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Flash flotation… and the plight of the coarse particle

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ABSTRACT

Coarse particles require distinctly different conditions to their fine and intermediate counterparts for successful flotation and recovery to the concentrate launder. These range from simple operational requirements such as shallow froth depth, reduced impeller speed and higher collector dosage to those that must be optimised specifically for the coarser size fractions such as air addition rate and bubble size, as well as the chemical environment (pH). This paper is the first of a series of publications on the topic of flash flotation and reviews many of the factors that affect coarse particle flotation with a view to how they impact the flash flotation process. A review of the current state of knowledge of the flash flotation process is presented and raises a number of issues in regard to both current operational knowledge and modelling practices.

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1. Introduction

From the perspective of a plant metallurgist or operator, the role of a flash flotation cell in a concentrator is to remove any liberated valuable mineral and/or any coarse composite particles rich in the target valuable mineral; and this has also been the long held belief of the authors. The single factor that is believed to distinguish a flash flotation cell from any other type of flotation device is the size of the particles it recovers (i.e. coarse particles), and this is repeatedly cited in the literature (Lynch et al., 2010; Lamberg and Bernal, 2009; Yan et al., 2005; Mackinnon et al., 2003; Sandström and Jönsson, 1988).

The role of particle size in the flotation response of an ore has long been recognised as a key parameter affecting overall

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performance. Considerable research has gone into this area, but until very recently has often been limited to the fine and intermediate size classes, with work frequently performed using single minerals or fabricated mineral mixtures in idealised laboratory settings. The study of unliberated coarse particles in an industrial setting, as would be experienced in the feed to a flash flotation circuit, has been somewhat neglected, as the nature of the particles presents one of the most difficult areas of study in this field. In this series of papers, the authors investigate both the nature and behaviour of the particles within a flash flotation system and also the processes occurring within an industrial flash flotation cell. This paper has been written to provide a comprehensive review of the flash flotation process and the available information on the coarse (mostly unliberated) particles that are its typical feed material. Subsequent papers will present a comparison of the results of laboratory tests with the actual measured plant flash flotation cell performance of the same refractory gold ore, and demonstrate how batch flotation tests can be used in conjunction with mineralogical analysis to predict the amenability of an ore to the flash flotation process. This will be followed by an investigation into the sub-processes that are occurring within an operating flash flotation cell with a view to develop a flash flotation specific model.

2. Flash flotation

The concept of floating coarse, potentially unliberated mineral particles within the grinding circuit is not modern in inception, but takes its origins from preliminary investigations conducted in the 1930s. The consequent development of ‘Maxwell’ or ‘Denver’ ‘unit cells’ was the precursor to what we now know as ‘flash’ flotation (Lynch et al., 2010).

The first modern flash flotation cell installed in an industrial concentrator occurred in June 1982 at the Hammaslahti concentrator in Finland (Bourke, 1995). Since then the use of this unit operation has increased dramatically, both in greenfields plants and as retrofits to existing concentrators. Consideration of flash flotation in any new flotation plant is readily accepted by the industry, with cells capable of processing 1800 tph being installed in new operations (Wade, 2006). Yet despite this widespread use for almost 30 years, there is very little technical information on its performance and no accurate flotation model specifically for flash flotation available in the literature.

Prior to the success of the flash flotation circuit, the most common methods for accommodating the different processing requirements of different size classes involved either split conditioning of the flotation feed (where the size classes are separated, fed into two separate conditioning vessels then recombined for flotation) or split flotation (where the size classes are separated and fed into two separate flotation circuits) (Alford and Clarke, 2007; Senior et al., 1994; Crawford and Ralston, 1988; Jameson, 1984; Trahar, 1976). Both of these methods involve considerable capital outlay and increased operating costs, and the complexity of the consequent flotation circuits makes them challenging to operate effectively. The use of a flash flotation cell reduced the cost and complexity considerably not only by having a small footprint in the plant but also by being capable of treating large volumes of material in a single cell.

The primary purpose of a flash flotation cell is to remove valuable minerals from the grinding circuit, preventing their over-grinding or sliming. Due to the higher SG of sulphide and precious metals, they tend to accumulate in the cyclone underflow stream and are liable to be ground to the very fine sizes required to make them light enough to report to the cyclone overflow stream. This would potentially incur recovery losses in the plant as fine particles are notoriously difficult to recover by conventional flotation (Mulleneers et al., 2002; Yoon, 2000; McIvor and Finch, 1991; Sandström and Jönsson, 1988; Trahar and Warren, 1976). The treatment of the cyclone underflow stream via flash flotation can remove these valuable particles before they become too fine. Treating the cyclone underflow stream also has the benefit that the fine particle sizes have been removed, allowing a much higher concentrate grade to be achieved by minimising the entrainment of unwanted gangue fines (Sandström and Jönsson, 1988; Kallioinen and Nitti, 1985).

McIvor and Finch (1991) suggested that flash flotation cells may be an appropriate addition to circuits where different target minerals (e.g. galena and sphalerite) can be separated where size (liberation characteristics) is a distinguishing factor; i.e. where the liberation size of galena for example is much coarser than that of sphalerite, the galena could be floated in the grinding circuit, allowing the sphalerite to undergo further grinding and subsequent flotation in a conventional circuit.

The contribution of a flash flotation cell to the overall performance of the plant has not been extensively studied, however the work of Sandström and Jönsson (1988) provided an excellent example of operating data from a number of different plants, with and without a flash flotation cell; illustrating that the cell is capable of producing a saleable concentrate in a single step and increased the plants overall recovery (Cu–Au ore). Their work also showed that the size range of particles recovered was extended from a top size of 125 μm to greater than 250 μm when the flash flotation cell was in use.

3. Process description

A schematic depiction of a flash flotation cell and where it is located relative to both grinding and conventional flotation operations is given in Fig. 1. Slurry feed to the cell is from the cyclone underflow stream and consists of a mixture of both small rocks and coarse sand-like material with water; typically this stream would be between 60% and 80% solids. In order to allow for effective flotation in this environment water is added to the feed stream, and reagents are employed. Reagent addition is typically done in one of two ways: all reagents are added simultaneously to the feed well of the cell; or either an activator and/or a collector is added to the grinding circuit, with all remaining reagents being added to the feed well. The method that is employed is specific to the ore being treated.

Where the feed material is very coarse, the cell conducts separation in two ways: firstly, as a classifier, allowing heavy coarse material and rocks to flow straight down to the bottom discharge point, effectively bypassing the flotation area of the cell; and secondly as a flotation cell, conducting a flotation process on the lighter, finer material present in the feed. This is depicted in Fig. 2. Air is added through the impeller shaft to form the bubbles that transport the valuable hydrophobic material to the concentrate launder. The effect of this dual action is that the bottom discharge point has a much higher per cent solids and coarser size distribution than material overflowing the concentrate launder. This allows the tailings stream to be sent directly to a secondary mill, whilst the concentrate stream is suitable for either further cleaning in subsequent flotation stages or may be of sufficient quality to be considered as final concentrate. Outotec flash flotation cells are designed specifically to act as both a classifier and flotation machine (Coleman, 2011).

In terms of operability, it is the experience of the authors that water management is the greatest challenge. A fine balance exists between the requirements of the flotation cell and those of the subsequent grinding operations; too little water impedes flotation performance, while too much water can be detrimental to comminution operations.