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Stability of the Oil-water Emulsion Formed During Amphiphilic Polymer Flooding

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The amphiphilic polymer can greatly improve the stability of produced liquid and thus makes it difficult to treat. It is of great necessity to study the stability of amphiphilic polymer flooding O/W crude oil emulsion. O/W crude oil emulsion tends to be more stable with increasing amphiphilic polymer concentration and decreasing holding temperature. Amphiphilic polymer flooding O/W crude oil emulsion is much more stable, especially when polymer concentration is above critical aggregation concentration. Aggregation formed by hydrophobic groups of the amphiphilic polymer is beneficial to the stability of amphiphilic polymer flooding O/W crude oil emulsions.

Keywords: aggregation, amphiphilic polymer, CAC, O/W emulsion, stability

1. INTRODUCTION

The emulsification of brine/water in crude oil is a common problem in the oilfield industry. It is essential to break these emulsions before transportation through pipelines and prior to refining (Krawczyk et al., 1991; Djuve et al., 2001; Sjoblom et al., 2003; Zhang et al., 2005). The formation of a viscoelastic, physically cross-linked network of asphaltene aggregates at oil–water interface has been recognized to be mainly responsible for the stability of emulsions (Xia et al., 2004; Strausz et al., 2008; Mullins and Strausz, 2009).

Two strategies are mainly employed to get insight on the stability behavior: (a) measurement of the zeta potential of the particle surface to predict the stability of the dispersion (Mullins and Strausz, 2009) and (b) ageing tests. The products are stored under specific conditions (e.g., temperature, light) and submitted to regular analysis.

Amphiphilic polymers are used in many oilfield operations including drilling, polymer-augmented water flooding, chemical flooding and profile modification (Chatterji and Borchardt, 1981; Sutherland and Kierulf, 1987; Sorbie, 1991). The role of the polymer in most EOR field applications is to increase the viscosity of the aqueous phase. This increase in viscosity can improve sweep efficiency during enhanced oil recovery processes. Amphiphilic polymers are water-soluble polymers that contain a small number of hydrophobic groups attached directly to the polymer backbone. In aqueous solutions, the hydrophobic groups of these polymers can associate to minimize their exposure to the solvent, similar to the formation of micelles by a

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surfactant above its critical micelle concentration. This association results in an increase in the hydrodynamic size of the polymer that increases solution viscosity.

The amphiphilic polymer can greatly improve the stability of produced liquid and thus makes it difficult to treat. It is of great necessity to study the stability of amphiphilic polymer flooding O/W crude oil emulsion.

2. EXPERIMENTAL

2.1. Material

The crude oil (with its water content <0.5 wt%) came from Gudong oil extraction plant of Shengli oilfield and its physical and chemical characteristics are shown in Table 1. The components of the Gudong simulated water are given in Table 2. The amphiphilic polymer (hydrophobic associating polyacrylamide) with an average molecular weight of 7.0×10^6 and a degree of hydrolysis of about 25% was commercial product provided by Daqing Oil Refining and Chemical Company, and the amphiphilic polymer is temperature and salt-resistant.

2.2. Preparation of Synthetic O/W Crude Oil Emulsions

The synthetic O/W crude oil emulsion was prepared by mixing certain volumes of the crude oil and the simulated water (2:8, V/V) using a FM-2 homogenizer (FLUKO Equipment Co. Ltd., Shanghai, China) at 55°C with a rotating speed of 3,000 rpm for 10 min.

TABLE 1
Physical and Chemical Characteristics of Gudong Crude Oil

Item	*Value*
Asphatenes, %	14.6
Resins, %	15.7
Aromatics, %	22.4
Saturates, %	46.8
Density, g/m^3, 20°C	0.94
Viscosity, mPa·sec, 50°C	57

TABLE 2
Components of Gudong Simulated Wastewater

Item	*Value*
K^+, Na^+, mg/L	2,786
Ca^{2+}, mg/L	66.8
Mg^{2+}, mg/L	20.8
Cl^-, mg/L	2,754
HCO_3^-, mg/L	818
Total salinity, mg/L	6,445.6

2.3. Stability of Synthetic O/W Crude Oil Emulsion

Dewatering rate φ was employed to evaluate the stability of the synthetic O/W crude oil emulsion, which can be calculated by the following formula:

$$\phi = V_t / V_0 \times 100\% \quad (1)$$

where C_0 is the original water volume of an emulsion sample before bottle test, and C_t is the separated water volume after setting for 15 days at 55°C. The bigger the dewatering rate is, the higher the stability of the synthetic O/W crude oil emulsion.

2.4. Particle Size Distribution Measurement

Particle size distribution was analyzed by Rise-2006 laser particle size analyzer (Jinan Rise Science & Technology Co., Ltd.) according to the full-range Mie scattering theory at room temperature. The measurement range is from 0.02 to 1,200 μm.

3. RESULTS AND DISCUSSION

Influence of polymer concentration and temperature on stability of synthetic O/W crude oil emulsions stabilized by amphiphilic polymer was studied.

It can be seen from Figure 1 that the dewatering rate of synthetic O/W crude oil emulsions decreased with increasing amphiphilic polymer concentration. The dewatering rate of synthetic O/W crude oil emulsions after setting for 15 days at 55°C decreased from about 50% with the polymer concentration of 200 mg/L to about 10% with the polymer concentration of 1,600 mg/L. When amphiphilic polymer concentration is above 800 mg/L, the dewatering rate decreased slowly. The results show that synthetic O/W crude oil emulsion tends to be more stable when amphiphilic polymer concentration increases. Figure 2 shows how polymer concentration affects the distribution of emulsified oil droplets in O/W emulsion. The average particle size of the

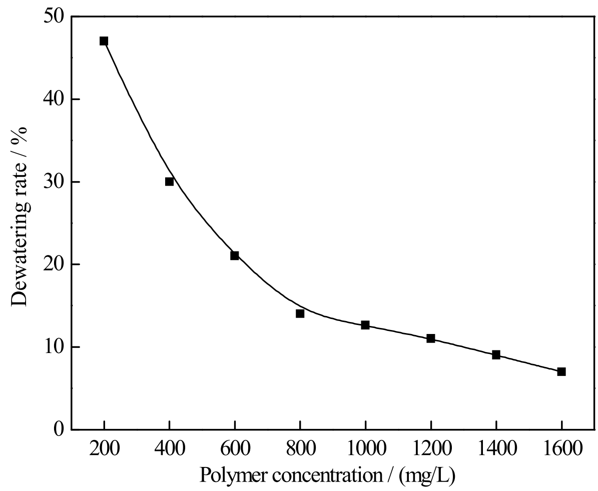

FIGURE 1 Influence of polymer concentration on stability of synthetic O/W crude oil emulsions (at 55°C).

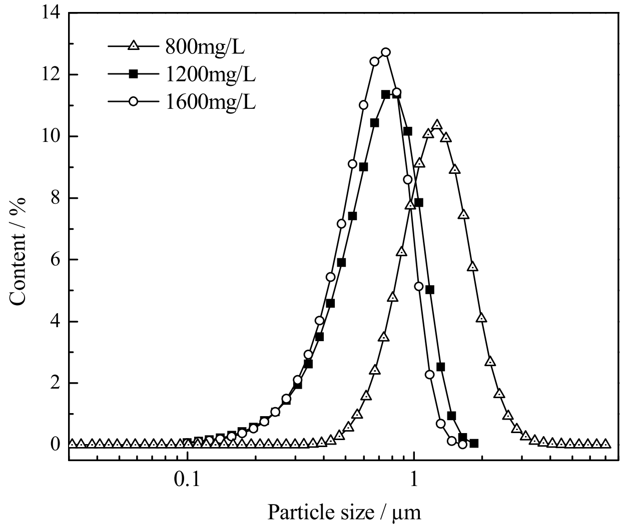

FIGURE 2 Oil droplets distribution versus polymer concentration.

emulsified oil droplets decreased with increasing amphiphilic polymer concentration. All the results show that synthetic O/W crude oil emulsion gets more stable when amphiphilic polymer concentration increases.

Figure 3 shows that the dewatering rate increased with increasing holding temperature.

According to the Stokes equation:

$$v = \frac{2r^2(\rho - \rho_0)g}{9\eta} \tag{2}$$

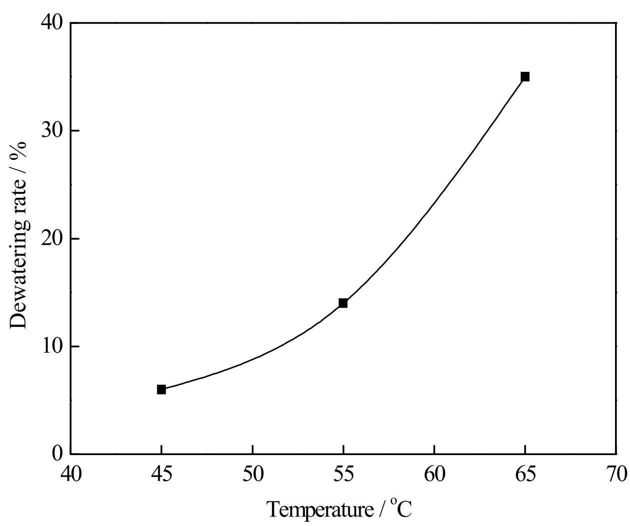

FIGURE 3 Influence of temperature on stability of synthetic O/W crude oil emulsions containing 800 mg/L polymer.

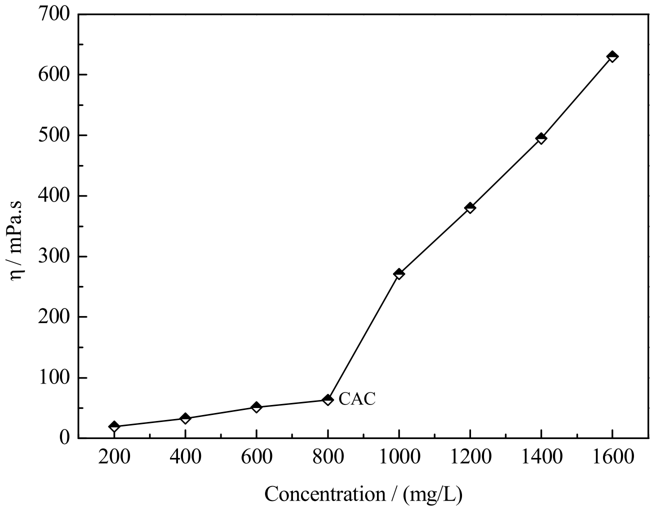

FIGURE 4 Apparent viscosity of amphiphilic polymer solutions.

where ν represents particles settling velocity; r the radius of particles; g the gravitational acceleration; ρ and ρ_0 the mass density of particles and the fluid, respectively; and η the dynamic viscosity of the continuous phase. When temperature increased, the dynamic viscosity of the continuous phase decreased, which led to the increase of particle movement. So the collision probability of oil droplets increases when temperature increases and thus makes the emulsion less stable.

It can be seen from Figure 4 that the apparent viscosity of amphiphilic polymer solutions increased with increasing polymer concentration. When polymer concentration is above 800 mg/L, the apparent viscosity of amphiphilic polymer solutions increased significantly. The critical aggregation concentration (CAC) of the amphiphilic polymer is about 800 mg/L. The viscosity enhancement at CAC is mainly due to intermolecular association. Below the CAC the introduction of hydrophobic groups results in a slight decrease in the reduced viscosity. This reduction is due to intramolecular association, which also reduces intrinsic viscosity and leads to an increase in the Huggins constant (Magny et al., 1991).

Above the CAC, aggregation formed by hydrophobic groups can effectively cross-link the associating polymer, which can enhance the viscosity of amphiphilic polymer solution. The aggregation formed by hydrophobic groups of the amphiphilic polymer can dissolve the organic substance in aqueous solution. Amphiphilic polymer flooding O/W crude oil emulsions are much more stable especially when polymer concentration is above the CAC. Aggregation formed by hydrophobic groups of the amphiphilic polymer is beneficial to the stability of amphiphilic polymer flooding O/W crude oil emulsions.

4. CONCLUSIONS

1. O/W crude oil emulsion tends to be more stable with increasing amphiphilic polymer concentration and decreasing holding temperature.
2. Amphiphilic polymer flooding O/W crude oil emulsion is much more stable especially when polymer concentration is above the CAC. Aggregation formed by hydrophobic groups of the amphiphilic polymer is beneficial to the stability of amphiphilic polymer flooding O/W crude oil emulsions.

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