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# Frother-related research at McGill University

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## Abstract

Over the past ten years the Mineral Processing group at McGill University has developed techniques to determine gas dispersion properties (gas superficial velocity, gas holdup, bubble size and bubble surface area flux) in flotation machines. This work is finding application in metallurgical diagnostics and cell characterization. The picture, however, will remain incomplete until the impact of chemistry on bubble production, and hence on gas dispersion, is understood. This has prompted investigations into frothers.

There are two areas addressed in this communication: frother analysis and frother characterization.

Coincident with the centenary, for 100 years there was no convenient frother analysis procedure. A colorimetric technique originally developed for alcohols had been applied to MIBC (Parkhomovski, V.L., Petrunyak, D.G., Paas, L., 1976. Determination of methylisobutylcarbinol in waste waters of concentration plants. Obogashchenie Rud 21 (2), 44–45). Using this as a starting point, the technique was successfully extended to a wide range of commercial frothers and shown to be robust against most common 'contaminants'. The technique is readily used on-site and some observations from plant surveys are described.

Characterization of frothers has taken two routes, determining water carrying rate and investigating properties of thin bubble films.

Second only to transporting particles the recovery of water by bubbles has the most influence on metallurgy. The question posed was whether this 'water carrying' property could be related to frother type. In a specially designed column the volume rate of water to the overflow per unit cross-sectional area ('carrying rate', $J_{wo}$) and gas holdup ($\varepsilon_g$) at controlled froth depths were measured. The $J_{wo}$–$\varepsilon_g$ relationship proved approximately linear and dependent on frother type, with four frother 'families' being identified.

Bubble thin films have been studied for soaps and the techniques were adapted for frothers. From infrared analysis it became apparent that the frother molecule, while itself not seen, had an impact on organizing water molecules, apparently forming a film of bound water on the bubble surface. Exploiting the interference pattern generated in UV/Vis the film thickness ($d$) was determined; for MIBC $d$ was less than 160 nm while for DF250 $d$ was ~600 nm. Taking a representative frother from the four families identified above, the water carrying rate at a given gas holdup increased with film thickness.

Possible implications of the findings on the role of frother in bubble production are explored.

*Keywords:* Flotation machines; Flotation frothers; Flotation bubbles

## 1. Introduction

A rather uninspiring title but two topics which should be of interest describing novel methods of frother analysis and frother characterization will be introduced shortly. First, however, let us consider the motivation for research in this area.

For over ten years the McGill Mineral Processing group (and others) has been developing tools (sensors) and techniques to measure gas dispersion properties (the collective term for gas superficial velocity, bubble size, gas holdup and bubble surface area flux) (Gomez and Finch, 2002). These measurements are finding increasing application in improving flotation performance (e.g., Cooper et al., 2004; Gorain, 2005) and characterizing cells. An example of the latter is Fig. 1, taken from Nesset et al. (2005). It shows bubble size (Sauter mean diameter, $D_{32}$) as a

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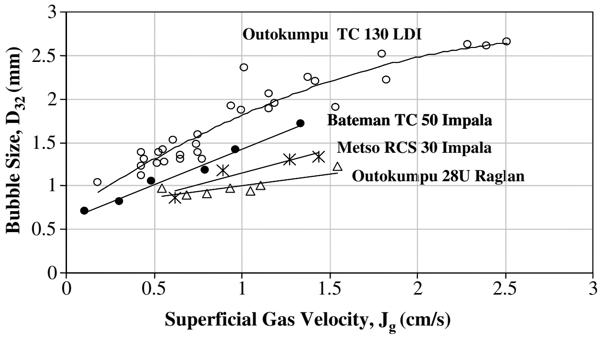

Fig. 1. Cell characterization: Sauter mean bubble size as a function of gas rate for four cell types. (Adapted from Nesset et al. (2005).)

function of gas rate (superficial gas velocity, $J_g$) for a variety of cells (all forced air). As Nesset et al. note, the relationship can only be properly interpreted when 'chemistry' is included. This largely means frother type and dosage but could extend to some collectors and high concentration of some salts. The importance of frother in determining bubble size is well documented: Harris (1976) at the A. M. Gaudin Memorial Symposium noted: "…major factor determining bubble size… is neither impeller speed nor air rate but frother concentration", and recently Cho and Laskowski (2002) have used the effect on bubble size to characterize frothers.

As steps towards including frother function in our gas dispersion work two topics are discussed in this communication, frother analysis and frother characterization.

## 2. Frother analysis: procedure and plant experiences

For the one hundred years of flotation there has been no convenient, on-site method of determining frother concentration. This has arguably restricted engineering the use of frother to achieve metallurgical targets. Approaches have included: gas chromatography (Tsatouhas et al., 2005), determining total organic carbon (Hadler et al., 2005), and using calibrations of bubble size and gas holdup vs. frother concentration (Weber et al., 2003). A literature search identified a colorimetric method used for MIBC (methyl-iso-butyl-carbinol) in wastewaters (Parkhomovski et al., 1976). The technique was based on the Komarowsky reaction employed in colorimetric analysis of aliphatic alcohols (Coles and Tournay, 1942).

The procedure, described in detail elsewhere (Gelinas and Finch, 2005), involves dehydration with sulphuric acid followed by reaction with an aldehyde to form a coloured compound. The technique proved amenable to a wide range of frothers. Linear calibrations are given over a range (e.g., up to 5 ppm Dowfroth 250) and there was no interference from a range of inorganic and organic reagents and contaminants typically encountered in sulphide flotation. Site work encountered two compounds that did react, fuel oil and butanol. However, the absorbance spectra were sufficiently different from the frother that conventional simultaneous analysis de-coupled the two (and gave additional information on both). The presence of butanol was as a contaminant in the xanthate, apparently a common situation. (What impact this alcohol had on gas dispersion (bubble size) is a matter of speculation.)

Three plant surveys have been conduced to date which have proofed the technique. After calibrating with the plant frother and water, sampling, decantation and dilution are generally all that was necessary. (Some notion of the dilution required is obtained from the dosage, usually given in g/ton, and the per cent solids.) For MIBC it was necessary to make the determination promptly as there was evidence of loss over time (sealed samples brought back to McGill showed no detectable frother) probably due to evaporation. Current evidence is that Dowfroth 250 does travel.

Two examples will serve to illustrate the technique in action. In Fig. 2 frother (MIBC) distribution down a bank of 11 cells and between pulp and froth is shown. The bulk of the frother is introduced in cell 1 (>90%) and clearly distributes down the bank, the concentration in the pulp liquor remaining ≈5–7 ppm. The frother did concentrate in the froth, notably towards the rear of the bank.

In Fig. 3 a distribution of frother down the 16-cell bank was employed, with 50% in the first cell, 25% in cell 5, 15% in cell 9 and 10% in cell 13. Process water (PW and QW) showed residual MIBC was returning to the circuit. The distribution scheme showed as step increases in concentration at each addition point (except the last) rising from ≈3.5 ppm to ≈5.5 ppm. The tails still showed ≈4 ppm. The concentration was determined at two positions in some cells, just below the froth (i.e., top, T) and near the impeller (bottom, B) to check mixing in the cell. Clearly the frother is well distributed in the cell.

Although mass balancing was not performed, the evidence is that the bulk of frother remains in the pulp water. Tsatouhas et al. (2005) have made the same observation. It corresponds to the common experience that frother obviously works its way through a circuit from a limited number of addition points (sometimes only one, at the head end). The observation is re-visited below.

One application of this new tool is to integrate with gas dispersion measurements. The metallurgical gain applying

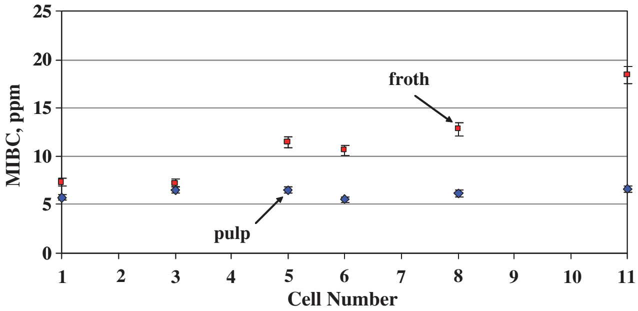

Fig. 2. Example of frother analysis: Distribution of frother down a bank and between pulp and froth.