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Foam break-up under swirling flow in inlet cyclone and GLCC©☆

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ABSTRACT

Experimental data are acquired on foam stability and break-up efficiency in a 0.025 and 0.05 m inlet cyclones and a 0.05 m GLCC compact separators. Additional data are collected in a 0.025 m inlet cyclone on the effect of increasing surfactant concentrations on foam stability and break-up efficiency.

The experimental results show that foam stability increases with increasing surfactant concentration, having an exponential decay effect on foam break-up efficiency in the cyclone. For the 0.05 m inlet cyclone and GLCC, at low *G*, only negligible foam break-up occurs. On the other hand, at high *G*, higher foam break-up efficiency is achieved. Comparison of the foam break-up efficiency demonstrates a slightly better performance of the GLCC, as compared to the inlet cyclone.

1. Introduction

Most of the foam found in the field is a result of gas entrainment in the oil or brine phases in the production streams. For crudes with high Gas-Oil Ratio, lowering the operating pressure causes gas to come out of solution and mix with any available surfactants, forming a foam layer on top of the flowing oil. This naturally occurring phenomenon must be addressed when designing process facilities for such crudes. If the oil is not properly defoamed it could foul equipment downstream of the wellhead, namely, separators, pumps, compressors, sweetening units, dehydration units and stabilizers. This will result in an undesirable decrease in oil and gas production rates.

In various field applications, foam is artificially generated to solve production operation problems. One such application is utilization of surfactants (such as soap sticks) to unload gas wells, whereby the surfactant generates foam, reducing the hydrostatic head in the wellbore and restoring production from the reservoir. The disadvantage of this operation is the necessity to break the foam upstream of the process facilities. Another possible application is the elimination of severe slugging in deep water offshore platform risers. For this case, a surfactant solution is injected into the bottom of the riser, generating foam in the riser. This reduces the mixture density and the gravitational pressure head, resulting in a continuous and steady flow in the riser, eliminating the occurrence of severe slugging. Once again the generated foam must be eliminated for proper crude processing.

The interactions between oil droplets and the foam lamella has been studies by Koczo et al. (1992). In this study, the aging foam phenomena such as drainage, bubble and rupture is considered. Experimental and theoretical investigations have been conducted by Neethling et al. (2005) to consider the trend of growing and collapsing foams. This study focuses the liquid drainage as well as evolution of liquid content. Osei-Bonsu et al. (2015) conducted experimental study to evaluate the effects of different surfactants and hydrocarbons on foam stability for enhanced oil recovery (EOR) applications. The foam stability has been studied for both bulk and bubble scales.

Various methods can be applied to treat foamy oils and eliminate foam, some of which have adverse consequences. Chemical injection is cost ineffective, whereby continuous chemical solutions are injected for defoaming the crudes. These solutions can severely damage the production, and they are also difficult to separate in downstream facilities. Thermally heating equipment or pipes to separate the foam is expensive and can also alter the properties of the oil, which can lead to further processing problems.

A cost effective solution to the foaming problem that protects the production facilities is utilization of mechanical foam break-up methods, such as cyclones. These are simple to install, with no moving parts, have lower capital costs, and are more compact and lighter. Foam break-up study in a 0.08 diameter Gas-Liquid Cylindrical Cyclone (GLCC) oper-

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ated at 1.7 $\times 10^5$ pa was conducted by Guzmán (2005). Experimental data were acquired, including the operational envelope for foam break-up. Hoffman and Stein (2007) discussed some of the basic principles and considerations of the foam cyclone design and behavior. Karaaslan (2009) performed a foam generation and characterization study utilizing a 0.025 m inlet cyclone, using SI-403 and Drill Foam F-450 surfactants. He quantified the effect of the *G* created in the cyclone on foam break-up using a 0.025 m inlet cyclone. Recently, Nababan (2015) studied experimentally foam break-up in standalone Churn Flow Coalescer (CFC) and GLCC, as well as integrated CFC/GLCC system under gas and liquid modes.

The objective of this study is to investigate experimentally foam break-up in an inlet cyclone and a GLCC, and compare their performances. The experimental phase includes the effect of increased foam stability (due to increased surfactant concentration) on the foam break-up efficiency and data acquisition on foam break-up in the cyclones.

2. Experimental program

The experimental facility, test matrices, fluid properties, testing and calculation procedures, and the experimental results are presented in this section.

2.1. Experimental facility

Foam Characterization Rig (FCR) skid, shown in Fig. 1, is used for the experimental program. The FCR is a 0.025 m flow loop mounts on a table that is 4 m long, 1.5 m wide and 2.2 m high. The flow loop is constructed from a transparent acrylic PVC pipe, capable of withstanding a maximum working pressure of 5.5 $\times$ 10^5 pa. There are seven main sections in the FCR, as shown in Fig. 1, including the storage, metering, foam generation, foam flow development, upstream sampling, and cyclone test sections, which will be described next.

2.1.1. Storage and metering sections

The FCR is equipped with two 0.38 m^3 storage tanks, one for storing tap water, while the other serves as a disposal unit for the water-surfactant mixture. The tap water tank is connected to a CRANE® centrifugal pump delivering a pressure range of 0–6.8 $\times$ 10^5 pa. The disposal tank is equipped with an Utilitech submersible utility pump for discharging used fluids. The surfactant mixture is prepared in a 0.02 m^3 cylinder and is pumped using a LMI Milton-Roy AA78 positive displacement pump. Compressed air is delivered to the flow loop by a SULLAIR® LS 100HP compressor, whereby the compressor outlet is connected through a high pressure hose into the FCR. The water and gas flowrates are measured by an array of rotameters, as shown in Fig. 2.

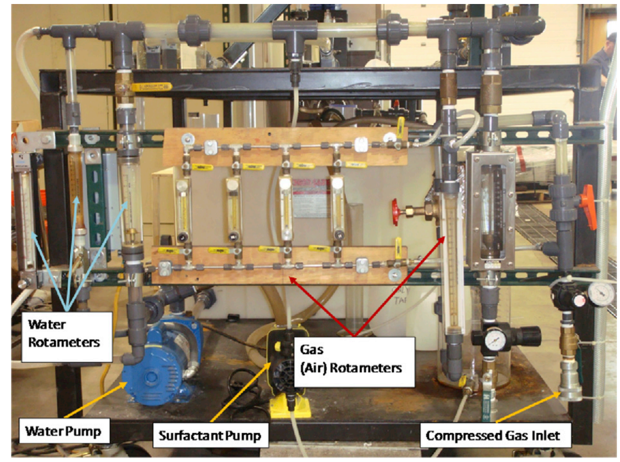

Fig. 2. Metering section.

2.1.2. Foam generation section

Once the compressed air, tap water and surfactant mixture are injected into the 0.025 m flow loop, the mixture flows upwards through a vertical section, namely, the foam generation section (see Fig. 3). This section is an inverted U shape PVC pipe that is equipped with a static mixer. It consists of a 0.15 m long 0.025 m diameter pipe, with 125 μm meshes at the top and bottom, and with a web of inclined steel plates orientated at different directions and angles. When the mixture is forced to flow upwards into this device, sufficient shear force is generated to produce good quality foam.

2.1.3. Foam flow development section

The generated foam flows through sufficient pipe L/d, to ensure fully developed flow with a continuous and stable flow pattern. As shown in Fig. 1, the foam flows through three straight pipe sections and two pipe bends, 0.025 m in diameter, before reaching the test section.

2.1.4. Sampling and cyclone sections

Two foam sampling ports are installed in the FCR. The first one is located upstream of the cyclone, close to its inlet. The latter is located downstream of the cyclone liquid leg component. The sampling ports are utilized to characterize the foam and also to quantify the foam break-up efficiency. The sampling test cylinder is made from a PVC pipe section and is 29 cm high and 15.24 cm in diameter. Before the samples are collected, the foam flows through the sample port until stable flow is observed. The sample is then taken by filling the cylinder with the foam flow mixture until the cylinder is completely filled (up to 29 cm). Three

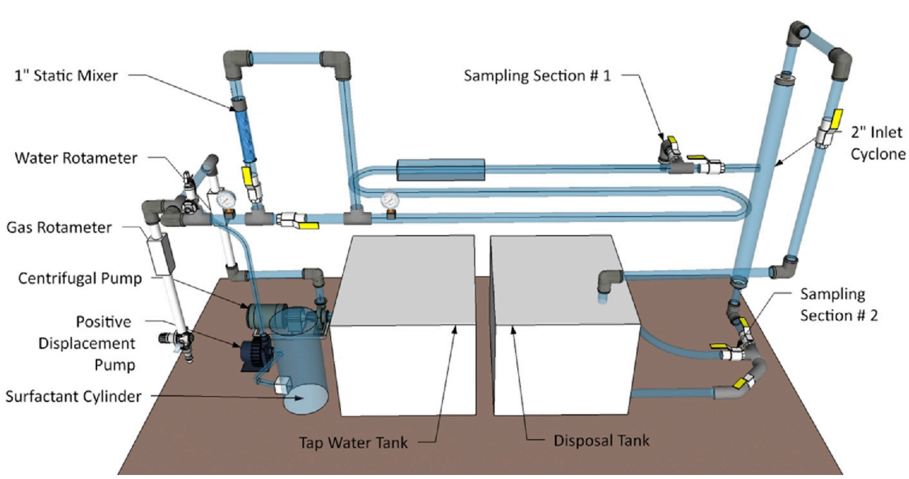

Fig. 1. Foam characterization rig (FCR) skid.