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Characterisation of coarse composite sphalerite particles with respect to flotation

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ABSTRACT

The flotation response of a typical zinc-lead (Zn/Pb) ore, with respect to coarse composite (sulphide/non-sulphide) particles is reported. The flotation tests were carried out on a selected feed particle size range (−600 + 75 μm, at P_{80} of 390 μm) and the recovery of Zn composite particles analysed on a size by size basis. The best results were achieved with the use of 75 g/t sodium isopropyl xanthate (SIPX), obtaining a Zn recovery of 77%, with a significant improvement at the coarse end of the particle size distribution. Computerised scanning electron microscope (QEMSCAN) was used to characterise value mineral grain size and degree of liberation, as well as gangue and sphalerite association in particles reporting to both concentrate and tailings. A new characterisation function (Locking ratio, LR) was developed based on the data from the automated mineralogical analysis to characterise particles into two-phase composites with different degree of locking texture (simple and complex). The function, which is based on the mode of occurrence of sphalerite, grain size, proportion and composition of the constituent minerals in each particle, was used to study the flotation response of the particles with different degrees of locking. The results highlight the difference in recoverability of the sphalerite bearing particles with different degrees of locking, with simple locking texture giving higher recovery than complex locking texture, for the same overall liberation.

1. Introduction

Froth flotation is one of the most important methods of mineral concentration, widely used in the mineral processing industry. It uses differences in surface hydrophobicity of minerals to effect the separation. In mineral flotation, the hydrophobic particles attach to the air bubbles, which transport them upwards into a froth layer which is skimmed off as concentrate. In contrast, hydrophilic particles stay in the flotation pulp to form the tailings stream. To selectively concentrate the valuable mineral, the host rock (ore) needs to be crushed and ground to liberate the minerals of interest, but perfect liberation is never achieved in practice (Meloy, 1984; Wen Qi et al., 1992; Wills and Napier-Munn, 2008), producing particles of "locked" value mineral and gangue known as composite particles (Sutherland, 1989; Wills and Napier-Munn, 2008; Xu et al., 2009; Wang, 2010). For efficient separation of value minerals to be achieved, it is recommended that the ore is ground finer to improve liberation, increase recovery and produce clean concentrate with little gangue (Pease et al., 2006). Fine grinding, however, increases the energy cost and can lead to production of very fine and untreatable particles which may be lost to tailings (Wills and Napier-Munn, 2008). Grinding is therefore a compromise between liberation and particle size (Wen Qi et al., 1992). Practically, it is often found that the middling stream (scavenger operations) contains higher amounts of composite particles. Regrinding of the concentrate after a coarse primary grind can be a strategy to reduce energy consumption (Lynch et al., 1981). However, this requires efficient recovery of coarse composite particles in the rougher or scavengers.

The flotation, process is particle size dependent; that is fine, intermediate and coarse particles show different flotation behaviour (Shergold and Ives, 1984; Marković et al., 2008). It has been established that there is an upper size limit below which particles float and this is dependent on the balance of forces acting on the particle–bubble aggregate (Schulze, 1984). The poor flotation behaviour of coarse particles (>100 μm) has been mainly attributed to the particles detaching from the bubbles in highly turbulent environment of the flotation cell (Trahar and Warren, 1976; Pyke et al., 2003; Gontijo et al., 2007) due to their high inertia (Dai et al., 2000).

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For composite particles, the degree of liberation (i.e. the surface exposure) of the hydrophobic mineral determines the overall floatability. However, it was reported by Wang (2010) that the floatability of coarse composite particles also depends on locking texture as in simple and complex locking texture (Fig. 1). Simple locking is a type of locking such that there is only one interface between the phases in a locked particle while complex locking gives particles with more than one interface between the phases. In simple locking, the exposed value mineral appears as one individual patch on the surface of the particles, while in complex locking it appear as a multitude of tiny patches, totalling the same surface area. In the studies of Wang (2010), two-phase synthetic composite particles of quartz in lead borate matrix at a controlled texture were used It was reported by Lin et al. (1992) and Woollacott and Valenta (1996) that it is difficult to control the locking texture of a real ore for the studies of composite particles flotation, but with synthetic composite particles the locking texture can be controlled. Developing a model to characterise a real ore into two-phase composite particles is very important as far as this work is concerned. The developed model will serve as a tool to characterise large number of real ores or synthetic composite particles into different locking textures using automated quantitative mineralogical tool such as QEMSCAN. Particles with simple and complex locking texture apparently respond differently to bubble attachment in flotation, as it is shown in this work. The texture of composite particles does not only depend on the locking of the particles (i.e., the fraction of exposed value mineral on the surface), but also the size of the valuable mineral patches and other mineral associations in the ore. In practice, composite particles occur in the coarser size fractions and they contribute to the loss of target mineral or mineral, of interest (Sutherland, 1989).

The objective of this work is to characterise coarse and composite particles from a real ore in terms relevant to flotation (surface liberation, grain size, texture and mineral association) and to correlate their properties to the flotation response. Another objective is to use the quantitative mineralogical analysis as a tool to characterise composite particles (value mineral locked in gangue) with different degree of locking and texture, and to predict their floatability and recovery using QEMSCAN. The influence of collector concentration on coarse and composite particles flotation is also investigated. A typical zinc-lead ore is used.

Fig. 1. Example of binary particles with complex texture (top row) and simple texture (bottom row) (Lastra, 2002).

2. Experimental

2.1. Materials and methods

2.1.1. Sample preparation

The zinc (sphalerite) ore was obtained from the Cominco Polaris operation Eclipse deposit on Little Cornwallis Island, Canada. The chemical composition of the ore is presented in Table 1. A sample of 25 kg was first crushed to <2.3 mm with a laboratory gyratory crusher followed by double roll crusher. The crushed product was then passed through a 0.6 mm sieve to produce <0.6 mm feed sample. The oversize material from the +0.6 mm sieve was further reduced to <0.6 mm using a laboratory disc mill. The <0.6 mm sample was mixed thoroughly, riffled and split into sub samples of 1 kg each. It was then purged with nitrogen and stored in a freezer prior to flotation testing.

2.1.2. Characterisation of the flotation feed

Mineralogical characterisation was first carried out on the feed using optical microscopy and X-ray diffraction (XRD) to identify composite particles with different locking texture and the various mineral phases in the ore, respectively. Prior to XRD analysis, the sample was placed into a sample cup ensuring that it was packed, flat and levelled with the top of the cup before analysing with Scintag ARL X'tra diffractometer and Cu Kα radiation. XRD traces were collected between 5° and 90° 2θ at 0.02° interval at rate of 0.05° per minutes. The minerals were identified using X-Powder software.

2.1.3. Flotation tests

The subsamples, of 1 kg each, were wet screened with 75 μm sieve to remove the −75 μm particles and a P_{80} of 390 μm was obtained. The −600 + 75 μm was used to investigate the flotation response of coarse composite particles. A pulp of 25% solids was prepared and transferred into a 1 L Denver laboratory flotation machine (Model D-12) for rougher flotation. The pulp was mixed for 2 min and the pH adjusted to 10 with lime. It was then purged with nitrogen for 5 min at a flow rate of 1 L/min to reduce the pulp oxygen content. Afterwards, sodium hydrogen sulphide (20 g/t NaHS at 1% solution strength) was added to further decrease the pulp Eh to 230 mV (SHE) to ensure higher copper uptake by sphalerite (Kartio et al., 1998). Copper sulphate (70 g/t at 1% solution strength) solution was added to the pulp and conditioned for 5 min to increase the surface affinity of the sphalerite particles for collector adsorption. The pulp was then conditioned with sodium isopropyl xanthate, (SIPX, at 1% solution strength) and frother, polypropylene glycol (PPG 425, 25 g/t at 5% solution strength) for 2 and 1 min, respectively. Different collector concentrations (25, 50, 75 and 100 g/t) were tested to ascertain the effect of collector addition rate. Impeller speed and pH during conditioning and flotation in the cell were maintained at constant 800 rpm and 10, respectively, for all experiments. Four flotation concentrates were collected after cumulative times of 1, 2, 4 and 8 min and at an air flow rate of 3.5 L/min. The dry masses of the four concentrates together with the tail were sieved and classified into different size fractions (−150 + 75 μm, −300 + 150 μm and −600 + 300 μm), weighed and then assayed for their elemental composition. Pulp potential (Eh) throughout the experiments was

Table 1
Elemental composition of the ore used in this study.

Elemental content (%)						
Zn	Pb	Fe	Ca	Mg	S	Si
19.1	5.7	1.0	13.1	7.1	12.0	0.9