) concentrations were 1200 mg/L. Xie et al.[15] synthesized six block polyether for demulsification of W/O emulsion produced by SP flooding (petroleum sulfonate and HPAM were 500 and 100 mg/L, respectively). It was found that the higher the HLB value of the demulsifier, the better the demulsification efficiency was. According to these research results, we can find that only the influence of anionic surfactant on the stability and

demulsification of W/O emulsion produced by SP flooding has been studied in the existing literature. However, the influence of surfactant type on the stability and demulsification of the W/O emulsion produced by SP flooding has not been systematically studied. If the impact of surfactant type on the performance of a typical demulsifier can be clearly defined, the surfactant selection of SP flooding can be guided from the perspective of the produced liquid treatment. In this work, sodium dodecyl sulfate (SDS), octylphenol polyoxyethylene
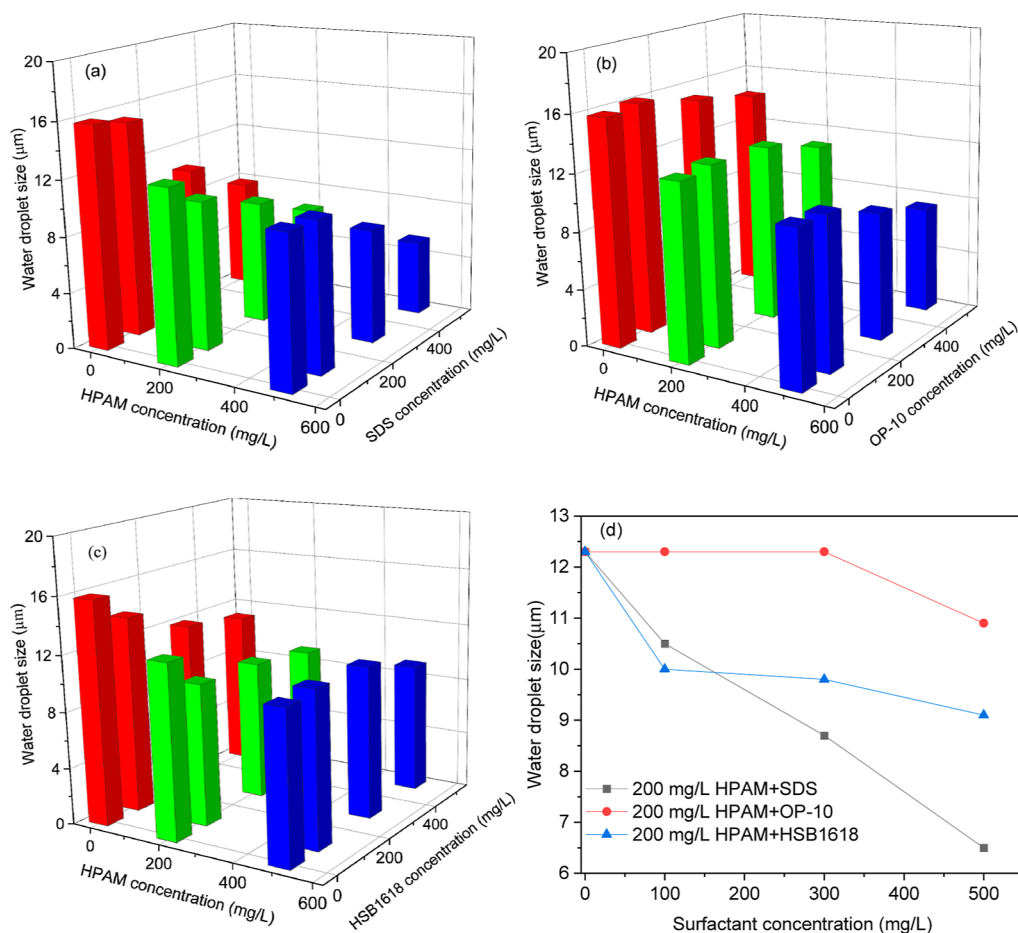
Figure 4. Water droplet size when W/O emulsion contained a different composite system (a) HPAM + SDS; (b) HPAM + OP-10; (c) HPAM + HSB1618; (d) size comparison when the surfactant is different.

ether (OP-10), and alkyl C16−18 hydroxypropyl sulfobetaine (HSB1618) were selected as the representatives of anionic surfactant, nonionic surfactant, and zwitterionic surfactant, respectively. Demulsification experiments and interface behavior experiments (including dynamic interfacial tension, interfacial elastic modulus G', and dynamic coalescence time measurement) were conducted to investigate their influences on the demulsification performance of a W/O crude emulsion demulsifier.

2. EXPERIMENTS

2.1. Chemicals. HPAM was prepared according to our previous work,[16] and its viscous average molecular weight was 4.86×10^6 g/mol. SDS, OP-10, and HSB1618 were obtained from Shandong Usolf Chemical Technology Co., Ltd. White oil and Span 20 were purchased from Chengdu Chron Chemicals Co., Ltd., Chengdu, China. Heavy oil was supplied by the Beijing Research Center of the China National Offshore Oil Corporation. Its density was 0.9404 (25 °C), apparent viscosity was 333 mPa s (80 °C), and the SARA contents were as follows: 42.72 wt % saturate, 30.00 wt % aromatics, 23.38 wt % resins, and 3.90 wt % asphaltenes. Polyether demulsifier D1 was obtained from the Oilfield Chemicals R&D Center, CNOOC (Tianjin) Oilfield Chemical Co., Ltd., Tianjin, China.

2.2. W/O Crude Oil Emulsion Preparation and Bottle Test Method. W/O crude oil emulsion preparation. W/O crude oil emulsion was prepared for the demulsification experiment. First, 50 g of crude oil and 50 g of polymer +

surfactant aqueous solution (1 wt % NaCl aqueous solution as the solvent) were heated at 80 °C (note: The treatment temperature on the offshore platform where we obtained the crude oil is 80 °C. Therefore, the experiment was conducted at 80 °C) for 30 min. Then, crude oil was stirred, and an aqueous solution was added dropwise into the crude oil at a stirring speed of 550 rpm. After aqueous solution addition and stirring for 15 min, a stable W/O crude oil emulsion was obtained. The apparent viscosity of the emulsion was measured by using a DV-II + Pro rotary viscometer (Brookfield, USA) at 80 °C under the condition of 18 # rotor and 1 rpm rotation speed. In addition, the emulsion was diluted 20 times with white oil (If not diluted, too many water droplets will overlap and the size of the water droplets cannot be measured), and an ECLIPSE Ts2 microscope (Nikon, Japan) was used to observe the micrograph of the emulsion (some typical pictures are shown in Figure 1) and the median water droplet size was obtained through software statistics. In particular, the W/O crude oil emulsion prepared in this paper was stable within 90 min, and no oil−water separation occurred.

2.2.1. Bottle Test. The emulsion was transferred to a graduated tube immediately after preparation, and demulsifier D1 (200 mg/L) was added to the test tube. After being shaken 200 times by hand, the emulsion was kept in a water bath at 80 °C. Dehydration volumes were recorded as a function of time, and the demulsification efficiency was assessed by the water separated, which was calculated as follows
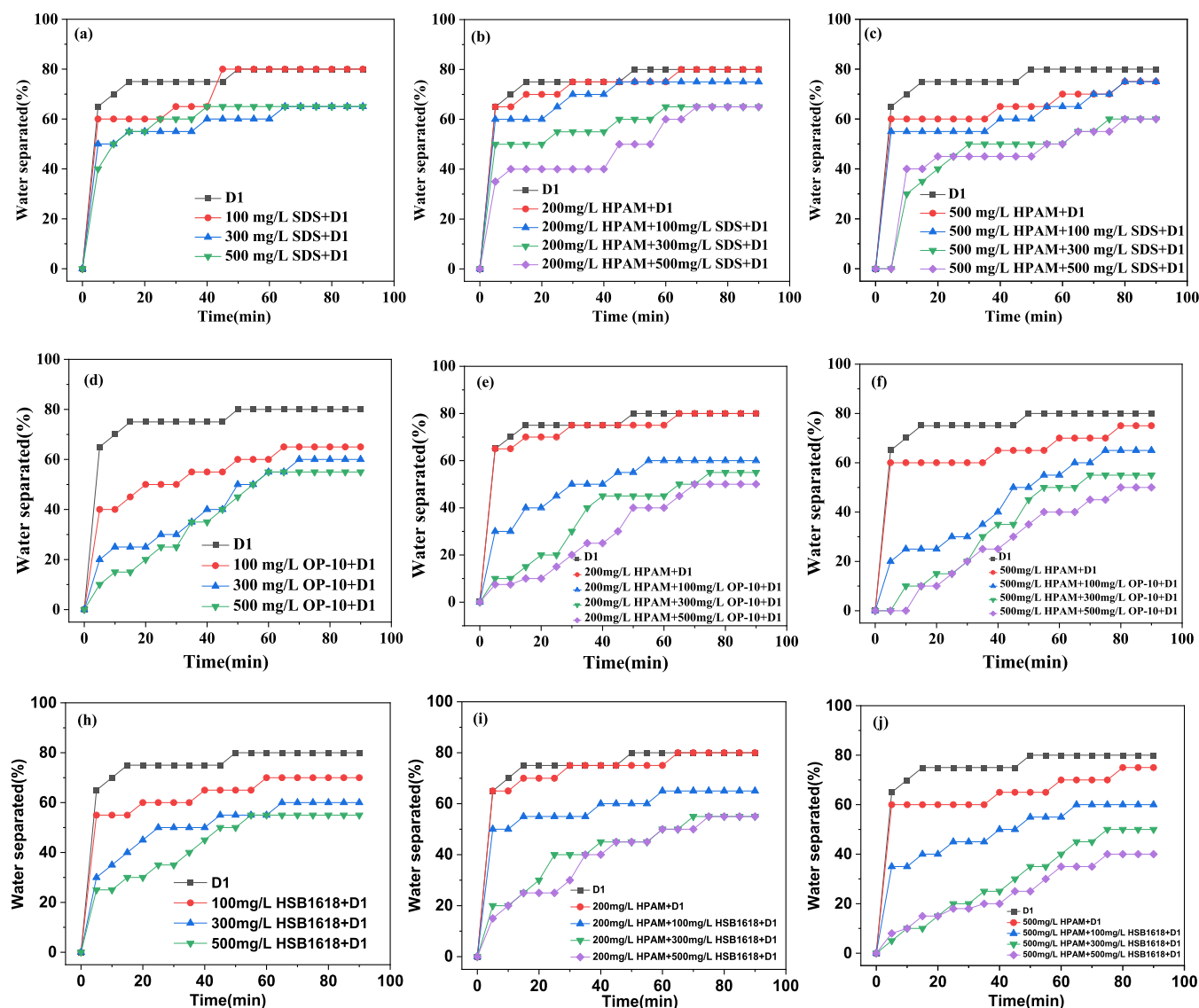
Figure 5. Demulsification experiment records when the HPAM concentration and surfactant concentration are different in water: (a) SDS; (b) 200 mg/L HPAM + SDS; (c) 500 mg/L HPAM + SDS; (d) OP-10; (e) 200 mg/L HPAM + OP-10; (f) 500 mg/L HPAM + OP-10; (h) HSB1618; (i) 200 mg/L HPAM + HSB1618; and (j) 500 mg/L HPAM + HSB1618.

$$\text{water separated} = V_s/V_t \times 100\% \tag{1}$$

where V_t is the total water volume in emulsion and V_s is the separated water volume at the bottom of the bottle.

2.3. Dynamic Interfacial Tension Measurement. Crude oil has high viscosity and is opaque to light; it cannot be directly used to measure the dynamic interfacial tension for water-in-oil. Because asphaltene was the main interface active substance, the asphaltene solution was used as the oil phase to do the dynamic interfacial tension measurement for water-in-oil.

Oil phase preparation: 100 mg/L asphaltene was added to the mixture of *n*-heptane and toluene (volume ratio 1:1) and stirred for 1 h for use.

Water phase preparation: Using a 1% NaCl aqueous solution as the solvent, a polymer + surfactant solution was prepared as the water phase.

The change of W/O interfacial tension (IFT) with time was measured using the DSA30 drop shape analysis system (KRÜSS Company, Germany) at 80 °C. First, the water droplet was kept in asphaltene solution for 15 min to allow asphaltene to adsorb

equilibrium at the W/O interface. Then, demulsifier D1 (5 mg/L) was added to the asphaltene solution, and IFT was recorded for more than 20 min. After the experiment, the experimental data was fitted using a dual exponential decay equation with reference to the literature,[17] as shown in eq 2. In the equation, the index *b* reflects the speed that demulsifier diffuses from the bulk phase to the interface, and the index *d* reflects the speed that demulsifier adjusts to its equilibrium conformation at the interface after adsorption. $y_0 + a + c$ is the IFT before adding demulsifier D1, and y_0 can be considered the equilibrium interfacial tension.

$$y = y_0 + a\,\exp^{-bx} + c\,\exp^{-dx} \tag{2}$$

2.4. Elastic Modulus of W/O Interface Measurement. Due to the same reason as the dynamic interfacial tension measurement, in this part, crude oil was not used. The oil phase preparation and water phase preparation were the same as those in Section 2.3. The elastic modulus of the W/O interface was measured at 80 °C using a DSA30 drop shape analysis system,
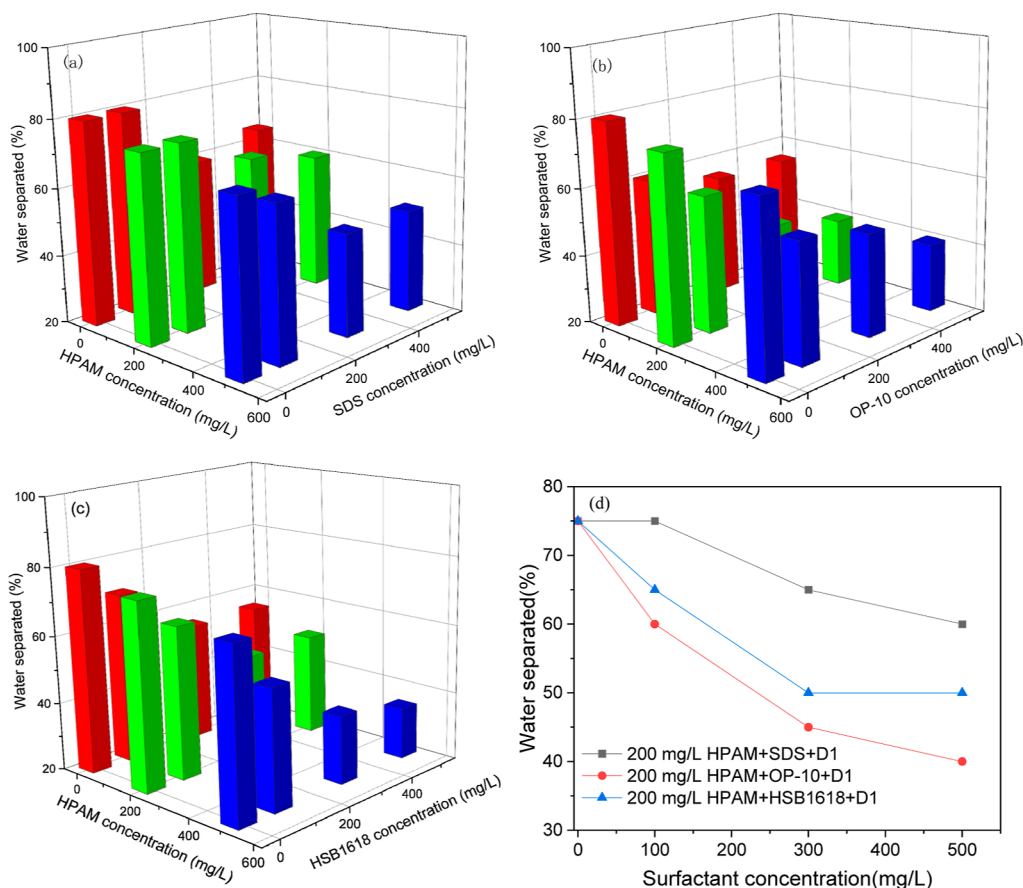
Figure 6. Water separation of D1 at 60 min when the HPAM concentration and surfactant concentration in water are different: (a) HPAM + SDS; (b) HPAM + OP-10; (c) HPAM + HSB1618; (d) water separation comparison when the surfactant was different.

and the oscillation frequency was 0.7 Hz. First, a water droplet was suspended in the asphaltene solution for 15 min, and the elastic modulus was measured. Then, after the addition of demulsifier to an asphaltene solution for 15 min, the elastic modulus was measured again.

2.5. Dynamic Coalescence Time Measurement. The study of the dynamic coalescence behavior of water droplets in oil was conducted by using the microfluidic method according to ref 16. During the experiment, the continuous phase was white oil (contained 0.01% Span 20 and 200 mg/L D1), and the dispersed phase was polymer + surfactant aqueous solution. The generated water droplets collided within the T-shaped microchannel neck. The experiment was conducted at 80 °C, and the collision result was observed by using a AE120 M high-speed camera (Revealer, China), as shown in Figure 2. The time from contact to coalescence of two water droplets was recorded as the coalescence time.

3. RESULTS AND DISCUSSION

3.1. Effects of HPAM and the Surfactant on the Properties of W/O Emulsion. *3.1.1. Effect on Emulsion Viscosity.* According to the Stokes law, the main factors affecting the stability of the emulsion are viscosity and particle size of the dispersed phase. The greater the viscosity and the smaller the particle size, the stronger the stability of the emulsion, thus affecting the difficulty of demulsification.[18]

Figure 3 shows the measurement results of the emulsion viscosity. With the increase of polymer concentration and surfactant concentration in water, the emulsion viscosity showed

an increasing trend. Relatively, with the increase of surfactant concentration, the emulsion viscosity increased more. The result showed that the surfactant had greater influence on emulsion viscosity than that of HPAM. When HPAM and surfactant coexisted in water, the emulsion containing HPAM + OP-10 had the highest viscosity, and the emulsion containing HPAM + HSB1618 had a higher viscosity than that of HPAM + SDS.

3.1.2. Effect on the Water Droplet Size. Figure 4 shows the measurement results of the water droplet size. With the increase of polymer concentration and surfactant concentration, the water droplet particle size decreased. Relatively, with the increase of surfactant concentration, the particle size decreased more. The result also showed that the surfactant had a greater influence on water droplet size than HPAM. When HPAM and surfactant coexisted in water, the order of water droplet size was as follows: HPAM + SDS < HPAM + HSB1618 < HPAM + OP-10.

From the above experimental results, it can be seen that when there were HPAM and surfactant in water, the increased emulsion viscosity and the reduced water droplet size could lead to enhanced emulsion stability, thus affecting the demulsification performance of the demulsifier.

3.2. Effects of HPAM and Surfactant on Demulsification. *3.2.1. Effect on Dehydration Speed.* The effects of HPAM and surfactant on the dehydration speed of D1 were investigated, and the results are shown in Figure 5. It can be observed that the curve between water separated and time can be divided into three stages: (1) the rapid dehydration stage, where the water separation increased rapidly with time and the
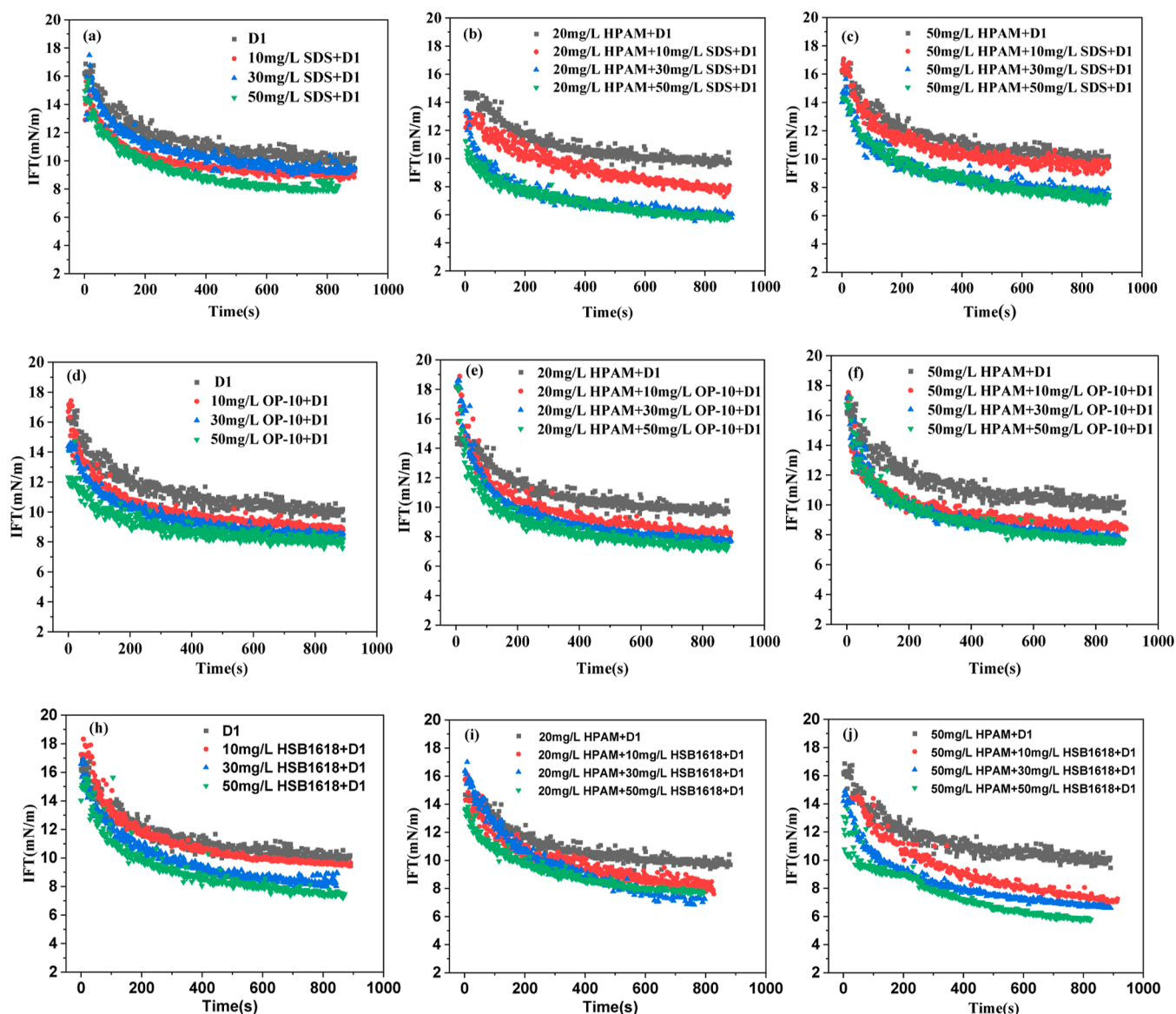
Figure 7. Dynamic IFT measurement results of D1 when the HPAM concentration and surfactant concentration were different in water: (a) SDS; (b) 20 mg/L HPAM + SDS; (c) 50 mg/L HPAM + SDS; (d) OP-10; (e) 20 mg/L HPAM + OP-10; (f) 50 mg/L HPAM + OP-10; (h) HSB1618; (i) 20 mg/L HPAM + HSB1618; (j) 50 mg/L HPAM + HSB1618 (note: the concentration was much lower than that in Figure 5 because when the concentration was too high, the suspended water droplets during measurement were very unstable).

curve was steep. (2) The slow dehydration stage, where the water separated, increased slowly with time. (3) The end of the dehydration stage, where the water separated no longer changed over time. The higher the water separated during the rapid dehydration stage, the faster the dehydration speed. When only HPAM was in water and its concentration was 200 mg/L, the dehydration speed of demulsifier D1 did not significantly slow down, while when the HPAM concentration was 500 mg/L, the dehydration speed showed a decrease. The reason for this result has been discussed in our pervious work[16] because high concentrations of HPAM had a negative effect on the conformational adjustment of the demulsifier at the oil−water interface. When there was only surfactant in water (see Figure 5a,d,h), as the surfactant concentration increased, the dehydration speed showed a significant decrease; especially, the influences of OP-10 and HSB1618 were significant. Their water separation at the rapid dehydration stage was much smaller than that of SDS. When HPAM and surfactant coexisted

in water, they had a significant negative coupling effect on the dehydration speed, with a more significant decrease in dehydration speed. There were even no rapid dehydration stage for 500 mg/LHPAM + 500 mg/L OP-10 (HSB1618). The negative impact of the composite system on dehydration speed was ranked as follows: HPAM + OP-10 > HPAM + HSB1618 > HPAM + SDS.

3.2.2. Effect on the Water Separated. The effects of HPAM and surfactant on the water separated from D1 at 60 min were investigated, and the results are shown in Figure 6. When water only contained HPAM, HPAM had no significant effect on water separation, which was maintained at around 80%. When there was only surfactant in water, water separation gradually decreased with the increase of surfactant concentration (see the red pillar in Figure 6). The lowest water separation was lower than 60% for OP-10 and HSB1618. When HPAM and surfactant coexisted in water, water separation also gradually decreased with the increase of surfactant concentration. Especially when

Table 1. Fitting Results of Dynamic Interfacial Tension of Demulsifier D1 When Water Contained HPAM and Surfactant

HPAM concentration (mg/L)	SDS concentration (mg/L)	y_0	a	b	c	d	R^2
0	0	9.9289	2.3121	0.0200	4.5875	0.0036	0.9500
	10	8.8827	3.2899	0.0200	2.8431	0.0032	0.9748
	30	8.7539	4.0593	0.0200	2.9772	0.0029	0.9828
	50	6.0895	1.7556	0.0200	2.6116	0.0026	0.9849
20	0	9.8568	2.3689	0.0200	5.2814	0.0035	0.9821
	10	6.6518	0.1409	0.0200	4.9831	0.0026	0.9479
	30	5.6542	2.6983	0.0200	2.3622	0.0024	0.9979
	50	5.1285	1.9416	0.0200	3.7736	0.0020	0.9812
50	0	9.9185	2.1565	0.0200	4.3568	0.0032	0.9823
	10	9.4584	3.8599	0.0200	4.1356	0.0026	0.9865
	30	7.1721	4.3036	0.0200	3.8732	0.0025	0.9897
	50	6.4631	3.4893	0.0200	5.0908	0.0021	0.9777
HPAM concentration (mg/L)	OP-10 concentration (mg/L)	y_0	a	b	c	d	R^2
0	0	9.9289	2.3121	0.0200	4.5875	0.0036	0.9500
	10	9.4025	4.7854	0.0200	4.4521	0.0034	0.9925
	30	8.7161	5.7267	0.0200	5.0668	0.0033	0.9789
	50	8.6024	2.8666	0.0200	3.8048	0.0029	0.9847
20	0	9.8568	2.3689	0.0200	5.2814	0.0035	0.9821
	10	7.9287	6.3108	0.0200	4.4987	0.0028	0.9845
	30	7.3862	7.9219	0.0200	4.0921	0.0027	0.9915
	50	6.4189	7.8522	0.0200	3.6096	0.0022	0.9842
50	0	9.9185	2.1565	0.0200	4.3568	0.0032	0.9823
	10	7.8290	5.4711	0.0200	3.0686	0.0027	0.9832
	30	7.3008	5.7000	0.0200	3.8317	0.0023	0.9843
	50	6.7540	5.3071	0.0200	4.5924	0.0023	0.9889
HPAM concentration (mg/L)	HSB1618 concentration (mg/L)	y_0	a	b	c	d	R^2
0	0	9.9289	2.3121	0.0200	4.5875	0.0036	0.9500
	10	9.2584	3.8544	0.0200	5.3158	0.0034	0.9825
	30	8.8954	2.1854	0.0200	4.9845	0.0029	0.9888
	50	7.8962	3.5895	0.0200	5.1256	0.0029	0.9714
20	0	9.8568	2.3689	0.0200	5.2814	0.0035	0.9821
	10	7.2894	3.2807	0.0200	5.7264	0.0033	0.9804
	30	6.5405	2.4231	0.0200	5.2494	0.0027	0.9868
	50	7.2249	2.0121	0.0200	7.7405	0.0028	0.9827
50	0	9.9185	2.1565	0.0200	4.3568	0.0032	0.9823
	10	6.4459	2.3043	0.0200	7.4667	0.0028	0.9804
	30	6.1969	4.1183	0.0200	4.8118	0.0025	0.9892
	50	5.2894	2.2545	0.0200	5.2689	0.0021	0.9901

the surfactant concentration increased from 100 mg/L to 300 mg/L, the water separation decreased significantly. When the HPAM concentration was the same, the negative impact of the composite system on water separation was also ranked as follows: HPAM + OP-10 > HPAM + HSB1618> HPAM + SDS (see Figure 6d). This order was consistent with the effect of the surfactant type on emulsion viscosity. This result showed that the W/O emulsion containing HPAM and surfactant with a larger viscosity will make demulsification more difficult than the one with a smaller water droplet size will make demulsification more difficult.

3.3. Dynamic IFT. The dynamic IFT measurement results of D1 with different polymer and surfactant concentrations in water are shown in Figure 7. After D1 was added to the oil phase, the IFT first decreased rapidly and then slowly decreased to a stable state over time. The dynamic IFT test results are fitted, and the results are listed in Table 1. During the experiment, D1 diffused from the oil phase to the oil−water interface, while the polymer and surfactant were in the water phase. Therefore, in theory, they had no effect on the diffusion speed of D1. It can be considered that the diffusion speed of the demulsifier from the

oil phase to the water phase should be the same, so the index b was fixed to be the same during the fitting process (0.02). After D1 diffused to the oil−water interface, it would adjust the conformation and achieve adsorption equilibrium. As can be seen from Table 1, the index d varied when the HPAM concentration and surfactant concentration were different. When only HPAM was in water, there was a slight decrease in d as the HPAM concentration increased. When only the surfactant was in water, there was a significant decrease in d as the surfactant concentration increased. When HPAM and surfactant coexisted, there was also a significant decrease with the increase of surfactant concentration, indicating that the decrease in d was dominated by surfactants when they coexisted. Three composite systems had no significant difference in their influence on the d-value. The decrease of d because the extent of demulsifier conformation can be adjusted was affected by HPAM and surfactant, and the adjustment speed was slowed down. The interfacial activity of surfactant was better than that of HPAM, as it could occupy more sites at the oil−water interface, thus having a greater impact on the conformational adjustment of the demulsifier. The higher the concentration of
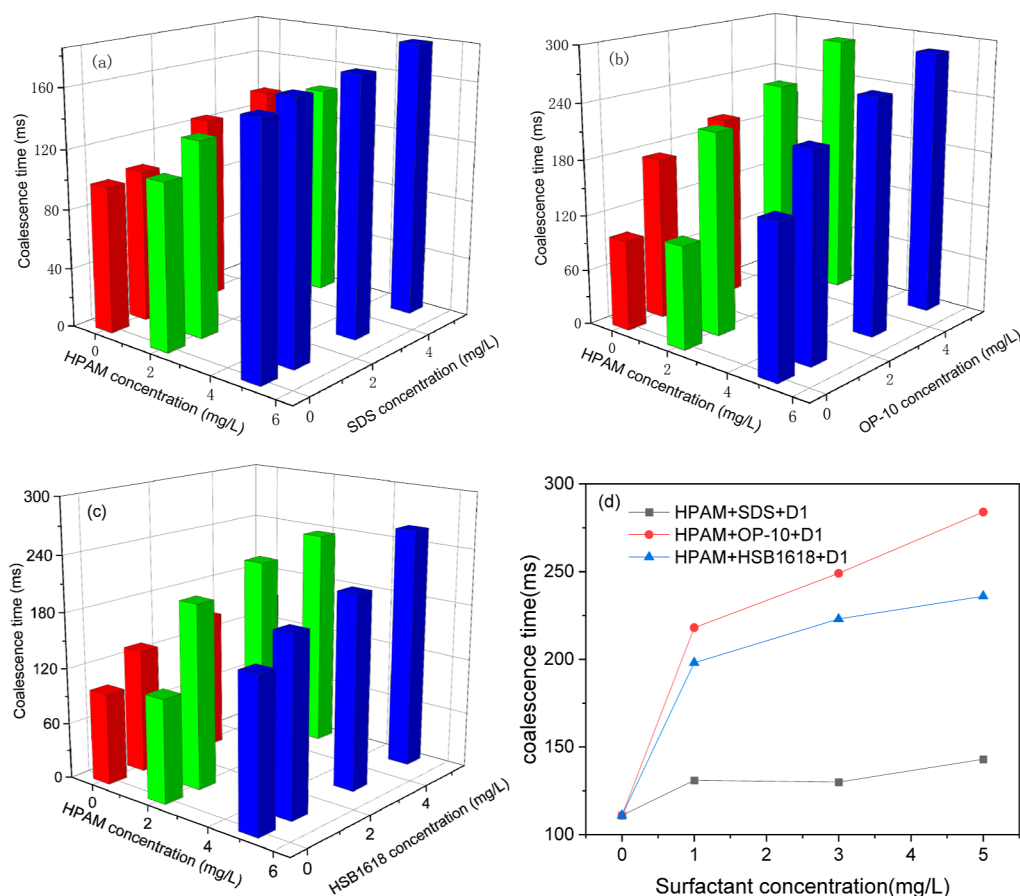
Figure 8. Coalescence time when the HPAM concentration and surfactant concentration in water were different (a) HPAM + SDS; (b) HPAM + OP-10; (c) HPAM + HSB1618; (d) coalescence time comparison when surfactant was different (note: the concentration was much lower than that in Figure 5 because when the concentration was too high, no coalescence occurred).
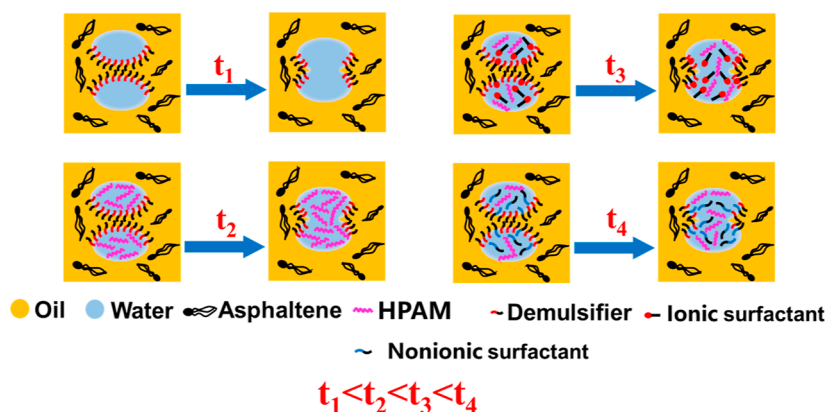

Figure 9. Schematic diagram of the effects of HPAM and surfactant on the coalescence time of two water droplets in oil.

surfactant, the more adsorption sites it occupies at the oil—water interface, the slower the speed at which the demulsifier completes adjustment, resulting in a greater decrease in d-value. The d values of the three composite systems were not significantly different, indicating that there is no difference in their influence on the conformational adjustment of the demulsifier. However, the composite water/oil interface formed by surfactant and demulsifier may have different interface properties due to different surfactants, thereby affecting the coalescence rate of water droplets and the strength of the interfacial film.

3.4. Dynamic Coalescence Behavior of Two Water Droplets in Oil. Usually, during the demulsification process of W/O crude oil emulsion, the dehydration speed is relative to the coalescence time of water droplets. The dehydration speed increases with decreasing coalescence time. In addition, the coalescence time of the two water droplets is determined by the liquid film drainage time when the water droplets approached. Figure 8 shows the coalescence time of two water droplets in oil when the water contained different concentrations of HPAM and surfactant. When there were HPAM and surfactant in water, the coalescence time was much longer than that of D1, that is
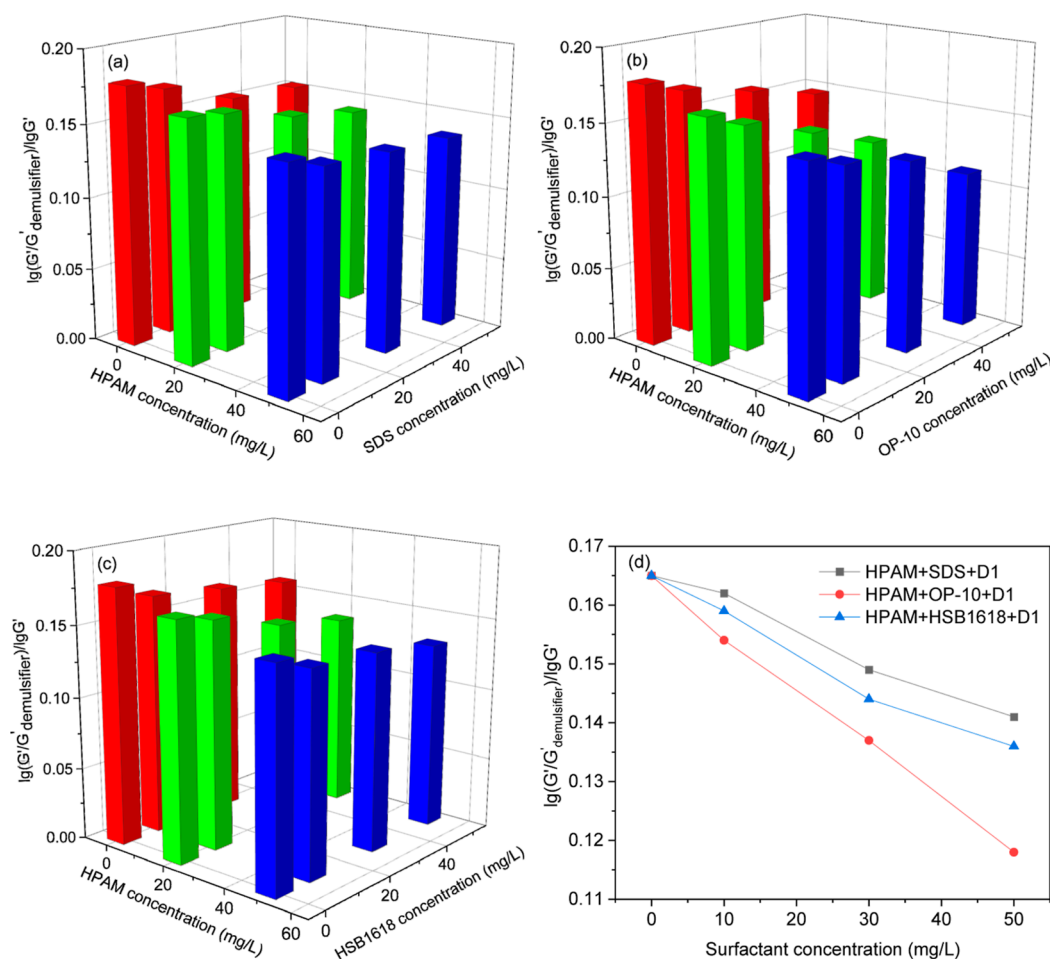
Figure 10. $\lg(G_1'/G_{demulsifier}')/\lg G_1'$ when the HPAM concentration and surfactant concentration in water were different (a) HPAM + SDS; (b) HPAM + OP-10; (c) HPAM + HSB1618; (d) $\lg(G_1'/G_{demulsifier}')/\lg G_1'$ comparison when the surfactant was different (note: the concentration was much lower than that in Figure 5 because when the concentration was too high, the suspended water droplets during measurement were very unstable).

why the dehydration speed was lower when water contained HPAM and surfactant. The coalescence time increased with the increasing HPAM concentration and surfactant concentration. The order of oil droplet coalescence time was HPAM + OP-10 > HPAM + HSB1618 > HPAM + SD. This order was consistent with the demulsification experiment results. The control step of water droplet coalescence is the drainage process between water droplets, during which the interface active substances need to be rearranged again at the interface.[19] This experimental result indirectly indicated that the rearrangement of the OP-10 + D1 composite at the interface was more difficult during the liquid discharge process. This may be due to the presence of polyoxyethylene chains in both OP-10 and D1, which have stronger interactions and may form large complexes at the interface, making rearrangement difficult (as shown in Figure 9).

3.5. Interfacial Elastic Modulus. Li et al.[20] found that there is a relationship between the water separated of demulsifier and the elastic modulus of W/O interface as follows.

$$W_{f,c} = \frac{100\lg(G_1'/G_{demulsifier}')}{\lg(G_1'/A_{crude}) + 3.95} \qquad (3)$$

where $W_{f,c}$ is the final water separated, $G_{demulsifier}'$ is the elastic modulus after the addition of demulsifier, G_1' is the elastic modulus before demulsifier was added, and A is the asphaltene content of crude oil. According to eq 3, the performance of the demulsifier was affected by the initial elastic modulus of the W/O interface and the degree to which the demulsifier reduced the elastic modulus of the W/O interface at the same time.

There is a positive correlation between the final water separation of the demulsifier and $\lg(G_1'/G_{demulsifier}')/\lg G_1'$. If $\lg(G_1'/G_{demulsifier}')/\lg G_1'$ is larger, the final water separated will also be larger. Figure 10 shows the $\lg(G_1'/G_{demulsifier}')/\lg G_1'$ when there were HPAM and surfactant in water. The $\lg(G_1'/G_{demulsifier}')/\lg G_1'$ decreased with the increasing HPAM concentration and surfactant concentration and the order of $\lg(G_1'/G_{demulsifier}')/\lg G_1'$ was HPAM + OP-10 < HPAM + HSB1618 < HPAM + SDS. We can find that the law of demulsification was consistent with the change of $\lg(G_1'/G_{demulsifier}')/\lg G_1'$.

4. CONCLUSIONS

In this work, the influence of surfactant type on the demulsification performance of demulsifier D1 for the W/O crude oil emulsion produced by SP flooding was studied. When there were HPAM and surfactant in the water, both the dehydration speed and the final water separation of D1 were negatively affected. The dehydration speed and the final water separation decreased with increasing surfactant concentration, regardless of the surfactant type. For three types of surfactant, the negative impact was ranked as nonionic surfactant (OP-10) > zwitterionic surfactant (HSB1618) > anionic surfactant

(SDS). OP-10 may have a strong interaction with D1 at the water−oil interface, which weakens D1's ability to reduce the drainage time when water droplets coalesce and the ability to reduce the strength of the water−oil interface film, leading to its greatest negative impact. Considering the difficulty of treating the produced liquid, it is recommended to prioritize the use of anionic and zwitterionic surfactants during SP flooding.

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Notes

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