Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 53(Special Issue 1) (2021) 85-88
DOI: 10.22060/mej.2019.15736.6193

# Experimental Study of Surfactant Type Effects on the Foam Stability and Mobility With the Approach of Enhancing Oil Recovery

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**ABSTRACT:** One of the methods to enhance oil recovery is the injection of foam into oil reservoirs. The most important restriction on the use of foam in enhancing oil recovery methods is maintaining its stability in the face of the oil phase. In this study, we tried to investigate the factors affecting the foam stability and its apparent viscosity by making laboratory setups. The stability of the bulk foam has been studied by measuring the height variation of the foam types within the vertical column. The stability of the foam bubbles has been investigated by making a transparent Hele-Shaw cell equipped with pressure sensors. The results show that the type of surfactant has a significant effect on the stability of the foam bubbles. Initially, sodium dodecyl sulfate and cocamido propyl hydroxyl sultaine foams showed the highest stability in the presence and absence of oil, respectively. But with the 1: 1 combination of them, the foam stability significantly increases. The results show that foam with a finer texture has a higher viscosity. Also, the quality of the foam directly, and the foam flow rate adversely, affect its apparent viscosity; however, as the foam flow rate increases, its dependence on foam quality is greatly reduced.

**Review History:**

Received: 2019-01-31
Revised: 2019-09-04
Accepted: 2019-09-22
Available Online: 2019-10-25

**Keywords:**

Oil recovery
Experimental study
Surfactant
Foam stability

## 1. INTRODUCTION

The use of foam is one of the alternative ways to improve oil recovery. The presence of foam bubbles significantly increases its viscosity relative to that of pure gas [1]. The high viscosity of the foam in the oil phase displacement process reduces the mobility ratio between the displacing fluid and the displacement fluid. By reducing the mobility ratio, the gas can penetrate the low permeability streaks and allow better oil displacement [2]. The foam is thermodynamically unstable. Foam instability is due to the tendency to decrease the free energy of the lamellae surfaces. Therefore, the most important challenge in using foam is to maintain its stability.

## 2. METHODOLOGY

To prepare a surfactant solution, distilled water and four different surfactants with 0.5wt% concentration, were used. The surfactants were used with their specifications are shown in Table 1.

Experiments have been performed on the bulk and bubble scales, respectively, in the chromatography column and the Hele-Shaw cell. Foam revolution has been studied by imaging them and Image analysis has been performed using MATLAB software.

## 3. RESULTS AND DISCUSSION

### 3.1. Stability of foam, bulk scale results

The main criterion for foam stability in the bulk scale experiments is its half-life (i.e. the elapsed time until the foam height is reduced to half the initial value). A longer half-life will indicate greater foam stability and vice versa. This criterion has so far been used in previous research [۶-۳]. Fig. 1 compares the half-life of different foams in the presence and absence of the oil.

According to Fig. 1, the unstable effect of the oil phase of the Decane and the reduction of the foam half-life is evident for all the surfactants used in this study. By ranking the stability of different foams in the presence of the Decane, CTAB and CAPBSDS have recorded the lowest and highest stability, respectively.

### 3.2. Stability of foam, bubble scale results

In this section, the coarsening and rupturing of bubbles which affect the foam stability have been studied. To quantify the dynamics and identify foam at the bubble scale, the normalized number of bubbles (the number of bubbles at each time divided by the number of bubbles at the start of the experiment) was calculated for each foam. Fig. 2 depicts the normalized number of bubbles for different foams over time.

According to the graph slope, the rate of bubble reduction of all foams at the beginning of the experiments was very high, but over time, the slope decreased, indicating the relative stability of the bubbles.

Fig. 2 shows that the least bubble coarsening is attributed to CAPBSDS foam. This is due to its high stability, which can be related to the thickness of the lamellar films. Since the cell is horizontal and the gravitational force does not play a role in the fluid discharge from the lamellae, the thicker lamellae

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**Table 1. Properties of surfactant solution (0.5% Concentration) used in our experiment**

| Commercial name | Viscosity (mPa.s) | Surface tension $(mN.m^{-1})$ | Name | Supplier |
|---|---|---|---|---|
| SDS | 1.177 | 34.23 | Sodium Dodecyl Sulfate | Merck |
| CTAB | 1.157 | 37.41 | Cetyl Trimethyl Ammonium Bromide | Merck |
| AOS | 1.244 | 36.26 | Alpha Olefin Sulfonate | PSG |
| CAPB | 1.247 | 34.44 | Cocamido Propyl Hydroxyl Sultaine | PSG |
| CAPBSDS | 1.182 | 31.71 | SDS 1:1 CAPB | - |

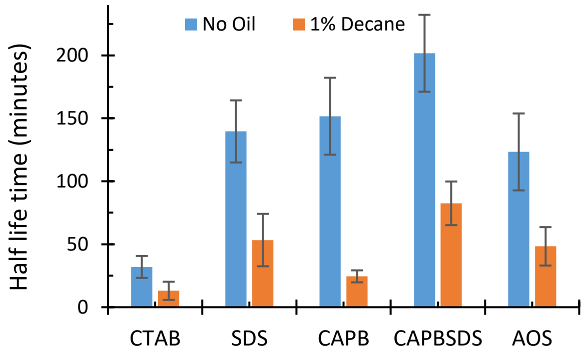


**Fig. 1. The half-decay times of foams in the absence and presence of Decane**

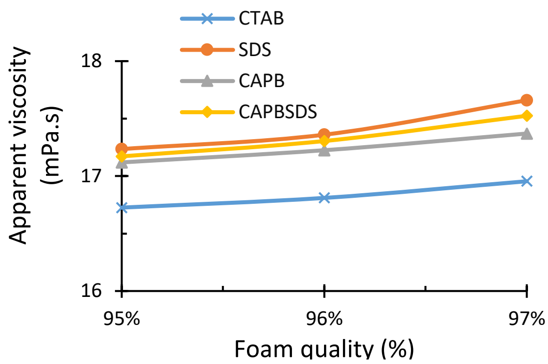


**Fig. 3. The relation between foam quality, surfactant type and apparent viscosity of foams**

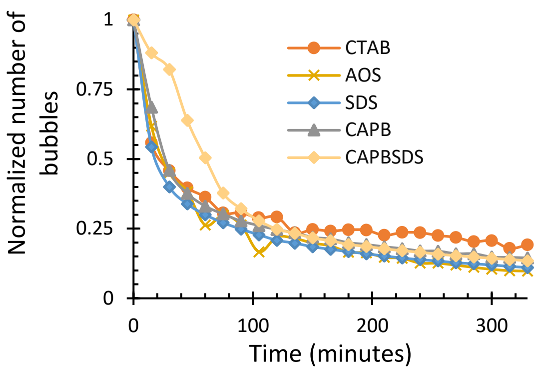


**Fig. 2. Normalized number of bubbles**

are more resistant to gas diffusion within the bubble and thus the foam will be more stable. The results of this section are in agreement with the results observed in Ref. [6].

### 3.3. Apparent viscosity

The experiments in this section calculate the apparent viscosity of the foam by injecting the foam into the cell and measuring the difference in inlet and outlet pressure. Fig. 3 shows the relationship between the quality of the foam and its apparent viscosity for different types of foam.

The results of Fig. 3 show that as the foam quality increases, its apparent viscosity increases, which is in agreement with previous studies [6]. Because foam with a higher gas ratio (higher quality) requires more deformation to yield and flow. Therefore, the yielding stress is higher and therefore it has less mobility (higher viscosity) [7]. In addition, it can be seen in Fig. 3 that in constant quality, the SDS, CAPB and CAPBSDS foams have a higher viscosity than the CTAB foam. Since the viscosity of the surfactant solution of all the foams is about the same, the main difference between the viscosity of the CTAB foam compared to the other foams tested is its coarse texture. In the previous research [8], foam texture has been one of the parameters governing the apparent viscosity of the foam. For a fixed foam quality, the foam with finer texture has a higher apparent viscosity and vice versa. because the foam containing smaller bubbles requires more deformation stress (higher deformation stress implies higher viscosity). The above results show that the higher quality of the foam does not certainly equal its higher viscosity, and the texture of the foam and the material of the surfactant also affect it.

## 4- CONCLUSIONS

According to the experiments, the following results were observed:

1. The Type of surfactant has a significant effect on the foam stability, such that, by combining two or more surfactants can have a significant effect on its stability.

2. The foam texture characteristics (bubble number, bubble size distribution and average bubble size) affect its stability so that the smallest foam texture with the least amount of bubble

size changes can correspond to the highest foam stability.

3. The texture of the foam affects the apparent viscosity of the foam so that the foam with smaller bubbles has a higher viscosity.

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**HOW TO CITE THIS ARTICLE**

*S.M. Razavi, M.M. Shahmardan, M. Nazari, M. Norouzi, Experimental Study of Surfactant Type Effects on the Foam Stability and Mobility With the Approach of Enhancing Oil Recovery, Amirkabir J. Mech Eng., 53(Special Issue 1)(2021) 85-88.*

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