Laboratory Investigation of Static Bulk-Foam Tests in the Absence and Presence of Crude Oil

Evans Anto-Darkwah, Muhammed Rehan Hashmet, and Ali M. Alsumaiti

Abstract—Bulk foam-tests have been conducted at ambient conditions in the absence and presence of oil using Doumeen and Ethomeen surfactants and Nitrogen as the primary mixing gas. The effects of brine salinity and surfactant concentration on foam generation and stability are investigated. In another set of experiments, both brine salinity and surfactant concentration are fixed and the effect of type of mixing gas (N2, CO2 and air) on foam generation and stability are studied. Foam height after mixing with gas is recorded and it represents foam generation. The time for foam to break to half of its original height is recorded to represent foam stability. Comparison of results for experiments in absence/presence of oil reveals that oil is detrimental to foam generation and stability in this studies. The rate of foam decay with time recorded. Visual observations of foam performance. Static foam performance have been found not to have direct correlation with dynamic foam performance [8], [9]. Vikingstad et al. [10] contends that notwithstanding the possible differences between static and dynamic foam tests, static-foam tests may reveal important parameters in foam-oil interaction tests. All experiments are conducted in the absence and presence of oil to check the effect of oil on foam generation and stability.

II. EXPERIMENTAL PROCEDURES

A. Materials Used

The surfactant used in all experiments is Doumeen (TTM) with a C16-C18 carbon chain length, a molecular weight of 240 g/mol and was provided by Akzo Nobel. The brine composition consists of NaCl = 182.3g; CaCl2.3H2O = 77.24g and MgCl2.6H2O= 25.62g. A typical light Middle Eastern crude oil is used in all experiments.

B. Procedures

The first series of experiments are conducted in the absence of oil. Different surfactant concentrations and brine salinity solutions were prepared from a surfactant stock solution of 5 wt% and brine stock of 275000 ppm by appropriate dilution with distilled water. The surfactants were stabilized with 5-7 drops of 10% HCl to move the pH to 7 (from cloudy to clarity). Total solutions of ten millimeters consisting of surfactant of different concentration and brine salinities are placed in a 50 ml graduated cylinder. The resulting solution was purged (mixed) with gas (Air, Nitrogen or Carbon dioxide) for 2 mins. The graduated cylinder was closed with a cork immediately after purging. The foam height above the liquid phase was recorded after gas purging stops. The height of the foam at time (t=0) represents the foam generation (foamability). The foam decay (breakage) was recorded as a function of time. The foam half-life is defined as the time taken for the original height of foam to break into half. The half-life is the stability characterization parameter for the foam.

The second series of experiments are conducted in the presence of oil using the same procedure and conditions outlined above. 2 ml of oil was added to the resulting 10 ml solutions of surfactant and brine and purged with gas for 2 mins. The foam height above the liquid phase was recorded and the rate of foam decay with time recorded.
1) Effect of salinity

In these set of experiments, the surfactant concentrations were fixed at concentrations of 0.5, 1 and 1.5 wt% and the brine salinities were varied from 108000, 125000, 165000 and 205000 ppm. The foam height and half-life are recorded to evaluate the effect of salinity on foam generation and stability at room temperature conditions.

Table II shows the results for fixed surfactant concentrations of 0.5, 1 and 1.5 wt%. Brine salinity variation is between 100000-200000 ppm.

Fig. 1 shows the results for the effect of salinity variation on foam height and Fig. 2 also shows the results for salinity variation on foam stability at a fixed surfactant concentration of 0.5wt%. The results correspond to experimental runs 1A and 1B.

![Fig. 1. Effect of Salinity on foam height.](image1)

![Fig. 2. Effect of Salinity on foam stability.](image2)

Results obtained at a fixed concentration of 0.5wt% (Runs 1A and 1B) shows that lower salinity promotes foam generation (see Fig. 1). The height for the low salinity brine (125000ppm) was recorded as 10cm at t=0 and that of the higher salinity brine (205000ppm) is 6cm. However, the stability time for foam is better for the higher salinity brine. This is to say that, the lower salinity foam breaks much quicker than the higher salinity foam. The same trend was observed in experiments using a fixed concentration of 1.5 wt% (Runs 2E and 1C) as shown in Table II. The trend of low salinity promoting foam generation was also observed for 1wt% surfactant concentration experiments. However, the stability time for low and high concentrations of brine are almost similar for Runs 3A, 2C and 3C (Refer to Table II).

2) Effect of surfactant concentration

The set of experiments under this section were performed such that the brine salinities were fixed at 125000ppm, 165000ppm and 205000ppm whilst varying the surfactant concentrations at 0.29, 0.5,1 and 1.5 wt%. The various experimental runs are shown in Table III.

![Fig. 3. Effect of surfactant concentration on foam generation.](image3)

![Fig. 4. Effect of surfactant concentration on foam stability.](image4)
3) Effect of mixing gas

These set of experiments were designed with fixed brine salinity of 165000 ppm and surfactant concentration of 1 wt%. Different gas types (Nitrogen, Air and Carbon dioxide) were used for mixing or generating foam. The foam height and half-life were recorded.

In general Nitrogen gas foams generated more foams followed by CO$_2$ and lastly air (Fig. 5). Air has more stable time for the foams formed, followed by Nitrogen and lastly CO$_2$ foams breaks quickest (Times<2mins). We observed that the foam heights for CO$_2$ foams vary significantly for all three runs even though the brine salinity and surfactant concentration are fixed. A brief explanation for this behavior may lie in the bubble size of foams formed during gas mixing. Even though bubble texture/size studies was not a focus of this study, it was observed visually that among all the gases, CO$_2$ foams formed bigger bubbles during mixing. In research conducted by [12] small textured foams were found to be more stable than bigger textured foams. This assertion is confirmed in the foam stability times

Fig. 6 and Fig. 7 shows the height and stability times for experimental runs 2B, 2C and 3C using different mixing gases.

4) Effect of brine salinity

The results in Fig. 7 and Fig. 8 compares the heights and half-life times for experimental runs 1A and 1B (Refer to Table II). Surfactant concentration is fixed at 0.5wt% and brine salinity is varied at 125000 ppm and 205000 ppm.

The same heights of foam were recorded for both salinities after mixing with nitrogen. Salinity had no effect on foam generation for both sets of experimental runs (1A and 1B) in the presence of oil. Comparison of foam heights in presence and absence of oil (see Fig. 7) reveals that, the foam breaks much quickly with lower salinity for Doumeen (TTM). A half-life of 10.58 mins was recorded for 205000 ppm and 5 mins for 105000 ppm. This shows that the higher salinity brine stabilizes the foam by approximately twice the time of lower salinity brine (105000 ppm).

5) Effect of surfactant concentration

Experimental runs 1E and 2C were repeated with oil...
addition to observe the effects of crude oil on foam generation and stability. The salinity was fixed at 165000ppm and concentration of surfactant was varied at 0.29 and 1 wt%.

Varying surfactant concentration does not seem to have much effect on foam generation. Only a point difference was observed (See Fig. 9). Also the foam stability time is only three points more for high surfactant concentration in the presence of oil. Comparison of Fig. 4 and Fig. 10 reveals the vast difference in half-life between oil absence and presence. Fig. 9 and Fig. 10 shows the results obtained for foam height and stability respectively.

The effect of mixing gas type was repeated at a fixed brine salinity of 165000ppm and fixed surfactant concentration of 1 wt%. The comparison between absence and presence of oil on foam generation and stability are shown in Fig. 11 and Fig. 12 respectively. Foam heights and stability times for various mixing gases in the presence of oil was in the order of Air>Nitrogen>CO2 respectively. Foam heights and stability times in the absence of oil were much bigger than in the absence of oil (Fig 11 and Fig. 12).

6) Effect of mixing gas

The effect of mixing gas type was repeated at a fixed brine salinity of 165000ppm and fixed surfactant concentration of 1 wt%. The comparison between absence and presence of oil on foam generation and stability are shown in Fig. 11 and Fig. 12 respectively. Foam heights and stability times for various mixing gases in the presence of oil was in the order of Air>Nitrogen>CO2 (Fig. 11). Foam heights and stability times in the absence of oil were much bigger than in the absence of oil (Fig 11 and Fig. 12).

IV. CONCLUSIONS

In the absence of oil, the following can be said:
1) Low salinities promote foam generation. However higher salinities (up to 205000ppm) stabilize foam for longer half-life.
2) Higher surfactant concentration generates more foams and also has longer stability than lower surfactant concentration.
3) Nitrogen as the mixing gas produces more foams and also the half-lives were higher for Nitrogen gas. This trend is followed by air and CO2 gas performs poorly.

Oil presence was detrimental on both foam generation and stability. The following are arrived at on the effect of parameters in the presence of oil:
1) Lower salt salinity generates more foams and high brine salinity stabilize foam than lower brine salinities. This trend was also observed in the absence of oil.
2) The effect of surfactant concentration on foam generation was not clear. Nonetheless, higher brine salinity stabilizes foam.
3) Air or Nitrogen as the mixing gas promotes more foam generation and foam stability. However, performance of CO2 was not convincing in foam generation and stability at room conditions.

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REFERENCES


**E. A. Darkwah** is a visiting graduate research assistant at the Petroleum Institute. Anto-Darkwah earned a bachelor of chemistry degree in 2009 from KNUST, Kumasi-Ghana and a master of science in petroleum engineering from Istanbul Technical University, Istanbul-Turkey in 2015. He is a member of the Society of Petroleum Engineers.