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Effect of Flotation Reagents on the Cake Moisture of Copper Concentrate

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Abstract: The effect of reagents used in separating chalcopyrite from pyrite on the cake moisture of the copper concentrate at Daye Iron Mine Mineral Processing Plant was investigated. The results showed that the dosage of lime used for depressing pyrite was the main factor that increased the filter cake moisture of copper concentrate. With increasing the dosage of lime, the cake moisture of copper concentrate increased sharply. The cause was concluded to be the addition of lime to the pulp, which resulted in the formation of floc and a high pH value. The collector Z-200#, used for collecting chalcopyrite, had, as well, an adverse effect on the cake moisture of copper concentrate, but its effect was inferior in respect to that of lime. The cake moisture of copper concentrate can be decreased by changing the method with which lime is added and the pH value of pulp is regulated. The experiment results showed that the sulfuric acid was the best regulator. When the clarified liquor of lime was used as a depressant and the pH value of the pulp was regulated to 6.5–7.0 by adding sulfuric acid, the cake moisture of copper concentrate was reduced from 15.49% to 13.13%. The examination of chalcopyrite surface by using ESCA (Electron Spectroscopy for Chemical Analysis) showed that calcium sulfate and iron hydroxide had formed on the surface of chalcopyrite when lime was added to the pulp. The formation of calcium sulfate and iron hydroxide on its surface increased the hydrophilicity of chalcopyrite so that its cake moisture increased. The addition of sulfuric acid to the pulp not only removed the calcium sulfate, but also reduced the concentration of iron hydroxide on the surface of chalcopyrite so that the cake moisture of copper concentrate was decreased.

Key words: flotation reagents; filtration; copper concentrate; cake moisture; ESCA

Daye Iron Mine Mineral Processing Plant, which is situated in Hubei Province, China, is a large one. Three products including iron concentrate, copper concentrate and sulfur concentrate are produced separately in the plant. The iron concentrate consisting mainly of magnetite is produced by low intensity magnetic separation. The copper (consisting mainly of chalcopyrite) and the sulfur concentrate (consisting mainly of pyrite) are produced by froth flotation. The circuit is the following: chalcopyrite and pyrite are floated together as a froth product known as mixed concentrate by using sodium ethyl xanthate as a collector. The lime is added to the mixed concentrate to desorb the collector and depress the pyrite, and finally the collector Z-200# is added to float the chalcopyrite, so that the copper concentrate (as a froth product) and sulfur concentrate (as an underflow product) are produced separately. One of the main problems existing in that plant is the high cake moisture of the copper concentrate, often resulting to be more than 15.0%, while the requirement is less than 14.0%. The high moisture of the copper concentrate renders the transportation and sale to be difficult. The objectives of this research work are to investigate what is the main factor causing the high cake moisture of copper concentrate, how the factors effect the cake moisture and finally to discover the method of decreasing the cake moisture.

1 Experimental Materials and Methods

The materials and reagents used in the experiments originated from the Daye Iron Mine Mineral Processing Plant. To simulate the real conditions, the pulp sample was taken instead of the dry, solid sample. The pulp was taken from the feed of the flotation bank used to separate the chalcopyrite from the pyrite, which was the main constituent of copper concentrate.

A wet sampler was used to prepare the batch samples for each experiment. Each batch sample contained 100 g of dry solid and was conditioned with reagents and then floated in a flotation cell with a volume of 0.5 L under various conditions. The froth product, known as copper concentrate, produced under different conditions was filtered in a laboratory apparatus to investigate the effects of different flotation conditions on the cake moisture of copper concentrate.

The filtration experiments were carried out with the apparatus shown in **figure 1** [1]. First, valve 1 was turned off and valves 2 and 3 were turned on. Second, the vacuum pump was turned on and the valve 2 was adjusted to keep the vacuum gauge showing the vacuum needed. The copper concentrate pulp from flotation was

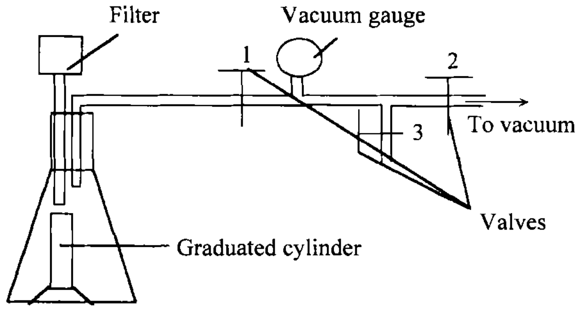

Figure 1 Diagram of apparatus for filtration experiments.

then added to the filter, after which valve 1 was turned on and a stop watch was contemporaneously started to record the filtration time, defined as the duration from the start time of filtration to the time when no water can be seen on the surface of the cake. The drying time was defined as the duration from the end of the filtration to the time when the vacuum pump was stopped. At the end of filtration, the filtrate volume in the graduated cylinder was read and the average flowrate, which was defined as the ratio of filtrate volume to the filtration time, was used to compare the effect of different conditions. Finally, the cake was dried in an oven at 105 °C for 3 h to determine the moisture content of the cake.

The pure chalcopyrite used for ESCA (Electron Spectroscopy for Chemical Analysis) measurement was purchased from the Geological Museum of China. The chemical analysis showed that the content of chalcopyrite in the sample was 98.0%. The chalcopyrite was grounded in a ceramic mill and classified to make all material pass a 325 mesh stainless sieve. Three samples were prepared. The first one was the original chalcopyrite, the second one was chalcopyrite treated by lime to pH = 12.5, the third one was chalcopyrite treated first by lime to pH = 12.5 then treated by sulfuric acid to pH = 6.5–7.0. The ESCA measurements were obtained with a Perkin Elmer Physical Electronics Division (PHI) 5100 Spectrometer using a Mg-K_α X-ray source operated at 300 W [2].

2 Results and Discussion

2.1 The effect of lime on the cake moisture and average flowrate of copper concentrate

Lime was used as a depressant of pyrite when chalcopyrite was separated from pyrite by flotation. The effect of lime amount on the grade and recovery of copper concentrate is demonstrated in **figure 2**; the collector Z-200# added was 88 g/t and the flotation circuit was one rougher and one scavenger.

The two froth products were combined as copper concentrate. It can be seen that the grade of copper increased by increasing the amount of lime, but the recovery decreased. To get a concentrate assaying more than 18.0% Cu, the lime must be added to the flotation cell. When the lime amount added was 1.9 kg/t the grade of copper concentrate was 18.98%, with a recovery of 93.12%.

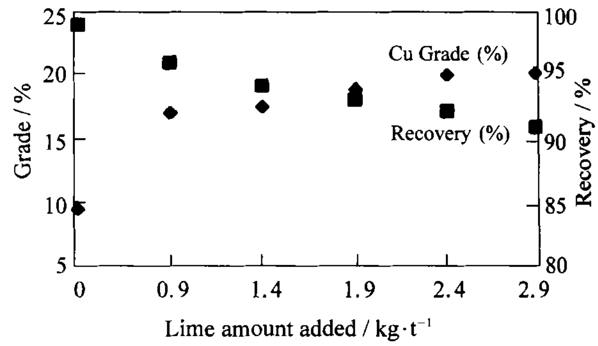

Figure 2 The grade and recovery of copper as a function of lime amount added.

Figure 3 shows the variation of cake moisture and the average flowrate of copper concentrate as a function of lime addition. The filtration conditions were the following: the vacuum was kept at 0.06 MPa and the drying time was 3 min. The cake moisture sharply increased from 10.20%, when no lime was added, to 16.80%, when lime amount was 2.9 kg/t. With an increased lime amount and a decreased average flowrate, the lime increased the resistance of cake. This proves that the lime amount is the main factor influencing the cake moisture.

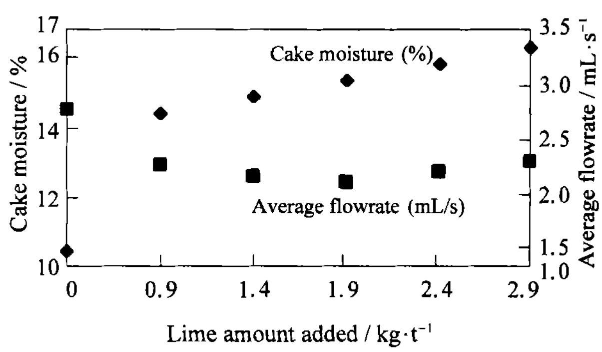

Figure 3 The cake moisture and average flowrate as a founction of lime.

It was also observed that flocs were formed when the lime was mixed with water. These flocs may block the pore of the cake so that its resistance increases. The method of adding lime was changed to reduce the effect of the flocs.

The lime milk was settled before being added to the pulp to remove the flocs and only the clarified liquor was added to the pulp. The experiments showed that the clarified liquor had the same depressing effect as non-settled lime milk, and the cake moisture was reduced from 15.50% to 14.58%.

Experiments were carried out whereby lime was replaced by the same amount of sodium hydroxide. The results showed that the pyrite can be depressed by sodium hydroxide, and the cake moisture of copper concentrate was reduced from 15.56% to 13.70%. It was therefore concluded that the effect of lime was related not only to the high pH value, but also to the Ca^{2+} produced when lime was added.

2.2 The effect of Z-200# on the cake moisture of copper concentrate

The Z-200# was used as collector and frother of chalcopyrite. The data in **figure 4** show the effect of Z-200# on the grade and recovery of copper concentrate. The lime amount added was 1.9 kg/t. It can be

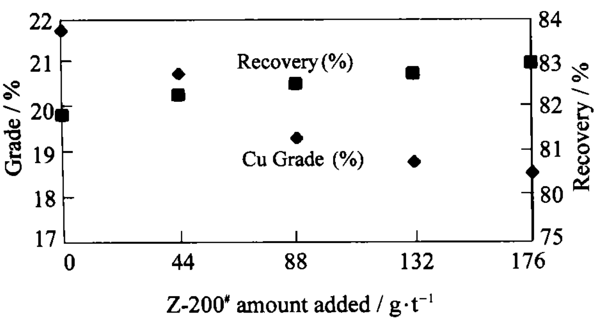

Figure 4 The grade and recovery of copper as a function of Z-200# amount added.

noted that the grade of copper decreases and the recovery increases by increasing the amount of Z-200#. To get a concentrate assaying more than 18% Cu with a recovery of 92.0%, the amount of Z-200# was 88 g/t. The data in **figure 5** show that the effect of Z-200# amount on the cake moisture and average flow rate was much smaller than that of lime amount.

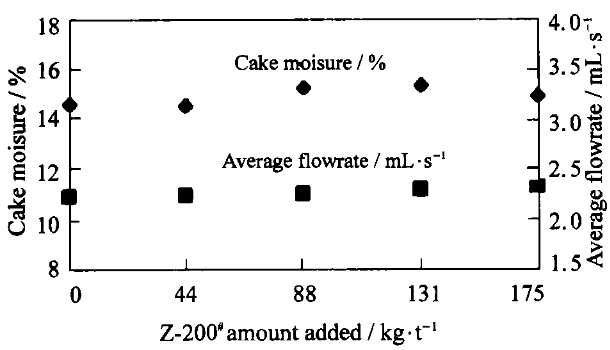

Figure 5 The cake moisture and average flowrate of copper concentrate as a function of Z-200# amount added.

2.3 The effects of adding different kinds of acids

To decrease the cake moisture of copper concentrate, the pH value of the pulp was regulated by different kinds of acids. The data in **figure 6** show the experimental results. The effects of different acids on cake moisture varied. The sulfuric acid was the most effective regulator. The cake moisture decreased by decreasing the pH value of the pulp for the addition of sulfuric acid, and when the pH value of the pulp was decreased to 4.5 the cake moisture decreased to 13.58%. The hydrochloric acid and oxalic acid had only little effect on the cake moisture. The phosphorous acid had adverse effect on the cake moisture by provoking a cake moisture of 17.40%. This proved that the effect of acids on the cake moisture depends on the radicals of acids, instead of hydrogen ions; the concentration of hydrogen ions was the same at the identical pH, but the radicals reacted differently with different acids. The cake moisture as well reacted differently with different acids at the same pH. If the clarified liquor of the lime milk is used as a depressant and the pH of the pulp of copper concentrate is adjusted to 6.5–7.0, the cake moisture of it can be reduced from 15.49% to 13.13%.

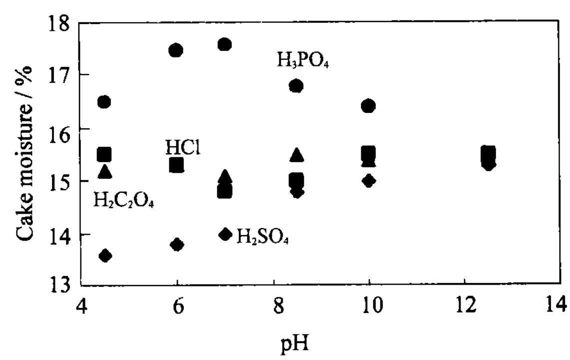

Figure 6 The cake moisture of copper concentrate as a function of pH regulated with different acids.

3 Mechanism

To investigate the mechanism of how the sulfuric acid decreased the cake moisture of the copper concentrate, the surface chemical constituents of chalcopyrite were studied by using ESCA. The data in **table 1** show that the surface chemical constituents of chalcopyrite were different under different conditions. The most distinct difference was the content of calcium. No calcium was found on the surface of chalcopyrite when it was under the original condition, but the calcium increased to 4.75% after treatment by lime milk. This demonstrates that some kind of Ca-containing compound was formed on the surface of chalcopyrite. The contents of Fe also increased which means that $Fe(OH)_3$ may be formed on the surface. The contents of Cu and S decreased, perhaps as the result of the formation of Ca containing compound and because $Fe(OH)_3$ reduced the con-

Table 1 Content of Cu, S, Fe, Ca and O on the surface of chalcopyrite under different conditions (in mass fraction) %

Conditions	Cu	S	Fe	Ca	O
Original chalcopyrite	19.20	41.94	2.56	0.00	36.30
Chalcopyrite treated by lime to pH 12.5	8.41	25.08	8.21	4.75	53.55
Chalcopyrite treated first by lime then by sulfuric acid to pH 6.5–7.0	18.32	41.93	2.67	0.00	37.08

centration of Cu and S on the surface. It was the hydrophilic Ca-containing compound and $Fe(OH)_3$ that increased the cake moisture. To determine the Ca-containing compound, the valence of sulfur on the chalcopyrite surface was also determined by using ESCA [3]. The results are shown in **table 2**. It can be seen that

Table 2 Content of different valence sulfur on the surface of chalcopyrite under different conditions (in mass fraction) %

Conditions	S^{2-}	S^{0}	S^{6+}
Original chalcopyrite	44.56	44.85	10.59
Chalcopyrite treated by lime to pH 12.5	40.87	41.86	17.27
Chalcopyrite treated first by lime then by sulfuric acid to pH 6.5–7.0	44.28	44.80	10.92

when lime was added the content of S^{2-} and S^0 decreased and the content of S^{6+} increased on the surface. This meant that the amount of SO_4^{2-} increased on the surface of chalcopyrite when the lime milk was added. It can as well be noted from table 1 and 2 that the surface chemical constituents of chalcopyrite almost returned to its original state when the sulfuric acid was added. The function, therefore, of sulfuric acid was to remove the Ca-containing compound and $Fe(OH)_3$. The electronic binding energy of Ca_{2p} of the Ca-containing compound on the surface of chalcopyrite was also measured by using ESCA, the value of which resulted as being 347.6 eV. This proved the compound was $CaSO_4$ because only CaF and $CaSO_4$ were possible when the binding energy of Ca_{2p} was between 347–348 eV, [3] and no F existed on the surface of chalcopyrite.

4 Conclusions

(1) The lime used for depressing pyrite was the main factor that increased the cake moisture of copper concentrate. With increasing the dosage of lime the cake moisture of copper concentrate increased sharply. The cause was concluded to be the formation of floc and the high pH value when lime was added to pulp.

(2) The collector Z-200#, used for collecting chalcopyrite, had as well an adverse effect on the cake moisture of copper concentrate, but its effect was much less than that of lime.

(3) The cake moisture of copper concentrate can be decreased by changing the method by which lime is added and the pH value of pulp is regulated. The sulfuric acid was the best regulator. When the clarified liquor of lime milk was used as a depressant and the pH value of the pulp was regulated from 12.5 to 6.5–7.0, the cake moisture of copper concentrate was reduced from 15.49% to 13.13%.

(4) The examination of chalcopyrite surface by using ESCA showed that calcium sulfate and iron oxide was formed on the surface of chalcopyrite when lime white was added to the pulp. The formation of calcium sulfate on its surface increased the hydrophilicity of chalcopyrite so that the cake moisture of it was increased.

(5) The addition of sulfuric acid to the pulp, not only removed the calcium sulfate, but also reduced the concentration of oxide of metals on the surface of chalcopyrite, so that the cake moisture of copper concentrate was decreased.

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