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A phenomenological model for an industrial flash flotation cell

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ABSTRACT

The measured slurry properties of an operating industrial flash flotation cell treating a refractory gold ore have been tested using a number of different modelling methods, including: axial dispersion; classification/partitioning; sedimentation dispersion; and rate equations. Limited success was achieved with the conventional approach to describing flotation vessels and instead a novel approach of interpreting the data from within the cell was developed. This method uses the residence time from within the quiescent/settling zone of the cell (the region between the mixing zone surrounding the impeller and the froth zone). In this situation particle residence time in the settling zone increases with increasing height in the cell, and axial profile data can be used to determine recovery by size at varying heights relative to the mixing zone. Valuable mineral (pyrite) recovery is observed to decrease with increasing residence time in the settling zone, predominantly as a function of the internal cell geometry (inner cone). Plotting the log first order kinetic rate constant for each size class k_i versus the residence time within the settling zone of the cell, τ_s, a near linear relationship becomes evident which is described by the relationship: $k_i = \alpha_i e^{-\beta_i \tau_s}$; where α and β are empirically fitted parameters for each size class i.

The residence time within each zone has been assumed to be constant for all size classes considered for this initial part of the model development work, as a very detailed residence time distribution study would be required to determine the variation in residence time for each size class.

Numerous mass balancing approaches have been tested, some of which attempted to incorporate the froth phase, however due to the complexities of trying to model the froth the most accurate fit was obtained when the froth zone was excluded from mass balancing calculations. In this case, β was found to be essentially constant across all size classes considered, at an average value of -1.41 (with a standard deviation of 0.056). The average value of β changes with the method of mass balancing used, with the attempts to incorporate the froth bringing in a greater level of deviation from the average. The value of α changes with size, and follows a pattern similar to a recovery by size curve, peaking through the size range of optimal floatability ($-212/+53$ μm). The shape of this curve, and also the values of α for each size class considered are similar regardless of the mass balancing method used.

Whether these two parameters (α and β) are intrinsic to the ore, the machine or the system as a whole would take a considerable amount of detailed sampling from within the flash flotation cell under consideration and consequent analysis work which were beyond the scope of this initial study. The relationships developed here require validation in other systems, however if they are found to be robust and universal, would allow for the unit recovery to be calculated using standard hydrodynamic equations.

1. Introduction

The flash flotation environment is different from other types of mineral flotation devices (columns, tank cells, etc.) in that the cell resides within the comminution circuit and receives very coarse and thick slurry as its feed. This feed material is typically the cyclone underflow, which may be up to 80% solids and contain particles that are better described as small rocks. In order to deal with this type of slurry the flash flotation cell has some unique features including a tangential feed inlet, conical bottom with a centrally located tailings outlet, a secondary tailings outlet located at a higher point and an inner cone to assist in froth transportation to the concentrate launder. These features are depicted in Figs. 1 and 2 and allow two additional sub-processes to occur as compared to a conventional flotation device: the direct and intentional bypass of very coarse material/small rocks directly to the tailings outlet; and the classification/segregation of particles within the 'flotation' zone of the cell. The effectiveness of these sub-processes is what makes flash flotation possible and understanding how they

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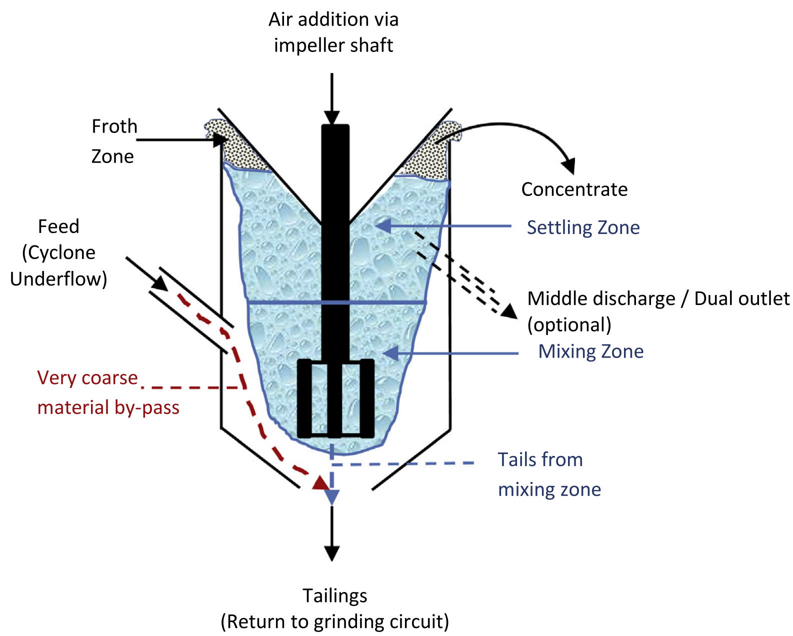

Fig. 1. Schematic of flash flotation cell operation (Newcombe, 2013a).

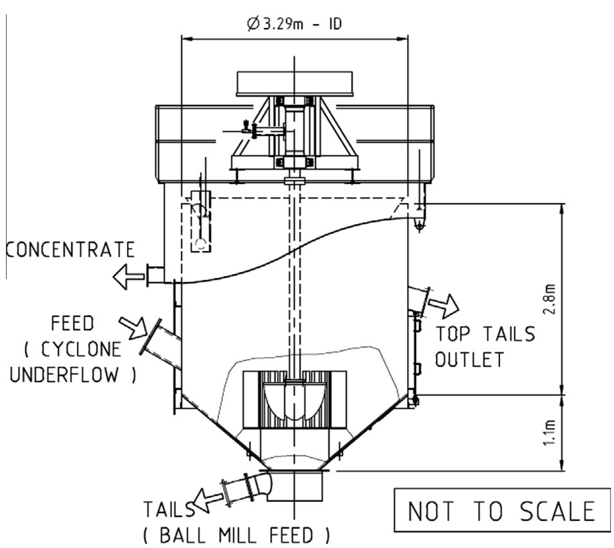

Fig. 2. Kanowna Belle flash flotation cell detail (Murphy, 2012).

occur is essential for process optimisation. To date there exists no hydrodynamic model specific to the flash flotation environment available in the published literature; this is possibly due to the difficulty in obtaining samples from both inside and around flash flotation cells in the operating environment. This paper provides a first attempt at mathematically describing the operating data that has been obtained through extensive survey campaigns of a refractory gold concentrator (Kanowna Belle Gold Mine), and internal hydrodynamic characterisation work of the flash flotation cell operating within that plant. Current flotation modelling methods will be discussed and their use in describing a flash flotation cell will also be addressed.

Results from the hydrodynamic characterisation of the flash flotation cell at Kanowna Belle (KB) have led to the division of the cell into various zones, as depicted in Fig. 1. A detailed review of the internal hydrodynamics has been previously presented (Newcombe et al., 2013a) but in summary the zones within the cell can described as follows:

- Bypass – this accounts for the short-circuiting of very coarse material and rocks to the tailings outlet, effectively acting as a first stage classifier.
- Mixing zone – this is the area surrounding the impeller where good mixing and suspension of solids is observed.
- Settling zone – this is a more quiescent zone, but differs from the quiescent zone of a conventional flotation cell in that segregation of coarse particles is still occurring, this region acts as a dual flotation/classification zone. Plant sampling involved taking samples at 30 cm increments with increasing depth into the cell, allowing this zone to be further divided into regions of discrete volume and measured slurry characteristics.
- Froth zone – similar to the froth zone of other flotation machines, however where an inner cone is in place there is a very limited open area of froth at the top of the cell.

The flash flotation cell that is the subject of this work is situated within the grinding circuit and receives a portion of the cyclone underflow stream as its feed. To allow the reader to understand how this cell interacts with the surrounding equipment, a process flow schematic is provided in Fig. 3. Cyclone underflow (CUF) material is discharged by the cyclones into a distribution box, a portion of the cyclone underflow is sent directly to the ball mill feed, with the remainder flowing via a weir and orifice plate arrangement to the flash flotation cell. The weir and orifice plate are used as a surge control system for the flash cell feed, with any large surges backflowing to the ball mill feed off-take. Dilution water is added to the distribution box directly above the flash feed inlet to allow the percentage solids of the flash feed material to be reduced to a level that is more amenable to flotation (approximately 65% solids), this water addition is controlled via an on-line density gauge and flow indicator through the process control system. The segregation of solids within the cell allows for an axial distribution of solids: decreasing per cent solids with increasing height in the cell, resulting in the region that is directly below the froth to have a much lower per cent solids than the tailings stream of the cell. This reduction not only in per cent solids, but also in average particle size is