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Effect of frother blends on hydrodynamic properties

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ABSTRACT

The effect of blending polyglycols (F150 and DF250) with alcohols (MIBC and pentanol) on bubble size, gas holdup and froth height in a two-phase system has been determined. A synergistic effect on froth height was observed accompanied by a change in bubble size: below the alcohol critical coalescence concentration (CCC) the addition of small amounts of polyglycol decreased bubble size and, unexpectedly, above the alcohol CCC the polyglycol increased bubble size. Gas holdup confirmed the bubble size response. No explanation of the latter effect is immediately apparent. Implications for possible independent control of froth stability and bubble size as a reason for using frother blends are discussed.

1. Introduction

Frothers are typically non ionic surfactants, commonly alcohols and polyglycols, used in flotation to help reduce bubble size and stabilize froth. This action is related to modification of the air–water interfacial properties but there is no consensus on the mechanisms, particularly with regard to bubble size control (Machon et al., 1997; Grau and Laskowski, 2006; Finch et al., 2008).

The observation is that the average bubble size decreases with increasing frother concentration to become approximately constant above a certain concentration (Klassen and Mokrousov, 1963) now referred to as the critical coalescence concentration (CCC) (Cho and Laskowski, 2002). The name implies that the mechanism is coalescence inhibition; that above CCC coalescence is prevented and the bubble size produced by the machine is preserved. A measure related to bubble size is gas holdup; as bubble size decreases bubble rise velocity decreases increasing bubble retention time which is reflected by an increase in gas holdup (Azgomi et al., 2007a, b). In addition to bubble size reduction, the type of surfactant also affects bubble rise velocity and hence influences gas holdup, making gas holdup a diagnostic measure in its own right (Rafiei et al., 2011). Together bubble size and gas holdup are sometimes referred to as 'gas dispersion properties'.

The second function, froth stabilization, is measured several ways; in this paper we use equilibrium froth height. To refer to both froth stability and gas dispersion the term 'hydrodynamic properties' has been suggested (Cappuccitti and Finch, 2008).

Rather than single frothers blends sometimes prove more effective (Cytec, 2002). There has been some fundamental research into MIBC/polyglycol blends. Laskowski et al. (2003), measuring bubble size and dynamic foamability index of MIBC blended with various polypropylene alkyl ethers, suggested the blend CCC was between the two individual frother CCCs and that froth properties were dominated by the polyglycol. Tan et al. (2005) studied MIBC blended with polypropylene glycols and found a synergistic effect on froth height for some combinations. A froth stabilizing mechanism based on blends increasing surface elasticity was proposed.

As a working hypothesis we suggest an advantage of blends is to provide some independent control over the two frother functions, that one frother may control bubble size and a second manipulate froth stability. The dosage of a single frother, arguably, seeks a compromise between these functions. From our knowledge of frothers, alcohols give excellent bubble size reduction with little froth stabilization (in absence of particles) while polyglycols can provide both properties (Laskowski, 2003; Cappuccitti and Finch, 2008). The concept was to use alcohols (MIBC, 1-pentanol) to provide the target bubble size (a 'base' frother) with additions of polyglycol (F150, polypropylene glycol; DF250, polypropylene methyl ether) to provide the froth control. The purpose of this paper is to determine the hydrodynamic properties of alcohol/polyglycol blends to explore this independent control hypothesis.

2. Experimental part

The test rig was based on a 3.5 m × 10 cm diameter Plexiglas bubble column (Fig. 1). Frother solutions were prepared in the mixing tank and pumped to the column through the base. The bubble generator used was a porous, stainless steel plate sparger (nominal 10 μm

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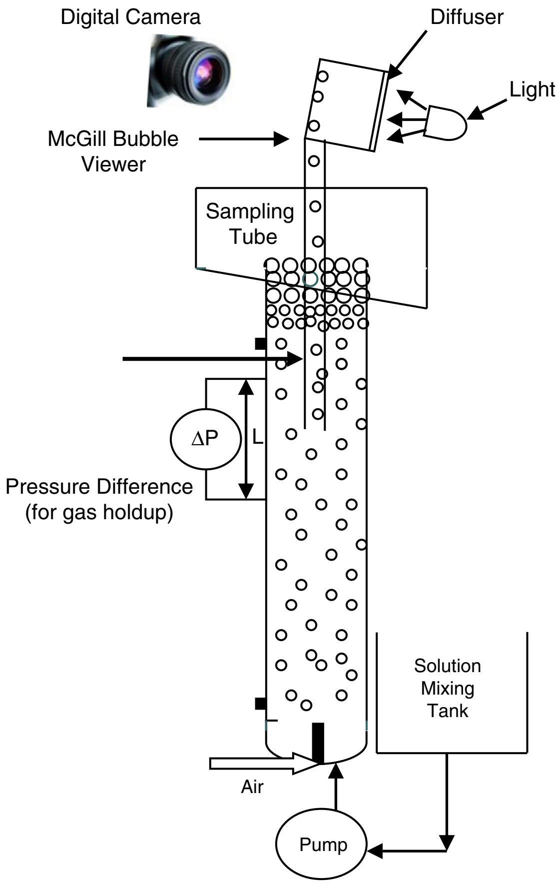

Fig. 1. Bubble column setup.

pore size) and all tests were carried out at 1 cm/s gas superficial velocity (J_g). Bubble size measurements were made using the McGill bubble viewer (Gomez and Finch, 2007). At least 3000 bubbles were counted and the Sauter mean diameter (D_{32}) determined. Gas holdup (ε_g) was determined using differential pressure ΔP measured over a known distance L ($\varepsilon_g = 1 - \Delta P/L$). The steady state (equilibrium) froth height was recorded visually, measured from the froth/solution boundary. All measurements were made at least three times and the mean and standard deviation are reported.

The frothers employed are listed in Table 1. Solutions were made with Montreal tap water (average conductivity: 293 μS/cm, major constituents: 30 mg/L Ca, 24 mg/L SO_4, 23 mg/L Cl, 13 mg/L Na, 8 mg/L Mg (Remillard et al., 2009)). Experiments were run at room temperature (20–22 °C).

3. Results

3.1. Gas dispersion

Fig. 2 shows the effect on bubble size (D_{32}) of increasing concentration for the four frothers individually. They show the same pattern:

Table 1
Frothers used in the blend experiments.

Frother	Formula	Molecular weight g/gmol	Supplier
1-Pentanol	$C_5H_{11}OH$	88	Arcos Organics
MIBC	$(CH_3)_2CHCH_2CH(OH)CH_3$	102	Dow Chemicals
F150	$H(C_3H_6O)_7OH$	425	Flottec, USA
DF250	$CH_3(C_3H_6O)_4OH$	264	Flottec, USA

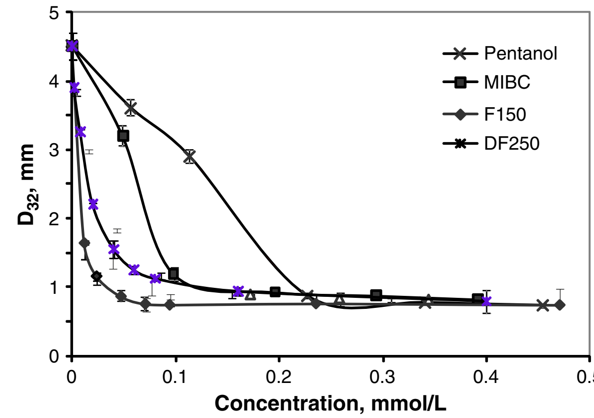

Fig. 2. Bubble size in presence of the four frothers individually.

a decrease in D_{32} to ca. 0.8 mm at a CCC that decreases in the order (approximate CCC (mmol/L) in brackets): pentanol (0.25), MIBC (0.13), DF250 (0.08) to F150 (0.04).

The effect on bubble size of adding small amounts of F150 (i.e., well below the F150 CCC) to MIBC compared to MIBC alone is shown in Fig. 3. At MIBC concentrations up to its CCC bubble size decreases but at MIBC concentrations higher than the CCC the bubble size increases by about 40%, from ca. 1 to 1.4 mm. Gas holdup (Fig. 4) confirms the bubble size results: compared to MIBC alone, upon addition of F150 to MIBC concentrations below CCC gas holdup increases and adding to MIBC concentrations above CCC gas holdup decreases, corresponding with the noted decrease and increase in bubble size, respectively.

The same behavior is revealed for pentanol in place of MIBC (Fig. 5) and DF250 in place of F150 (Fig. 6): upon addition of small amounts of polyglycol to alcohol concentrations below the alcohol CCC bubble size decreases and above the alcohol CCC bubble size increases. In the pentanol with F150 case the increase is ca. 75%, from 0.8 to 1.4 mm. Fig. 7 emphasizes it is small addition of polyglycol (below polyglycol CCC) that causes the increase in bubble size: at a base MIBC concentration of 0.2 mmol/L (i.e., above the MIBC CCC), addition of F150 initially increases bubble size but eventually the size in the blend approaches that for F150 alone.

3.2. Froth stability

As an example, froth height with F150 and pentanol alone and as blends with pentanol as base is shown in Fig. 8. Froth height with

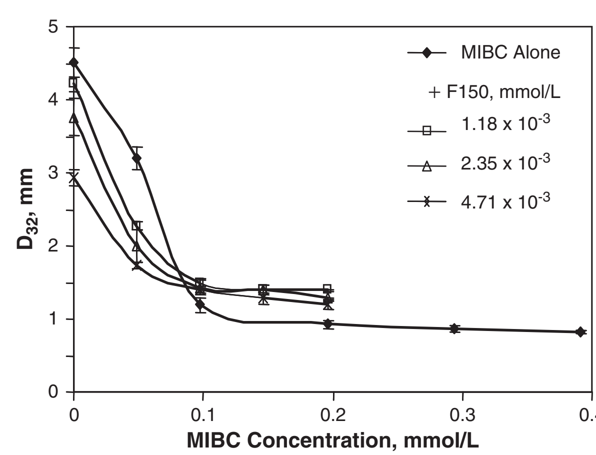

Fig. 3. Effect of F150–MIBC blends on bubble size compared to MIBC alone.