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Fundamental properties of flotation frothers and their effect on flotation

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Abstract

Froth flotation process requires the use of frothers. These important flotation agents are commonly characterized as either "selective" or "powerful" and are chosen following general guidelines and verification by laboratory and/or pilot plant tests.

Fundamental properties of the flotation frothers have been extensively studied over the last few years. These studies have led to the development of standardised procedures to characterise frothers in terms of their ability to reduce bubble size and to increase foam stability.

In this research project, the performance of five frothers in flotation of coal is evaluated and related to the fundamental properties of these agents. Since the recovery of water in the concentrate is closely related to the non-selective transport of solid particles by entrainment, the tested frothers are also assessed in terms of their ability to promote the transport of water towards the froth collection zone, both in absence and in presence of solids.
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Keywords: Flotation frothers; Flotation froths; Flotation bubbles

1. Introduction

The research projects of the latest decade clearly demonstrated that the first-order flotation rate constant is linearly related to S_b, the bubble surface area flux, which in turn is inversely related to the bubble size (Gorain et al., 1997). The size of bubbles is mainly determined by frothers which operate by preventing bubbles from coalescence. The frothers which are more efficient in reducing bubble size were also shown to produce more stable foams (Cho and Laskowski, 2002a,b).

Mineral particles report to the froth product either via selective attachment of hydrophobic particles to bubbles which carry them to the froth, or via the entrainment with the pulp water which is carried out to the froth by a swarm of bubbles, or via entrapment between particles in the froth attached to air bubbles (Sawassai et al., 1998). Generally, entrainment is insignificant for particles coarser than 50 μm (Smith and Warren, 1989), but the actual size of the entrained particles strongly depends on the froth properties. This is determined by frother concentration, but also by wettability of solid particles and thus also by collector concentration, particle size distribution and the content of particles.

Foams are classified as unstable or metastable (Kitchener and Cooper, 1959). The former are also referred to as wet foams (Malysa, 1992). The wet foams are assemblies of spherical bubbles separated by thick liquid walls and they are well exemplified by dilute solutions of flotation frothers. Such foams can exist only during bubbling and collapse when the foam formation process is stopped. In a metastable ("dry") foam, bubbles acquire a polyhedral shape and are separated by planar or only slightly curved liquid films (Kitchener and Cooper, 1959).

Pure liquids do not foam. For a liquid to foam, it must be able to form a shell around the gas bubble that opposes the thinning of the lamellae. Foaming does not occur in

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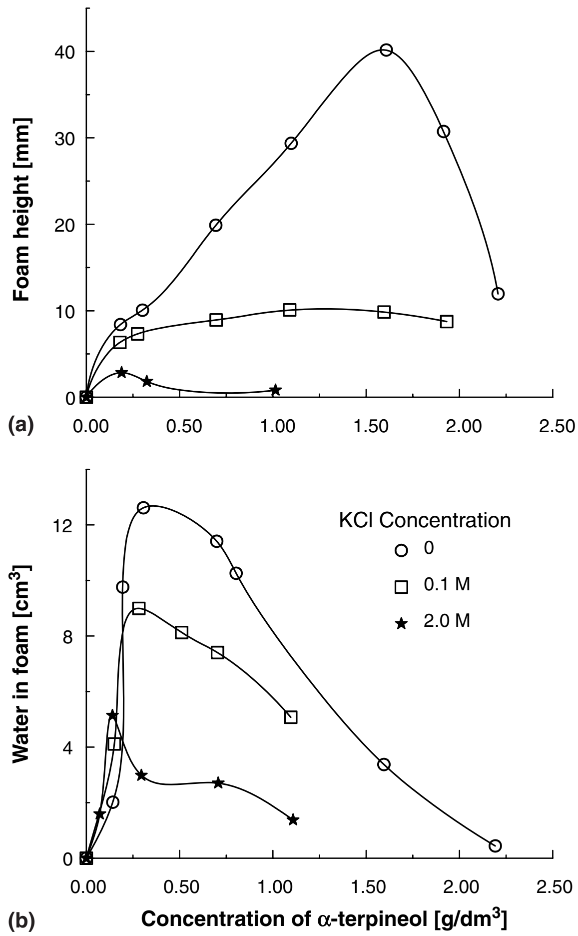

Fig. 1. Effect of concentration of α-terpineol and KCl on foaming and water content carried out by bubbles (from Iskra and Laskowski, 1969).

pure liquids because there exist no such mechanism (Kitchener and Cooper, 1959). As Fig. 1(b) shows (Iskra and Laskowski, 1969), individual bubbles carry increasing amount of water with increasing concentration of α-terpineol (up to a given point) used in these experiments. This increasing amount of water associated with a liquid/gas interface stabilizes the foam which thus becomes more voluminous. (Fig. 1(a)). The water content in a two-phase foam depends critically on the frother concentration (Malysa, 1998).

It is worth pointing out that what Fig. 1(b) shows is the amount of water carried out by individual bubbles as measured by a simple test developed by Klassen and Tikhonov (1964). This amount of water increases with increasing concentration of α-terpineol; according to the bubble swarm phenomenon (Smith and Warren, 1989) additional amount of water is carried to a foam/froth by a swarm of bubbles.

The three-phase flotation froth contains not only hydrophobic particles attached to bubbles, but also hydrophilic particles in the inter-bubble water. The entrainment was identified to be linked to the amount of water carried in the froth (Engelbrecht and Woodburn, 1975; Bishop and White, 1976; Lynch et al., 1981; Smith and Warren, 1989; Govindarajan et al., 1991; Maachar and Dobby, 1992; Sawassai et al., 1998; Tao et al., 2000; Rahal et al., 2001). A wetter froth should, therefore, produce higher entrainment. But at the same time thicker inter-bubble films (in wet foams) should allow for easier flow of water through the foam and drainage of the entrained hydrophilic particles. Malysa (1998) contended that what is important here is the water distribution along the foam height. The wet foam, which allows for drainage of the entrained (hydrophilic) particles at the bottom of the froth layer, would thus be advantageous, but the water content in the upper part of the froth should be as low as possible.

The froth, as opposed to a foam, is stabilized not only by a frother but also by the presence of solid particles. Therefore, while simple tests carried out with two-phase systems have been recently developed to characterize flotation frothers, it is still not clear how such indices developed to characterize the frothers could be used to predict the properties of a three-phase flotation froth. These issues are further studied in this paper.

2. Experimental

2.1. Materials

2.1.1. Reagents

Five different frothers were tested in this research (Table 1). The frothers were added as a 1 g/L solution prepared with distilled water at room temperature.

The effect of frothers on bubble size has recently been extensively studied (Cho and Laskowski, 2002a,b; Laskowski et al., 2003). It was found that the effect of frothers on bubble size results from their ability to prevent bubble coalescence. As shown schematically in Fig. 2, with increasing frother concentration, the degree of bubble coalescence decreases and at a particular concentration (critical coalescence concentration, CCC), the coalescence of the bubbles is completely prevented. As Fig. 2 explains, the CCC values are obtained by finding the intersection of the horizontal

Table 1
List of tested frothers

Frother	Chemical formula	Molecular weight (g/mol)	DFI (sd m^3/mol)	CCC (ppm)
MIBC	$(CH_3)_2CHCH_2CH(OH)CH_3$	102	37000	11.2
DF-200	$CH_3(PO)_3OH$	206	196000	18.4
DF-1012	$CH_3(PO)_{6.3}OH$	400	267000	6
α-Terpineol	$CH_3–C_6H_8–C(CH_3)_2–OH$	142	138000	–
Diacetone alcohol	$(CH_3)_2(OH)CCH_2C(O)(CH_3)$	116	12000	–

Also includes the CCC (critical coalescence concentration) and DFI (dynamic foamability index) values.

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