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Development of a laboratory method to predict plant flash flotation performance

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ABSTRACT

Flash flotation cells are increasingly being employed to recover valuable material present in the grinding circuit, reducing the potential for over-grinding and enhancing plant performance with the added advantage of reduced capital outlay and operating costs. However it is not always possible to quantify the contribution of the flash to overall recovery or to predict how this will alter with changing feed ore properties.

This paper is the second in a series of articles written on the topic of coarse particle and flash flotation and examines the nature of the particles being recovered by an industrial flash cell and compares them with those recovered by a laboratory batch flotation cell. The applicability of batch flotation test methods for predicting whether an ore is amenable to the flash flotation process is investigated and shows that a targeted batch flotation test can be used in conjunction with mineralogical analysis to predict the response of the target (valuable) mineral to an industrial flash flotation process.

Laboratory tests were conducted on a refractory gold ore taken as a belt cut, allowing the results of the laboratory analysis to be directly compared with the actual plant performance of the same ore. Direct comparison of laboratory flotation test concentrates with that of the plant flash flotation cell shows that the mineralogical response observed in a batch flotation test can be used to predict the nature of the particles that will be recovered in an industrial flash flotation cell. Both the size distribution of the concentrate and upgrade ratios of the coarse size fractions are able to be determined by laboratory methods; however differences in the recoveries and kinetic parameters between laboratory and plant were observed. This paper discusses these results and demonstrates how the tests can be used in conjunction with mineralogy data to predict the amenability of an ore to the flash flotation process.

1. Introduction

Flash flotation cells are located within the grinding circuit, receiving the cyclone underflow stream as their feed. The process of flash flotation involves the recovery of fast floating material, which is typically well liberated valuable particles, in a single stage of flotation. The process differs from conventional flotation methods in that the feed material is typically very coarse (often containing small rocks), with high slurry per cent solids (up to 70%); the cells have high throughput (up to 1800 tph) and there is minimal contact time with reagents (no conditioning stage prior to flotation). A schematic of a flash flotation cell is presented in Fig. 1. A thorough description of the process of flash flotation has been presented by the authors in a previous paper, and the reader is directed to that publication if further detail is required (Newcombe et al., 2012).

Current methods of predicting flash flotation performance involve testing an ores kinetic response in the laboratory at various feed size distributions, or applying the same parameters and models that are used for conventional flotation circuits. Where funding is available, pilot scale testwork is often required to give an indication of the suitability of flash flotation to a given ore and treatment route (Lamberg and Bernal, 2009). This project has tested the current methods for their relevance and applicability to a flash flotation circuit and developed a specific laboratory batch flotation test method for the site under consideration (Kanowna Belle, Western Australia) that can be used in conjunction with mineralogical information to determine whether an ore is amenable to processing with flash flotation, and allow accurate plant performance predictions to be made for a given ore block from the underground mine. The target mineral for flotation recovery at Kanowna Belle is pyrite (FeS_2). Sulphur (S) assays can be used to directly infer pyrite flotation performance as there are only trace amounts of sulphide gangue minerals present in this particular ore.

As part of this study, the nature of the role of a flash flotation cell in a concentrator has been examined, showing that the industrial flash cell recovers only very fast floating material that is very well liberated and predominantly in the intermediate and fine size classes (i.e. <150 μm). Mineralogical analysis has been used on both the laboratory batch test concentrates and plant flash

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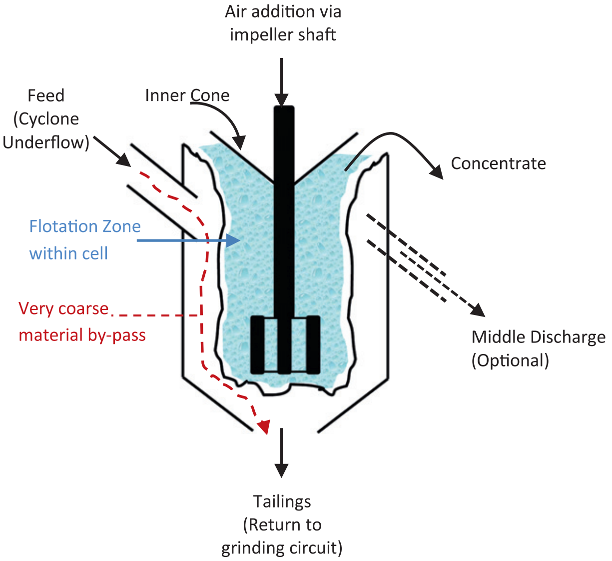

Fig. 1. Schematic of a flash flotation cell (Newcombe et al., (submitted for publicatioon)).

flotation cell streams to quantify the exact type of particles being recovered in both circumstances.

The methodology developed here compares the performance of the laboratory batch flotation cell with that of the plant flash flotation cell against the following criteria:

- initially, assay data is used to compare the elemental distribution by size of Au, S and Fe in concentrates to indicate target mineral species (Au and pyrite) performance. The laboratory concentrate that is found to have the closest 'match' to that of the plant flash flotation cell can then be used in further analyses;
- upgrade ratios of pyrite in each size class, as indicated by sulphur assays;
- kinetic parameters of pyrite for each size class;
- recovery of pyrite in each size class; and
- mineralogical characteristics of each size class in concentrate (liberation characteristics of pyrite).

These criteria have been selected to quantify the performance of the target mineral (pyrite) under both laboratory and plant conditions independently of the differing hydrodynamic and froth conditions present in each cell. It is important to note that the basis of comparison between the laboratory and plant cell performance used in this work is the behaviour of the valuable mineral particles. Grade-recovery curves have deliberately not been used, and assessment of performance is based on the size-by-liberation characteristics of the particles reporting to the respective concentrates. Whilst grade and recovery information is discussed, the primary purpose of this work was to see if the valuable mineral response observed in the plant flash flotation cell, as indicated by its size-by-liberation distribution data, could be matched by that of a laboratory batch flotation cell concentrate.

2. The role of the batch test

Laboratory batch flotation tests have played a significant role in the history and development of the flotation process, with results being used for countless purposes ranging in complexity from simple plant performance tests to determine operating losses, to reagent selection testwork, through to evaluation for full scale plant design. The use of batch flotation tests has come under scrutiny in recent years, questioning their relevance to the industrial application and the appropriateness of translating what is observed in the laboratory to what is or will be observed in an industrial concentrator. The literature is beset with examples of various batch tests claiming they are able to accurately predict the performance of a given ore – but there is very little industrial evidence to support this. At the time of writing there is no publication available that can prove the ability to accurately predict the performance of a new ore in an industrial plant on the basis of batch flotation test results alone. The methods available in the literature generally require a current ore of known metallurgical performance to be tested (i.e. it has to be calibrated against a measured result in the plant), in order to develop a model that can then only be used for that specific ore and kinetic operating conditions.

The differences observed between batch test data and industrial performance can be explained on the basis of a number of different operating variables; hydrodynamic differences such as power input and impeller design, aeration differences including bubble size and gas hold-up, as well as differences in the froth characteristics. With this in mind it may well be that the results of batch tests are better served to provide guidelines or an indication of expected plant response, rather than using the exact results themselves.

From over a decade of plant experience the author found a perplexing issue when reviewing batch flotation test data from an operating plant. In every case the 'recipe' to predict the plant performance on a given ore was to:

1. Grind in a laboratory mill to achieve the plant cyclone overflow 80% passing size (P_{80}), transfer to the flotation cell.
2. Condition with reagents in the order as used in the plant and typically at the same dosage rate.
3. Introduce air and float for a time that has been pre-determined to ensure maximum extraction of the valuable material (generally taking between 3 and 5 concentrates).
4. Where final concentrate grade is required to be estimated, the concentrate from the step 3 is then re-floated a number of times until the desired result is achieved.

This 'recipe' was found to be the same on almost all flotation concentrators, irrespective of whether a flash flotation cell was present in the grinding circuit. A flash flotation cell does not receive cyclone overflow material as its feed and often does not utilise the same reagents as the rest of the plant, making the applicability of the results obtained from 'standard' batch testing to the operating plant questionable. As will be shown in this paper the flash flotation cell under consideration removes approximately half of the floatable valuable material present in the plant feed, at a distinctly different size distribution and in order to account for this a flash flotation specific test methodology should be developed.

The results of batch flotation tests form the basis of many of the well-known flotation modelling and simulation packages (*JKSimFloat*, *FLEET*) and also provide a platform for much of the research and development work that is being undertaken in this field. As will be discussed here, many have attempted to match the performance of laboratory scale tests to the known performance of a plant, with varying levels of success, but key lessons have been learned along the way.

Pietroben et al. (2004) used matching of the pulp chemical environment in an effort to match the collection zone efficiencies of a batch cell with that of an operating plant on a complex lead/zinc float. The pH during the grinding stage was found to be the most important factor for recovery and selectivity of the ore studied, and whilst a good correlation was found between the laboratory and plant for the primary (Pb) float, the results of the secondary (Zn) float were not similar. This work highlighted that the chemical