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Recovery of coarse particles in the froth phase – A case study

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ABSTRACT

This study explores the role of the froth phase in the collection of particles that are introduced into the froth layer in a flotation cell. A bench-scale flotation cell was tested at an operating concentrator, using a feed taken directly from the plant. The equipment was constructed so that dropback from the froth phase was separated from the pulp phase. A stream taken from the plant cleaner feed was floated in the apparatus, thus creating a stable froth layer. A separate sample was taken from the feed to the plant rougher cells, and added directly into the froth layer in the experimental apparatus. The performance of the test cell was evaluated, in terms of the copper grade and recovery on a size-by-size basis. The experimental variables were the superficial gas velocity, the froth depth and the location of the feed distributor relative to the overflow lip of the test cell. The results show that the froth is an effective medium for the recovery of coarse particles that are poorly recovered in conventional flotation cells. This was especially evident when the particles were just introduced below the froth surface.

1. Introduction

The ability to separate minerals by froth flotation is strongly dependent on the particle size. For metallic ores, particles respond well to flotation up to 100 μm, but above this size the recovery rate declines significantly with increasing particle size (Jowett, 1980; Trahar, 1981). The reasons for poor flotation of coarse particles are well-established and include detachment from bubbles due to the centrifugal forces arising from the rotational motion of bubble-particle aggregate in the turbulent field (Schulze, 1983) and the limitation due to the buoyancy force of the bubbles. It has been claimed that coarse particles are vulnerable to detachment at the pulp-froth interface during their transfer from the pulp zone to the froth layer (Falutsu and Dobby, 1989; Ata, 2012).

One way to overcome these limitations is to introduce particles directly into the froth (Malinovskii et al., 1973). This approach was found to be quite effective for the recovery of coarse particles, and led to a number of processes in the former Soviet Union. Flotation in the froth phase however requires a strong froth to be able to hold and carry the particles to the surface. A bubble film that is formed only of liquid and surfactants is generally weak and can easily be destroyed under the action of particle weight (Livshits and Dudenkov, 1965; Koczo et al., 1994). An effective way to make the froth strong enough is to use fine particles. Such an approach was used recently (Lambert and Jameson, 2001) to extend the upper particle size limit when coarse coal particle (+500–2000 μm) were introduced on the surface of a froth that had been previously stabilised by particles less than 500 μm in diameter. The presence of fine particles that were floated out of the pulp, helped to form a strong stable froth which could withstand the direct application of coarse particles into the froth layer. The importance of fines in improving the froth stability so as to retain coarse particles has also been reported by others (Moudgil and Gupta, 1989; Rahman et al., 2012). Apart from the creation of a strong froth, previous investigations on the recovery of hydrophobic particles in the froth phase suggest that the recovery is strongly influenced by the froth depth or residence time, the available bubble surface area to accommodate the particles, and the hydrophobicity of the particles (Schultz et al., 1991; Ata et al., 2002).

This work is concerned with the behaviour of particles that are introduced in a continuously operated flotation cell special design. The work was conducted with a small test rig operated in an operating plant. A fine feed sample was taken from the feed to the first stage of cleaners and floated in the cell, to create a stable froth. Simultaneously, a sample from the feed to the rougher bank was placed directly into the froth phase. The effect of system parameters on the collection rate of particles was studied.

2. Experimental

The plant investigation was carried out in a concentrator processing a complex sulphide ore. The copper mineral is mainly chalcopyrite; other minerals present are magnetite, pyrite and bornite. During the period of testing, the ore was crushed and ground in a closed circuit to 80% passing 220 μm. The head grade of rougher

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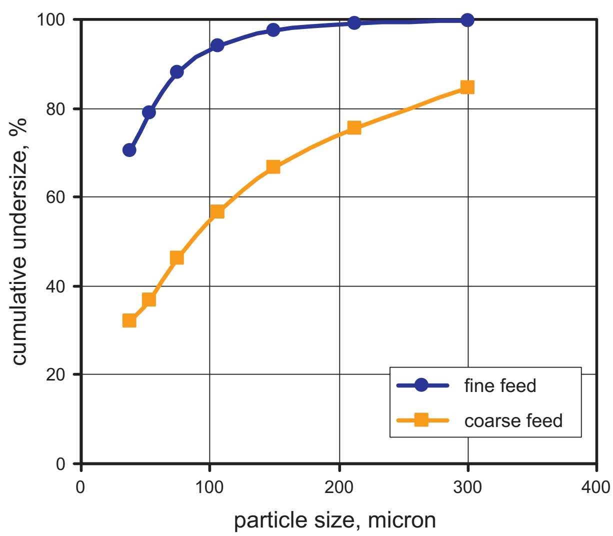

Fig. 1. Particle size distributions of the samples used in the testwork.

feed and cleaner feed were on average 1% and 16% Cu, respectively while the d_{80} diameters of the rougher and cleaner feeds were 220 μm and 76 μm, respectively. There is a regrind mill in the circuit to treat the rougher concentrate, so the size distributions of the fine and coarse feeds are markedly different. Fig. 1 shows typical a size distribution of both feeds used in the testwork. Sodium isobutyl xanthate, (SIBX) and Polyfroth were used as a collector and frother, respectively. During the test the dosage rates of chemical reagents addition were collector – 3.2 g/ton and frother – 10.5 ppm. The rougher and cleaner feed had average pulp density of 47% and 38% by weight, respectively.

2.1. Apparatus

The experimental rig employed in the flotation testwork is very similar to that described by Ata et al. (2002). A sketch of the apparatus is shown in Fig. 2. The froth from the cell passed into the base of a column, which was offset so as to allow material that may have drained out of the froth to be collected separately from the tailings and from the flotation cell. The flotation took place in a 300 mm diameter cell. The bubbles laden with particles are guided into a column of diameter 150 mm through a transition piece. The overall height of the froth can be changed by inserting columns of different heights between the flotation cell and the overflow launder, up to a maximum of 900 mm. The feed to the froth was added through a single point, a 12.5 mm pipe in the middle of the froth column. The pipe was located 300 mm below the surface of the froth although in some tests the position of the feed distributor was varied. The impeller speed remained constant at 750 rpm.

The impeller, of diameter 150 mm, was surrounded by a stator of conventional design, consisting of 16 vertical stationary guide blades. To generate bubbles, air was introduced at the bottom of column through 12.5 mm tube. The gas flowrate was controlled by a needle valve attached to a pressure regulator.

2.2. Procedure

The feed samples used in the testwork were taken from the feed box to the rougher flotation bank, and the feed box to the first cleaner stage separately, and transferred to two sumps of volume 300 L and 500 L, respectively (see Fig. 2). From this point, the samples from the rougher and cleaner stages will be referred as "coarse feed" and "fine feed", respectively. The feeds were used as received, and therefore had the same pH, pulp density and chemical environment as the relevant streams in the plant. Once both sumps were mixed sufficiently, the fine feed was added into the cell at 10 L/min using a Warman slurry pump. As soon as a stable froth was formed, the coarse feed was introduced to the froth. Timed samples of the concentrate, dropback, and tailings were taken after the concentrate flowrate reached a steady state condition. All samples were filtered, dried and weighed. The concentrate samples were then sized and analysed as described below.

The system was operated on a continuous basis. The concentrate, tailings and dropback streams were not recycled back to the feed tank. A variable-speed peristaltic pump was used in the tailings to control the flowrate at 2.5 L/min. The pulp-froth interface was set at the same level using a gravity level controller in all the runs, well below a point at the level of the partition between the pulp zone and the dropback collection column. Due to the presence of the coarse particles and high density material (such as magnetite), it was found that settling of the particles was a main problem especially in the coarse feed sump and line which made it impossible to feed the coarse feed into the froth using a peristaltic pump. To maintain the coarse feed in suspension, a Warman slurry pump was used to transfer pulp continuously at 10 L/min from the bottom of the coarse feed sump and recirculate it into the sump from the top. This helped mixing and kept the coarse particles in the suspension. The coarse feed was then fed directly from the recirculating line at about 2.7 L/min as shown in Fig. 1. The

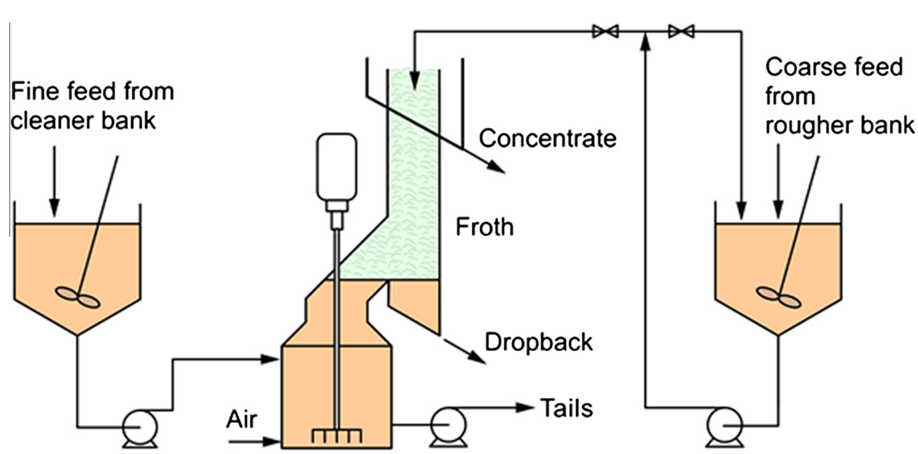

Fig. 2. Schematic diagram of the flow sheet used in the test work.