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The hydrodynamics of an operating flash flotation cell

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ABSTRACT

Key parameters for evaluating the hydrodynamic conditions within an operating flash flotation cell have been investigated. Profiles of the slurry at increasing depth within the cell have shown a strong trend of increasing slurry density (per cent solids) and coarseness (P_{80}), with a clear indication of segregation on the basis of particle specific gravity. Results of local gas dispersion measurements, taken with the Anglo-Platinum Bubble Sizer, show that bubble coalescence is occurring at shallower depths within the cell and there is a clear trend of decreasing gas velocity (J_g) with increasing depth at the axial location of measurement. Due to access restrictions gas dispersion measurements were taken close to the cell wall, but all data obtained falls well below the recommended minimum values for mechanically driven conventional flotation cells. However, the flash flotation environment is significantly different to a conventional cell, with higher per cent solids and a significantly coarser feed material, making this comparison qualitative (as unfortunately within the literature, there exists no other flash flotation data sets of this nature on which to base a comparison). The residence time distribution of solids indicates a significant amount of short-circuiting and/or internal recycle within the cell. Yet despite these findings, this cell contributes up to half of the pyrite recovery to the final concentrate at a very high grade.

1. Introduction

The process of flash flotation can be broadly described as the flotation of valuable material that is present within the grinding circuit. A flash flotation cell typically receives cyclone underflow material as its feed; a portion of this feed material (very coarse particles and small rocks) will bypass directly to the tailings stream (which usually doubles as a secondary mill feed), while the finer material and a higher proportion of the water will be drawn into the impeller mixing zone, where it is contacted with air bubbles to undergo a froth flotation process. A general schematic of a flash flotation cell is presented in Fig. 1. The key factors that distinguish the flash flotation process from other types of mineral flotation include:

- very coarse feed material (cyclone underflow);
- very high per cent solids in slurry (up to 70%);
- short residence time (typically less than 3 min);
- limited contact with reagents prior to flotation (there are no conditioning tanks used in flash flotation circuits); and
- lower power input to the slurry from the impeller, to actively promote the bypass of coarser sized material.

A thorough description of the flash flotation process has been provided elsewhere by the authors and the reader is directed to that paper if more detail is required (Newcombe et al., 2012a).

Providing an accurate description of the hydrodynamics within a flash flotation cell is not an easy exercise. Operating factors such as high slurry per cent solids, coarse particle sizes, short-circuiting and internal recycle zones, which make hydrodynamic modelling difficult, all culminate within the flash flotation environment. A further complication occurs in installations where a middle discharge (dual outlet) pipe is utilised, making mass balancing more difficult than for conventional cells. Residence time distribution (RTD) information is often used to characterise a flotation cell's behaviour, and the measured residence time will be impacted by operational variables such as air addition rate, feed addition rate, slurry density and particle density and size distribution. Flash flotation cells have very high feed rates, very high slurry density and very coarse size distributions compared to their conventional counterparts, factors which not only impact on the residence time distribution, but also affect gas dispersion within the cell. Given that currently no published data exists on the hydrodynamics of an industrial scale flash flotation cell, there is some uncertainty as to the expected results. With this in mind, this paper presents the first published investigation into flash flotation hydrodynamics.

2. Hydrodynamic characterisation

In order to evaluate the hydrodynamic performance of a flotation cell a number of key parameters need to be considered. These include:

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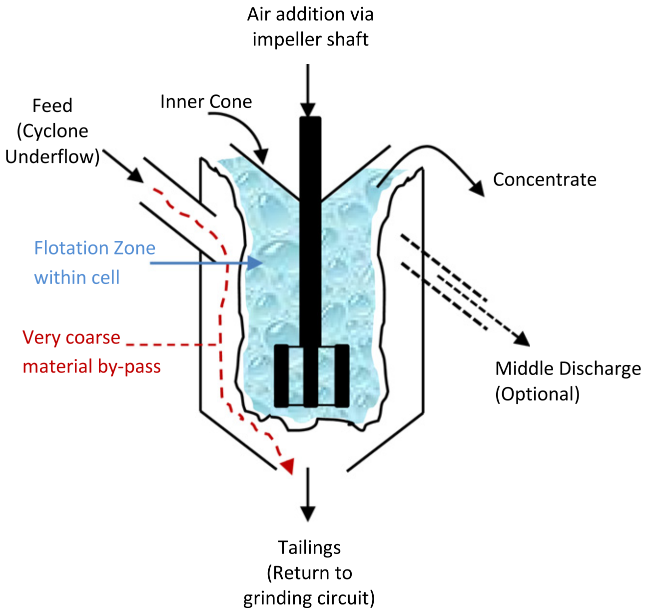

Fig. 1. Schematic of a flash flotation cell.

- aeration data including superficial gas rate, gas holdup, bubble size distribution and bubble surface area flux;
- residence time distribution of both liquid and solid (preferably by size) phases;
- effective pulp volume;
- profiles of percentage solids, particle size and grade (preferably axial and with depth).

Dahlke et al. (2005), Yianatos et al. (2005), Lelinski et al. (2002), Yianatos et al. (2001) and Mehrotra and Saxena (1983).

In the operating environment of a mechanically driven conventional flotation cell, determination of these parameters involves taking gas dispersion measurements and slurry samples at various points across the cell and with depth, in conjunction with a tracer test (preferably a radioactive tracer for both the liquid and the varying size classes of solids). From the data available in the literature, the consistency of slurry observed within conventional cells (Yianatos et al., 2001; Mehrotra and Saxena, 1983) makes determination of their mixing regimes and effective volume a relatively easy calculation, when compared to the mechanisms at work within a flash flotation cell.

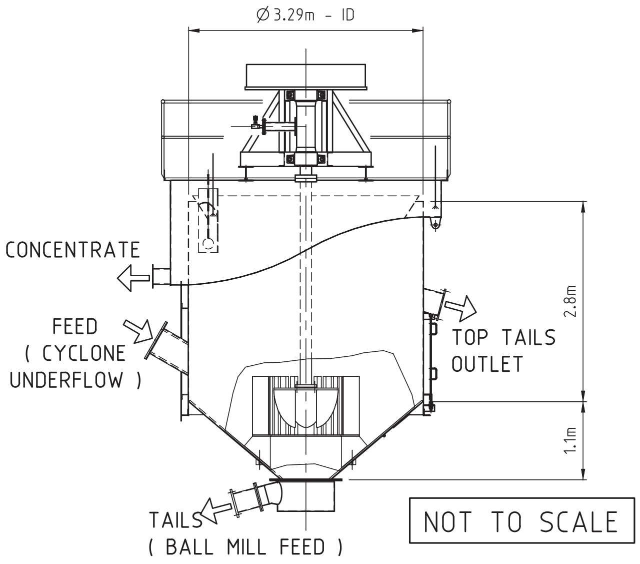

Fig. 2. Kanowna Belle flash flotation cell detail (Murphy, 2012).

A schematic of a flash flotation cell is presented in Fig. 1, and shows two key features of flash flotation operation:

1. The presence of an internal short circuit stream, which allows any very coarse material and rocks to flow directly to the tailings outlet as a very thick slurry (typically > 60% solids).
2. A 'flotation zone' within the cell where finer particles are contacted with bubbles to undergo the flotation process.

The idea of a 'flotation zone' within the cell originates from the slurry and particle properties measured with increasing depth in the cell, which, as will be shown have distinctly different properties to the feed and tails streams, however the exact size and shape of the flotation zone is still unknown. As shown in Fig. 2, the feed stream to the cell under consideration in this work enters into the side of the cell at an angle to the horizontal plane; this type of feed entry may mean that the flotation zone within the cell is skewed toward the side of the cell opposite the feed pipe, and may also have a greater cross-sectional area above the feed entry point. A further consideration when dealing with flash flotation data is that there is classification of particles occurring within the flotation zone of the cell, causing segregation by size and density. This is further complicated in some installations by the use of an additional discharge pipe located in the middle section of the cell (not all flash flotation cells utilise the middle discharge pipe, shown in Fig. 2 as the 'Top Tails Outlet'). As will be shown by the data presented in this paper, it is the characteristics of and processes occurring within the flotation zone that are critical to cell performance.

2.1. Experimental

All work for this study has been performed on the flash flotation cell at Kanowna Belle Gold Mine (Barrick), located near Kalgoorlie in Western Australia. This plant treats a refractory gold ore, with pyrite as the target mineral for flotation recovery. A detailed description of both the ore and the plant has been presented by the authors elsewhere (Newcombe et al., 2012b, in press). It should be noted that the flash flotation cell at Kanowna Belle is fitted with a middle discharge pipe, however it was never in use during any of the work performed by the lead author. Extensive survey work has been carried out (separately to the results presented in this paper), and has shown that the flash flotation circuit at Kanowna Belle contributes approximately half of the total flotation plant recovery at a grade typically between 30% and 33% sulphur (Newcombe et al., 2012b, in press).

The recommendation for accurate hydrodynamic characterisation of a flotation cell is to take measurements at a number of different positions across the cell and at varying depths. However this is not always practically achievable. In this case, access to the flotation zone is limited by an inner cone (see Fig. 1), which allows

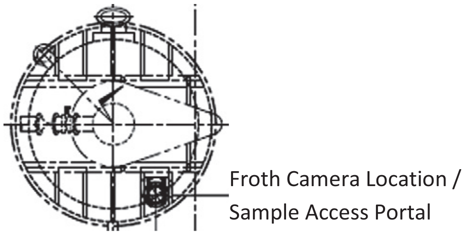

Fig. 3. Plan view of froth camera housing location/sample access portal.