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Short communication

Removal behavior of slime from pentlandite surfaces and its effect on flotation

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ABSTRACT

Jinchuan is the largest nickel producer in China. The separation of pentlandite from serpentine gangue is difficult in this flowsheet because serpentine slime can attach to the valuable minerals as a slime coating. To solve this problem, the removal of different sized serpentine slimes from sulfide surfaces and its effect on flotation were studied using flotation experiments, particle size analysis, and X-ray diffraction. The results illustrated that the slime particles attached to coarse particle surfaces after grinding and depressed pentlandite flotation. The slimes comprised mainly MgO minerals. High-intensity conditioning could be used to remove the coarser slimes, while sodium hexametaphosphate could be used to remove the fine slimes. These two methods were used in combination in the flotation of Jinchuan nickel sulfide ore and the metallurgical performance was significantly improved: nickel recovery increased from 82.97% to 86.27% and the MgO content decreased to 6.22%.

1. Introduction

Nickel is a silvery-white transition metal, usually used as an alloying element in stainless steel and other alloy steels. Nickel deposits can be classified into two main groups: laterites and sulfides. Although nearly 70% of nickel resources are contained in laterites, the bulk of production comes from sulfides due to the complex and high-cost processing required for laterites (Bacon et al., 2002). The main nickel-producing countries are Russia, Canada, Australia, Indonesia, China, and New Caledonia.

Jinchuan Nickel Mine is located in Jinchang city, Gansu Province, China. It is the largest nickel producer in China. The value mineral in the ore is mainly pentlandite and the dominant gangue mineral is serpentine (Feng et al., 2012a). Serpentines break readily and this size reduction produces fines or slimes, which are considered to be particles of less than about 10 µm. These gangue slimes can interfere with flotation by forming a coating on the pentlandite surface (Edwards et al., 1980; Li, 1993). This has two consequences: dilution of the concentrate when partially coated pentlandite remains floatable and lowering of pentlandite recovery when extensively coated pentlandite becomes hydrophilic (Bremmell et al., 2005; Feng and Luo, 2013; Pietrobon et al., 1997).

To improve the flotation separation efficiency of pentlandite from serpentine gangue, sodium hexametaphosphate (SHMP), sodium silicate, carboxymethyl cellulose, and other agents can be used to disperse slime particles of MgO-type minerals on sulfide surfaces and improve sulfide flotation performance (Bremmell et al., 2005; Feng et al., 2012b; Lu et al., 2011). Also, nickel recovery from the flotation process depended on both conditioning speed and time (Chen et al. 1999a,b; Engel et al., 1997). Many researchers have studied the role of the dispersant and high-intensity conditioning (HIC) on the flotation of nickel sulfides and found that these two methods have different mechanisms of action. The dispersant can change the surface potential of serpentine and change the attractive force between the sulfide and serpentine to a repulsive force (Feng et al., 2012b); in contrast, HIC mechanically cleans the pentlandite surfaces, consequently improving the pentlandite flotation performance. The amount of slimes removed from the surface depended on HIC speed and HIC time (Chen et al. 1999a,b; Engel et al., 1997). However, it is still unknown which method is more suitable for flotation of nickel sulfide ores.

In this work, the removal of slimes from the sulfide surface by these two methods and the effect on Jinchuan nickel ore flotation is studied to provide a technical reference for the utilization of nickel sulfides that contain serpentine gangue.

2. Methods

2.1. Samples and reagents

The ore sample was supplied by Jinchuan Corporation. The nickel grade of the sample was 1.43% and the MgO content was 34%. Quantitative X-ray diffraction indicated that the main sulfide minerals

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Table 1
Mineral composition of the ore (%).

Mineral	Pentlandite	Chalcopyrite	Pyrrhotite	Magnetite
Abundance/%	3.85	1.82	8.15	6.61
Mineral	Pyrite	Josephinite	Vallerite	Chlorite
Abundance/%	0.73	0.15	0.95	3.45
Mineral	Serpentine	Olivine	Tremolite	Pyroxene
Abundance/%	46.45	18.73	3.94	1.79

were pentlandite, chalcopyrite, pyrrhotite, and pyrite, while serpentine, olivine, and other magnesium silicate minerals were the main gangue minerals (Table 1).

2.2. Flotation tests

Ore samples were ground in a mild steel rod mill to a P70 of 74 µm. Sodium carbonate, as pH regulator was added to a dosage of 2500 g/t at the grinding stage. Bench-scale flotation tests for the nickel ore were performed in a self-aerated XFD-63 flotation cell (Nanchang Mining Machinery Company, China) with a volume of 1.5 L. The slurry was transferred to the flotation cell and diluted to 35% (w/w). The standard flotation tests were performed using an agitation speed of 1800 rpm. During the conditioning, dispersant SHMP, collector (150 g/t) and further (30 g/t) were added and conditioned for 3 min respectively. Then the flotation started with the injection of air into the flotation cell. A total of five concentrates were collected at times of 1, 3, 6, 10, and 15 min. The HIC studies were carried out similarly to the standard flotation tests, with the exception that PAX (150 g/t) was added and conditioned for different times at the required conditioning speed (see Fig. 6 for details). The relationship between power and conditioning speed is shown in Table 2.

2.3. Measurement of removal behavior of slimes

The removal of slime was measured using a sieving technique developed by Chen et al. (1999a,b). Pulps were sampled from a flotation cell before and after HIC (or added SHMP) and introduced to a sieve (74 µm) to remove −74 µm particles. The +74 µm samples from the pulps before HIC and after a specified period of HIC, were introduced to a Malvin laser particle size analyzer to measure the size distribution (As shown in Fig. 1). The fine fraction (< 74 µm) is defined as the slimes particles adhering to the surfaces of the large mineral particles in the +74 µm size fraction. The change of particle size distributions in the fine fraction can be used to represent the removal behavior of slimes.

To determine the mineral compositions and size distribution of the slimes, the +74 µm samples (No HIC) were also sonicated to remove the slimes and the supernatant was collected for XRD and size distribution analysis.

3. Results and discussion

3.1. Removal of slime from coarse particle surfaces

Several studies have shown that coatings of slime form during the flotation of Jinchuan nickel ore (Cao et al., 2015; Feng et al., 2014); however, the mineral composition and particle size composition of the slime were not identified. The mineral composition and size distribution of the slime adhering to the coarse particle surfaces were first studied the results are shown in Figs. 2a and 2b. Fig. 2a shows the size distributions of slime that adhered to the surface of +74 µm particles: most slimes had particle sizes smaller than 3 µm. Fig. 2b shows

Table 2
The relationship between power and conditioning speed.

Conditioning speed (r/min)	1500	1800	2000
Powder (W)	50	65	78
Conditioning speed (r/min)	2250	2500	2802
Powder (W)	96	122	143

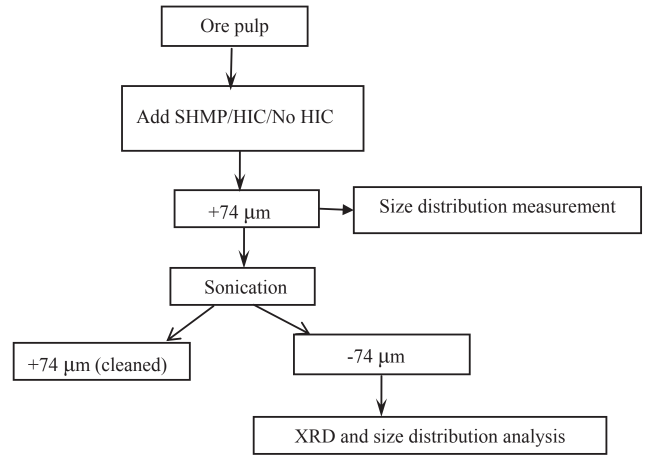

Fig. 1. Measurement of removal behavior of slimes.

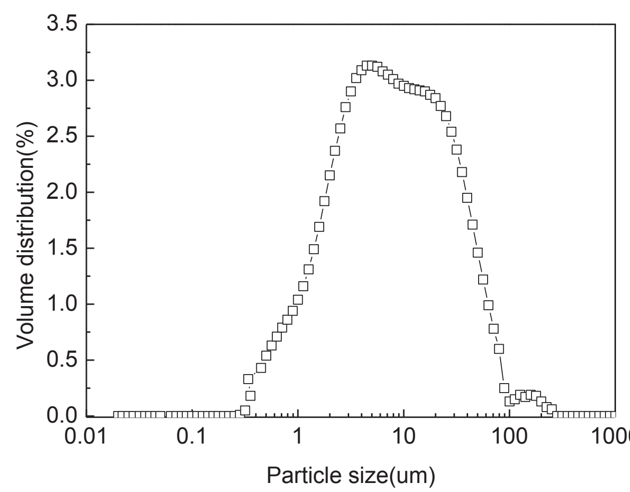

Fig. 2a. The size distribution of the slime adhering to the coarse particle surface.

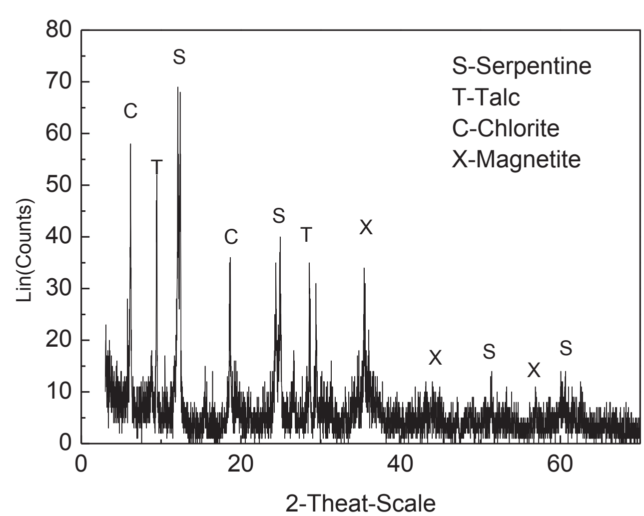

Fig. 2b. The mineral composition of the slime adhering to the coarse particle surface.