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Short communication

A new method for flotation rate characterization using top-of-froth grades and the froth discharge velocity

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ABSTRACT

A new methodology is proposed for flotation characterization in industrial operations. The approach considers the mineral recovery to be proportional to both the top-of-froth (TOF) grade and the froth discharge velocity down a bank of cells. The procedure allows for the identification of the fractional recovery profile from the discharge velocities and the TOF grades. In addition, if the total recovery of the bank is available, the cell recoveries can be estimated by scaling the fractional recoveries. For this purpose, a single parameter was used to scale the recoveries for each sampling survey in order to obtain the kinetic response along the flotation banks. Industrial tests were performed in two rougher banks; one bank consisted of six 250 m^3 self-aerated cells in a 1-1-1-1-1-1 arrangement, and the other bank consisted of nine 130 m^3 self-aerated cells in a 1-2-2-2-2 arrangement. The results showed good agreement with the recovery profiles obtained from the cell-by-cell mass balances along two industrial flotation banks.

1. Introduction

The metallurgical characterization of a flotation bank is typically performed using the feed, the concentrate and the tail grades. All of the key streams are sampled, and repeats are conducted to improve the data reliability (Di Sandro et al., 2013). In addition, data reconciliation is performed if an excess of information is available (Wills and Napier-Munn, 2006). From the mass balance results, kinetic models can be fitted to the mineral recovery data to evaluate and to compare flotation banks. The model analysis allows for the evaluation of the flotation process and detection of opportunities for improvement in the design, operation and control of the circuit (Yianatos et al., 2006).

The sampling of the different streams is subject to access limitations, sampling constraints (e.g., circuit layout, personnel) and measurement uncertainties (Di Sandro et al., 2013). Therefore, the mineral recovery estimations are sensitive to errors in both the sampling procedures and the grade analyses. For example, feed and tail grades in rougher circuits have low values and are susceptible to measurement errors, which may lead to biased results in the mineral recovery.

Despite the usefulness of metallurgical evaluations, sampling surveys are not frequently conducted due to their high preparation requirements, time of analysis, and high costs (Wills and Napier-Munn, 2006). Yianatos and Henríquez (2006) proposed a methodology for metallurgical characterization that consists of two mass balances: one around the first cell and the other around the overall flotation bank. In this approach, only five streams must be sampled to characterize the flotation kinetic of an arrangement of cells in series.

The relationship between the mineral recovery and the air recovery has been studied in the literature based on vision systems in industrial flotation machines. Air recovery has been found to be a suitable estimate of the mineral recovery in rougher flotation banks (Smith et al., 2010; Hadler and Cilliers, 2009; Neethling and Cilliers, 2008). Air recovery was estimated from the inlet air flowrate to the froth, the froth height over the lip, the weir lip length and the froth discharge velocity. The latter was obtained using visual techniques in the froth surface image. The potential to optimize the metallurgical results by using changes in the aeration distribution along the flotation bank was observed. Hadler et al. (2012) related the air recovery to the froth depth and observed a peak in the air recovery as the froth depth increased.

Some authors have used the bubble load measurement to study the flow of particles collected by true flotation that enters the froth zone. Yianatos et al. (2008) and Falutsu and Dobby (1992) developed devices to sample collected minerals in flotation machines. Yianatos et al. (2008) used the bubble load measurement and the total mass balance in an industrial flotation cell to estimate the froth and collection zone recoveries. More recently, Yianatos et al. (2014) studied the collection of valuable minerals in rougher

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flotation circuits using the top of froth (TOF) as an alternative approach to the bubble load measurement. This methodology considered that, for non-selective froths, the TOF material retains the characteristics (grade and particle size) of the mineral entering the froth via true flotation. Compared with the bubble load, the TOF measurement allows a complete flotation bank to be sampled with sufficient mass for size analysis and chemical assays. Therefore, the evolution of the collected mineral along a flotation bank (non-selective froths) can be determined. This information motivates the development of a procedure to estimate the kinetic response using TOF measurements.

In this short communication, a new methodology to estimate the fractional recovery profiles along rougher flotation banks is presented. Data on the TOF grade, the froth discharge velocity and the total recovery of the bank are required to obtain the recovery profiles. For this purpose, the TOF grade and the froth discharge velocity measurements were performed at industrial scale. The fresh feed, the final concentrate and the final tail were also measured to obtain the total recovery of the flotation bank. This total recovery was used to scale the fractional recoveries and for estimating the kinetic response along the flotation banks.

2. Plant description and experimental procedure

2.1. Plant description

Experimental tests were performed in an industrial copper flotation plant fed by approximately 8000 tph from SAG grinding. The tests focused on two of the eight banks of the rougher circuit: banks A and B. As shown in Fig. 1a, bank A consists of six 250 m^3 self-aerated cells that are arranged in a 1-1-1-1-1-1 configuration. This circuit includes a cell at the beginning of the bank that operates as a pre-rougher (PR). The concentrate from the PR cell is mixed with the concentrate from cell 1 (C1), and the tail from the PR cell feeds cell 1. The rougher circuit B consists of nine 130 m^3 cells arranged in a 1-2-2-2-2 configuration, as shown in Fig. 1b. The cell pairs in the rougher banks B (*i.e.*, 2–3, 4–5, 6–7, and 8–9) are connected by an open section (communicating vessels). Level control is implemented at the end of each pair of cells. In each flotation cell shown in Fig. 1 (both banks A and B), the froth discharge velocity is measured using VisioFroth cameras (Metso Minerals, 2006) and recorded using the PI (process information) system. In these rougher circuits, all reagents were added in the conditioning tank located at the head of the flotation banks.

Metallurgical samplings for mass balances were performed in each cell of the rougher flotation banks. Three sampling campaigns were conducted in bank A, and one sampling campaign was conducted in bank B. The feed, tail and concentrate were sampled per circuit during the surveys of approximately 2–3 h, depending on availability. Feed samples were collected from the feed box, which was located at the beginning of the rougher flotation bank, using a slurry sampler. In bank A, the PR cell tailing was sampled using a Grindex submergible pump located inside the cell near the bottom. The use of this type of submergible pumps was evaluated in previous work reported by Concha (2009), where simultaneous samples of industrial cell tailings were collected using a submergible pump and a manual in depth sampler. A good agreement between both results was obtained. The tailing samples of the remaining cells of bank A were collected using auxiliary gate valves. These auxiliary valves are located in an emergency exit tube connected to the tailing pipelines of each cell. Only the first cell and the overall bank were sampled in bank B. Cell-by-cell and short-cut methods were used to characterize both banks (Yianatos and Henríquez, 2006). The method used in each bank is shown in Table 1. The samples were assayed for Cu to estimate the cell-by-cell recovery. The grade data were reconciled to satisfy the total and component mass balances in each cell of the flotation banks. Table 1 also summarizes the feed characteristics, the range of the operating conditions and the metallurgical results around the rougher flotation circuits A and B. The Cu recoveries were approximately 90–92% for bank A and 84% for bank B.

2.2. Top-of-froth measurements

The top-of-froth measurements (TOF) were conducted along the rougher banks in parallel with metallurgical samplings. Each measurement corresponded to a sample of approximately 500 mL from the froth surface of each cell. Fig. 2a shows the TOF sampler with the typical sampling location (Fig. 2b). The sampling point was located between the froth crowder and the peripheral concentrate launder. This location minimizes contamination by entrainment and avoids stagnant zones (Yianatos et al., 2014). Using the TOF measurements, the characteristics of the mineral (grade and particle size) that overcame the drainage and coalescence processes were determined.

Repeats of the TOF measurements in cells PR, C1, C2 and C6 were conducted in the sampling campaign 1. From these datasets, the estimate for the standard deviation of the TOF grades was 1.3%, which shows an adequate repeatability and reproducibility of the measurement procedure.

2.3. Froth discharge velocity measurements

The froth discharge velocity was measured in each rougher cell using the installed VisioFroth cameras. Fig. 2b shows the sampling point location. The VisioFroth system includes software that computes the froth discharge velocity, the bubble size distribution, the froth stability (bubble collapse rate), the froth colorimetry, and changes in the froth texture amongst other properties. The froth velocity was obtained from the displacement between consecutive

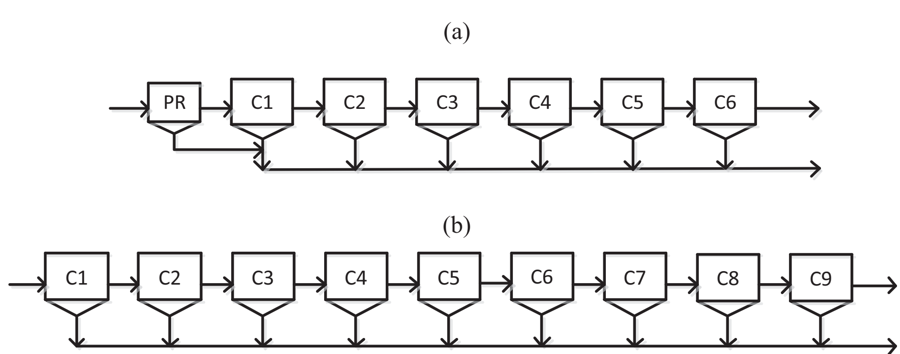

Fig. 1. Arrangement of cells in series, rougher flotation (a) bank A and (b) bank B.