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Technical Note

Visualization of flow in froth

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ABSTRACT

Froth is formed and transplanted on top of dye-containing solution to trace liquid flow. Sufficiently stable froth was formed with soap but with frothers (1-pentanol and polypropylene glycol) talc was necessary to produce transportable froth. With the soap froth liquid penetration was faster than for the talc-stabilized froth.

1. Introduction

Formation of froth in flotation is considered one of the prime functions of frother (Harris, 1982). Characterization of frothers has involved various tests of froth stability including static tests where froth is formed and lifetime measured (e.g. Wang and Yoon, 2008). These tests are used to rank frothers and probe froth stabilizing mechanisms.

Stability of static froth is governed by the rate at which liquid drains under gravity. Processes which oppose drainage will increase stability. One stabilizing mechanism derives from capillary pressure driving ("sucking") liquid from the large radii Plateau borders at the base of froth in contact with solution to the progressively smaller radii Plateau borders up through the froth (Kruglyakov, 1988). Other mechanisms derive from surface tension gradients that are generated by unequal surface distribution of surfactant resulting from drainage (Schmidt, 1996). The gradients give rise to surface elasticity that opposes film thinning and induces flow into the film, the Marangoni effect (Harris, 1982; Tan et al., 2005). Together these stabilizing phenomena will be lumped as 'surface chemistry' effects. Particles in froth introduce mechanical stability by acting as barriers to drainage (Hunter et al., 2008).

In a demonstration of liquid (water) flow associated with surface chemistry effects, Sarma and Chattopadhyay (2001) transplanted a soap bubble onto the surface of soap solution containing dye to visualize liquid motion on the bubble surface. Acuna et al. (2008) adapted the technique to image flows on the surface of bubbles blown in 1-pentanol and polyglycol frother solutions. The purpose of this paper is to apply the technique to froth; that is, to form and transport froth to solution containing dye to visualize liquid flow into the froth.

2. Experimental part

2.1. Materials

Three surfactants were tested: a soap (RONA brand liquid dish soap) selected as a known frothing agent, and two frothers, 1-pentanol (Fisher) and F150 (polypropylene glycol, molecular weight 425, Flottec), selected to give a range from low to high frothing 'strength', respectively (Moyo et al., 2007). The soap readily generated froth stable enough to sample and transport. The frothers did not and talc was used to provide stability. The talc was ca. 50% passing 12 μm (Fisher). The dye was $KMnO_4$ (Fisher) and water was Montréal tap (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)).

2.2. Apparatus and procedure

The setup (Fig. 1) consisted of a glass dish to hold the solution with a plastic weigh tray supported above to anchor the top of transplanted froth. A video camera acquired side-view images to record motion of the dye.

Solutions of 30 mL were prepared in two 50 mL glass vials. To one vial 9 mg $KMnO_4$ was added and this solution was placed in the dish. The second vial was shaken by hand to produce froth. A spatula was used to extract a sample of froth and place on the bottom of the over-turned weigh tray, which was then inverted to sandwich the froth between the solution and the tray (Fig. 1). The distance between the solution and the tray was ca. 0.5 cm. A summary of conditions to produce froth is given in Table 1. The lower of the two frother concentrations is consistent with their use in flotation while the upper levels reflect unsuccessful attempts to produce transportable froth without talc.

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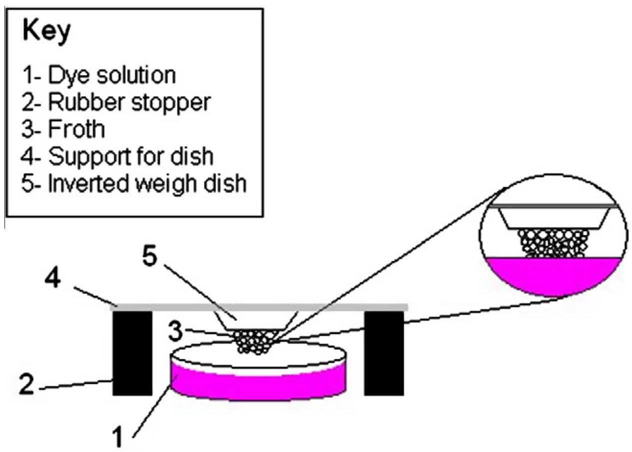

Fig. 1. Experimental Setup.

Table 1
Experimental conditions to produce froth.

	RONA soap	1-Pentanol	F-150		
Concentration (ppm)	3700	18	500	18	2600
Talc (g/30 mL)	None or 0.2	0.5	0.2	0.5	0.2

Table 2
Soap concentration in dye solution.

Condition	1	2	3	4
Concentration (ppm)	0	3700	3700 + talc	7400

The soap gave two types of froth, 'wet' and 'dry'. For wet froth, the sample was taken immediately after shaking from well below the froth surface; the wet foam would produce and sit on a thin layer of water when placed on the tray, which when inverted would produce a small bead of water at the bottom. The dry foam sample was drawn from the top of the foam, after waiting several seconds for it to drain. This froth was light and adhered to the tray with no water layer. No wet or dry distinction was apparent in the frother-talc cases.

The dye solution for the frother tests had the same frother concentration but for the soap tests it was varied from zero soap to twice the concentration in forming the froth and included one test in presence of talc (0.2 g/30 mL) (Table 2).

Image acquisition, running on IFIX software, was initiated immediately the froth was in place. Images were collected till dye reached the top of the froth (ca. 0.5 cm distance). The procedure was repeated at least three times for all conditions.

3. Results

The results for soap are shown in Fig. 2 (wet) and Fig. 3 (dry). The dry froth drew in liquid to fill the froth in less than 20 s while the wet froth took upwards of 10 min. Random samples of soap froth would fill in typically 40–60 s. In both wet and dry cases the condition of the dye solution (concentration and presence of talc) was not a factor.

Fig. 4 shows the results for the two frothers at 18 ppm. Filling of the froth took close to 10–20 min similar to the wet soap froth. Also like the wet soap froth case, there is initial (time 0) liquid penetration that stalls. The situation was the same at the higher concentration of frother (not shown). By comparison with random samples of soap froth, frother-based froth exhibited lower penetration rates.

Visually, soap froth had smaller bubbles than the frother-based froth. Small bubbles build froth more readily than large bubbles but talc is known for producing large-bubbled but stable froth. 1-pentanol gave smaller bubbles than F150, which probably reflects adsorption of F150 by talc (Kuan and Finch, 2010).

4. Discussion

As an extension of the visualization technique on single bubbles the approach forming and transporting froth samples proved

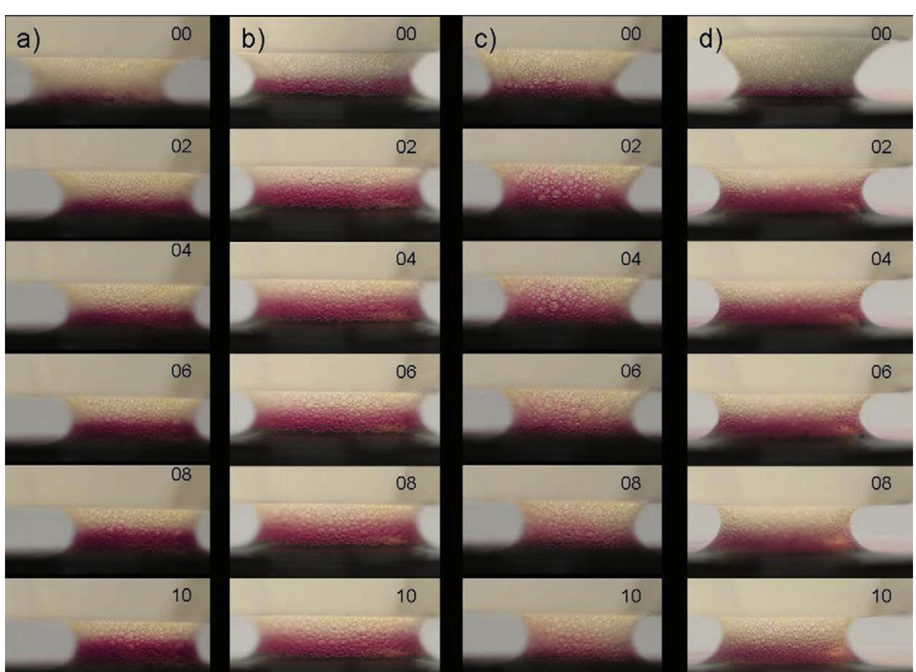

Fig. 2. Series of images for "wet" soap foam with: (a) condition 1, (b) condition 2, (c) condition 3, and (d) condition 4, all showing similar behavior. Time is in minutes.