THE EFFECT OF HARDNESS AND TEMPERATURE ON INTERFACIAL TENSION OF INDIVIDUAL AND MIXED SURFACTANT SYSTEM

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Abstract

Surfactant flooding is one of the techniques of chemical enhanced oil recovery (CEOR) which can be used to increase oil recovery. The surfactant injection decreases the interfacial tension (IFT) between oil and water, and mobilizes the residual oil towards the producing well. In this paper, the performance of alkyl ether carboxylate (AEC) and calcium lignosulfonate (CLS) in individual and mixed surfactant systems were investigated based on their ability to reduce the IFT through a spinning drop method. The IFT of individual and mixed surfactant systems in different brine systems were measured against decane at 25°C and 98°C. The results show that the individual and mixed surfactant systems in 3.5 wt.% NaCl brine has a significant reduction in IFT at 98°C. In contrast, the presence of hardness in 2.5 wt.% NaCl and 1.0 wt.% MgCl₂ brine reduces the IFT of the individual AEC surfactant system and mixed surfactant system significantly at 98°C except for the individual CLS system. Meanwhile, the IFT of mixed surfactant system decreases with increasing surfactant concentration in two brine systems and at 98°C. The findings show the significant application of the AEC and CLS surfactant mixture considering the harsh reservoir conditions for the chemical enhanced oil recovery application.

Research Highlights

The reduction of IFT for individual and mixed surfactant systems are substantial with the presence of hardness in 2.5 wt.% NaCl and 1.0 wt% MgCl₂ brine system compared to the 3.5 wt.% of NaCl brine. The same trend of IFT were observed at high temperature of 98°C for individual and mixed surfactant systems except for the individual CLS system. There is no significant changes of IFT of individual CLS system in 2.5 wt.% NaCl and 1.0 wt% MgCl₂ brine at 25°C and 98°C. The IFT of mixed surfactant system further decreases with the inclusion of CLS at 0.1 wt.% of AEC surfactant, at 98°C in 3.5 wt.% NaCl brine.

Research Objectives

This research aims to investigate the effects of hardness and temperature on the IFT of individual and mixed surfactant systems for alkyl ether carboxylate (AEC) and calcium lignosulfonate (CLS). Previously, lignosulfonate has been introduced as an additive to petroleum sulfonate due to its surface-active properties (1-3). However, despite a high tolerance to the temperature, some of the sulfonate surfactants are sensitive to the high salinity conditions (4, 5). Hence, in this research, the performance of carboxylate surfactant which has shown excellent performance under harsh reservoir conditions (5-7) was investigated with the calcium lignosulfonate. This research has a significant advantage in the potential alternatives for the CEOR application considering the harsh reservoir conditions.

Methodology

The IFT of individual and mixed surfactant systems of alkyl ether carboxylate (AEC) and calcium lignosulfonate (CLS) against decane in two brine systems were assessed by spinning drop tensiometer at 25°C and 98°C. The two brine systems 1) 3.5 wt.% NaCl and 2) 2.5 wt.% NaCl and 1.0 wt.% of MgCl₂ were prepared with the same ionic strength to investigate the effect of hardness on the individual and mixed surfactant system's IFT. In the individual system, the IFT of 0.02 wt.% to 0.30 wt.% of AEC and 0.02 to 1.0 wt.% of CLS were measured. Meanwhile, in the mixed surfactant system, the IFT of 0.1 wt.% AEC and various concentration of 0.02 to 1.0 wt.% CLS were evaluated. The densities of the solutions were determined using a density meter (Mettler Toledo, DM40 model).

Results

The IFT of the individual AEC system decreases with increasing the concentration of AEC surfactant in both brine systems and the reduction in IFT at the temperature of 98°C is more substantial with the presence of hardness. While in the individual CLS system, the IFT decreases significantly with concentration at 25°C but the trend is quite constant at 98°C. Nevertheless, there is no significant reduction of the IFT for the individual CLS system in 2.5 wt.% NaCl and 1.0 wt.% MgCl₂. Concurrently, in the mixed surfactant system, at 25°C, the addition of 0.02 wt.% of CLS increases the IFT and it decreases after the addition of 0.06 wt.% CLS. Meanwhile, at 98°C, the IFT keeps decreasing with the addition of CLS concentration. However, with the presence of MgCl₂, the IFT increases with the addition of 0.02 wt.% of CLS before the reduction of the IFT taking effect after 0.1 wt.% of CLS.

Findings

The reduction in IFT is more substantial in 2.5 wt.% NaCl and 1.0 wt.% MgCl₂ brine, compared to 3.5 wt.% NaCl brine and at 98°C. The lower IFT is achieved at high temperature as the oil solubility of the surfactant is enhanced (6, 8). The presence of hardness reduces the repulsive force charges between the surfactant molecules thus contributes to the surfactant molecules being tightly packed (6, 8, 9). Therefore the less ionized surfactant molecules were strongly adsorbed at the oil/water interface (10). In addition, the presence of CLS in the mixed surfactant system substantially reduces the IFT in 3.5 wt.% NaCl brine system at 98°C due to the enhancement of the interfacial activity at the interface by the presence of calcium in the lignosulfonate (2).

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