USING LINEAR ALKYL BENZENE SULFONATE TO REDUCE INTERFACIAL TENSION OF CRUDE OIL

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Abstract

Interfacial tension (IFT) is one of the main causes of crude oil movement obstruction in oil reservoirs. To enhance oil recovery, a reduction in crude oil interfacial tension is needed. This research aimed to study the reduction of interfacial tension by adding a surfactant solution into crude oil. Linear alkyl benzene sulfonate (LAS) was selected to use as an IFT reducing additive. The effects of the LAS concentration (5%, 10%, and 15% of concentration by volume) and temperature (40°C-90°C) on IFT of crude oil samples from the Sansai oil field, located in the Fang basin, were measured by the ring and plate method based on the ASTM D971-99 standard. As a result, it was found that a maximum reduction of 20% crude oil IFT occurred after adding the LAS solution at 10% by volume at 70°C. IFT was decreased from 26.53 dynes/cm to 21.1 dynes/cm.

Keywords: Linear alkyl benzene sulfonate, Interfacial tension, Surfactant, Crude oil, Sansai oil field

Introduction

Secondary oil recovery methods have been developed and applied to many reservoirs around the world. Waterflooding is a widely used method because of its low cost, availability, and its being well known. It can give more oil recovery compared with primary production. However, some wells can be made to produce only one-third of residual oil after primary production and still have two-thirds left behind. To solve this problem, enhanced oil recovery (EOR) is the applicable method. A surfactant flood is a kind of EOR method that has been employed for more than 40 years in particular in the USA and mostly in depleted oil reservoirs after waterflooding. This technology has been of increased interest and developed in many countries because of the increasing oil price. Though there are many researches for finding new agents to bring the residual oil up from the reservoir, most of the agents used are hazardous to the environment and are still so expensive. Therefore, although chemical flooding is a process that is unattractive in some countries, it is still needed for some oil reservoirs.

The most common surfactant used in micellar/polymer flooding is sulfonated hydrocarbon. The term “crude oil sulfonates”

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refers to the product when a crude oil is sulfonated after it has been topped. Petroleum sulfonates are sulfonates produced when an intermediate-molecular-weight refinery stream is sulfonated, while "synthetic sulfonates" are the product when a relatively pure organic compound is sulfonated. In general, crude oil and petroleum sulfonates have been used for low salinity application (< 2 to 3 wt% NaCl). These surfactants have been widely used because they are effective at attaining low IFT, are relatively inexpensive, and have been reported to be chemically stable (Green and Willhite, 1998).

Some Researches and Experiments Using a Surfactant to Reduce IFT

Chen *et al.* (2005) investigated IFT between oil solutions and cationic gemini surfactants. It was found that the gemini surfactants were more effective and efficient than corresponding conventional surfactants in reducing IFT and could lower the tension of the kerosene-water interface to ultra-low at a very low concentration without other additives. The addition of salt resulted in more effectiveness of the surfactants in reducing the tension of the kerosene-water interface and also showed that the gemini surfactants had a synergism with salt. This experiment used crude oil from the Zhongyuan oil field in China.

Iglauer *et al.* (2009) investigated 4 different types of surfactants for their effectiveness in tertiary oil recovery (TOR). They used basic screening analysis, which included IFT measurements, adsorption measurements and phase behavior studies. Performance in terms of EOR showed that the surfactant generated a low IFT and also showed low adsorption on the reservoir rock material. The selected surfactant formulations a) di-tridecyl sulfosuccinic acid ester, b) coconut diethanolamide, c) alkylpolygycosides, and d) alkyl propoxy sulfate sodium salts were tested for their enhanced oil recovery performance by using coreflood tests on Berea sandstone. Consequently, due to reductions of IFT, this led to significant additional incremental oil recovery of 40% TOR, 15% TOR, 75% TOR, and 35-50% TOR, respectively.

Due to its properties that can reduce crude oil IFT, its being easily soluble in water, inexpensive, and friendly towards the environment, this research selected LAS as the IFT reducing agent to study. The expected result of this study was that this surfactant would reduce crude oil IFT and could be an alternative IFT reducing agent to use in the oil flooding process in the future.

Materials and Methods

Materials

Crude oil samples were from the Sansai oil field, located in the Fang basin, and were provided by the Northern Petroleum Development Center, Defence Energy Department, Fang district, Chiang Mai province, Thailand. The physical properties of the crude oil of the Sansai oil field were collected from a previous study by Chumkratoke (2004) and are shown in Table 1.

Linear alkyl benzene sulfonate (LAS), used as the IFT reducing agent in this study, is a synthetic anionic surfactant. It was introduced in the 1960s as being more biodegradable and was used instead of highly branched alkyl benzene sulfonate in general. LAS is a nonvolatile compound produced by alkylation and sulfonation of benzene (Sablayrolles *et al.*, 2009). The chemical structure of LAS is illustrated in Figure 1.

Method

The IFT test conducted in this study was a static test ignoring the influences of high pressure and salinity. The IFT of the LAS solution and crude oil was measured by the Du-Nouy ring method and Wilhelmy plate method with a KRUSS K10ST tension meter (KRUSS GmbH, Germany) based on ASTM D971-99 standard (ASTM, 1989). In the Wilhelmy plate method, as illustrated in Figure 2, when the bottom of a verticallyoriented detection plate makes contact with a liquid surface, the liquid wets the plate surface upward and a meniscus is created. At this moment, the surface area of the liquid is expanded and IFT tends to contract the surface area as a counteraction, and immerse the plate downward. This method determines the surface tension or interfacial tension by measuring the force bringing the plate downward via a counter balance. The KRUSS K10ST tension meter used in this study has a range of solutions between 1 and 999 dyne/cm and a range of temperatures between 0 and 100°C. Then IFT can be calculated by the following equation.

$$\ell = \frac{F}{L \cos \Theta}$$

where ℓ = interfacial tension (mN/m)
L = wetted perimeter of the plate (mm)
Θ = the contact angle between the liquid phase and the plate (°)
F = force (mN/m)

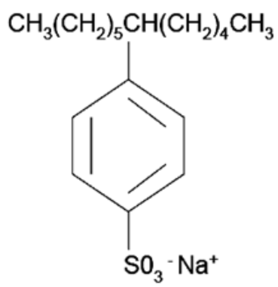

Figure 1. Chemical structure of Linear Alkyl Benzene Sulfonate basis substance in dishwashing liquid (Industry Coalition for the SIDS Assessment of LAS, 2005)

In this study IFT test processes were conducted as the following steps:

- The LAS solution was prepared in various ratios between the LAS and water as 5%, 10%, and 15% by volume, respectively.
- The LAS solution and crude oil samples were mixed in 30 cc glass cups with the ratio of 5%, 10%, and 15% by volume concentration, respectively. The compounds were stirred until they were dissolved into the solvent and then cooled down to room temperature.
- The IFT of the crude oil was measured at a range of temperatures between 40°C and 90°C. This was because at a temperature below approximately 40°C crude oil samples became a wax which could not be measured.

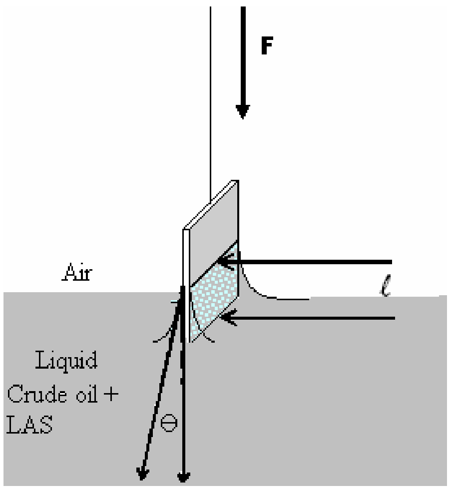

Figure 2. Wilhelmy plate method modified (Holmberg, 2002)

Table 1. Physical properties of Sansai's crude oil (Chumkratoke, 2004)

Properties	Value
Density	0.86 (g/cc)
Viscosity	20.1 (cp)
API gravity	34 (°API)

Results and Discussions

The measured IFT (dynes/cm) of crude oil at various concentrations and temperatures (°C) were shown in Table 2 and also graphically illustrated in Figure 3. The IFT of crude oil measured at 40°C at 0%, 5%, 10%, and 15% by volume LAS concentration was 31.87, 29.96, 29.1, and 27.9 dynes/cm, respectively. After the temperature had been elevated, it was found that the IFT of every LAS solution concentration tended to decrease (Table 2 and Figure 3).

From Figure 3 it is clearly indicated that when the LAS surfactant was added to the solvent at 5% by volume concentration, the dissolved surfactant molecules were dispersed as monomers. However, when the concentration of surfactant increased to 10% by volume concentration, the molecules tended to aggregate. This is because, above a specific concentration called the critical micelle concentration (CMC), further addition of surfactant to 15% by volume concentration tended to result in the formation of micelle.

Conclusions and Recommendations

It could be concluded that the change to a decline in the crude oil IFT resulted from the concentration and temperature of the solutions being increased up to the CMC.

After the CMC had been reached, a greater concentration of LAS and a higher

Table 2. Measured crude oil IFT from laboratory at various surfactant solution concentrations and temperatures

Temperature (°c)	LAS at 0% concentration	LAS at 5% concentration	LAS at 10% concentration	LAS at 15% concentration
40	31.87	29.97	29.1	27.9
50	27.27	27.6	21.8	26.6
60	26.73	27.43	21.4	25.6
70	26.53	26.8	21.1	26.53
80	26.03	26.5	21.47	26.47
90	25.47	26.2	21.3	26.37

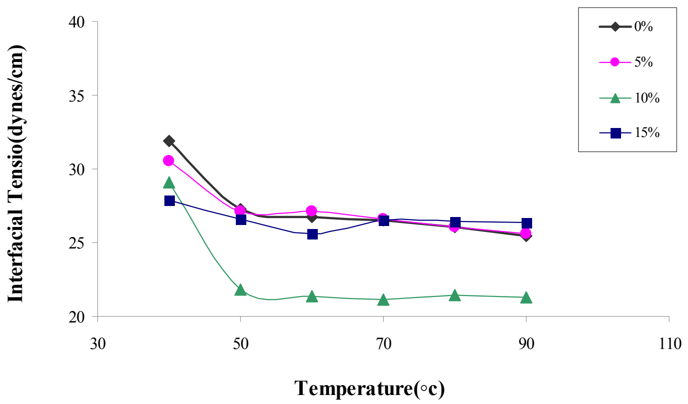

Figure 3. IFT of crude oil with and without adding surfactant solution at selected ratios

temperature would not significantly affect the crude oil samples' IFT.

For further study and to get more resolutions, the authors recommend as the IFT measurement method the spinning drop method which has a wider range of IFT measurement at about 10−5 mN/m to 102 mN/m.

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