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PROCESSING OF COPPER AND BAUXITE ORES IN CHINA

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China's copper ore resources are widely dispersed, yet relatively concentrated mainly in a few provinces such as Jiangxi, Yunnan, Gansu, Hubei, Anhui and Shanxi, and Tibet Autonomous Region. Copper ores fall into two principal categories, i.e. sulfides and oxides, with the first ones dominant. The copper sulfide ores are in turn divided into four types, namely porphyry, copper containing pyrite, skarn, and sedimentary-metamorphic copper deposits. The copper mining industry as well as other industries has achieved considerable progress since the founding of New China. Now there are one hundred and so copper mills operating in the mainland, equipped almost with China-made machines and facilities. Reagents used in mineral processing are also supplied by domestic factories. Research and design institutions for mining and metallurgy are set up directly under the central ministries concerned and in most mineral-producing provinces and autonomous regions to back up the development of copper and other mining industries. Years' efforts have resulted in sustained improvement and modernization of the techniques applied in copper mills and the mining industry as a whole. Despite the ever decreasing copper grade in crude ores, recovery of copper in concentrates is still kept at an average of 88%.

China's alumina resources are mainly found in Guangxi Autonomous Region, Guizhou, Henan, Shandong and Shanxi Provinces, which, based on different Al/Si ratio, are treated by Bayer process, combination process or sintering process. Among them, there are a large proportion of diasporite-kaolinite type bauxite ores, which are unacceptable to Bayer process, and can be treated only by combination or sintering process. In order to raise the Al/Si ratio in such ores to render it amenable to Bayer process, beneficiation tests have been conducted with more or less satisfactory results. However, operation of such kind has not yet come into being.

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PROCESSING OF COPPER ORES

1. Flowsheets and Technology

Progress has been made in upgrading the technology and diversifying the flowsheets for copper mineral processing.

1.1 Partially selective-bulk flotation

Bulk flotation flowsheet was originally practised at Fenghuangshan Copper Mine, Anhui Province, with bulk flotation of chalcopyrite and pyrite followed by separation of each other. Later on the expansion of grinding section led to an insufficient capacity of flotation banks, as a result production of pyrite was ceased for a time, with single copper flotation circuit operating. In order to recover the pyrite lost without additional flotation equipment, a partially selective-bulk flotation flowsheet has been adopted. Using the well selective cyanooctyl butyl xanthate ester (CSK-43) as collector, a 30%Cu high grade copper concentrate is first produced with a 60%Cu recovery, followed by bulk flotation of chalcopyrite and pyrite from the tailings, and the bulk concentrate is sent for further separation. Since the yield of such bulk concentrate is reduced, the existing flotation capacity is therefore sufficient for separating chalcopyrite from pyrite. In this way, while copper flotation metallurgy is kept at the same level, not only is recovered pyrite and reduced reagent consumption, but silver recovery in the copper concentrate is raised as well.

1.2 Partially bulk-selective flotation

A selective flotation process was adopted at Hongtoushan Copper Mine, Liaoning Province, to recover chalcopyrite and pyrite. This process appeared unacceptable with unsatisfactory separation results, because of the close flotability of chalcopyrite and pyrite and higher consumption of flotation reagents. Later a shift was made to partially bulk-selective flotation process, i.e. first bulk flotation of chalcopyrite and pyrite with further separation of these minerals, followed by flotation of sphalerite from the bulk flotation tailings. Changing over to the new flowsheet has been raising the recovery of copper from 90% to 93% and that of sulphur in pyrite concentrate by 19%. Additional 0.8%Cu

increase in copper recovery has been gained after a regrind operation added to the original two stage grinding and flotation process. Furthermore, the recovery of zinc has gone up from 78% to 83% owing to aerated agitation for oxidizing pyrite before zinc flotation.

1.3 Regrinding of middlings and aerated agitation before separation

Bulk flotation flowsheet with two stage grinding and flotation was originally used at Xinye Copper Mine, Hubei Province, to recover chalcopyrite and pyrite altogether at first with further separation of these minerals from the bulk concentrate. Afterwards, a regrinding circuit of middlings from bulk flotation is supplemented, and the original parallel separation system of copper from pyrite changed into a serial one with aerated agitation of pulp at higher pH(11.3) for a longer time before their separation, which resulting in increasing copper concentrate grade from 20%Cu to 25%Cu at a 91%Cu recovery.

1.4 Two stage grinding followed by single stage flotation

At Yuben Mill, Yimen Copper Mine, Yunnan Province, treating copper ores with 25-30% oxidation ratio, the original two stage grinding and flotation flowsheet has been turned into a two stage grinding with single flotation process. The result has been not only reduced reagent consumption and shorter flotation duration, but also an increase of copper recovery by 3%, up to 91% at a 29%Cu grade.

1.5 Separate grinding and flotation of sand and slime

Ores, treated at such copper mills as Tongguanshan, Shizishan and Tongshan, Anhui Province contain various amounts of primary slime. Separate treatment of sand and slime fractions after scrubbing or washing in the crushing operation has been proved capable of improving copper metallurgy. For example, separate grinding and flotation of sand and slime at Tongshan Mine has raised its copper recovery by 1-1.5%.

1.6 Simplified flotation

Simplified or branched flotation process has successfully been operated at a number of Pb-Zn mills. It was tested in commercial scale at two sections of Dongting Copper Mill, Jiangxi Province, and satisfactory results were reported.

Compared with the conventional flotation flowsheet, the ramified flotation has raised copper concentrate grade by 2.4%Cu and recovery by 1.7%Cu, while reducing the consumption of xanthate and ether alcohol by 30% and one stage cleaning.

1.7 Combined column and cell flotation

Since the 60s column flotation has been practised at Chimashan Copper Mine, Hubei Province, with good results recorded for rougher and scavenger operations. Comparison tests were made at this mine between cell and column flotation at cleaning stage to identify which one could give better cleaning results. Cleaning results by column were found worse than those by cell flotation, the reason is that the coarse fraction of copper rough concentrate contains more copper values than the fine fraction does. After this, flotation cells have been introduced to clean the rough and scavenger concentrates from columns separately, and the copper concentrate has been upgrading from 24%Cu to 29%Cu with its recovery remained at the same level.

1.8 Blending of different ores

At Baiyin Non-ferrous Metals Co., Gansu Province, two separate sections were run to treat massive and disseminated copper-pyrite ores. A blending operation has then inserted in the process. A bulk concentrate containing chalcopyrite and pyrite is produced at lower pH pulp from disseminated ore, such concentrate is then sent to the grinding section for massive ore. Copper concentrate is obtained from the ground product leaving the tailings as pyrite concentrate. Blending method is able to produce from the disseminated ore a pyrite concentrate grading over 40%S at a 50-60%S recovery. In addition, the consumption of collectors for massive ore flotation can be cut down by one third.

1.9 Cementation of copper ions in grinding process

The massive Cu sulphide ore treated at Baiyin Non-ferrous Metals Co. demonstrates higher acidity, natural pH of pulp 4, showing oxidation rate 10-30% and containing 1300-2200 mg/l copper ions. Such ions can be cemented as copper metal in the grinding process in the absence of lime. After grinding lime is added to depress pyrite, and chalcopyrite and metallic copper are floated. Compared with

the case of lime added to the grinding process, it can raise copper recovery by 2-10%, but at the expense of higher grinding medium consumption.

1.10 Using loess as adsorbent

At Baiyin Co., when the lead found in the form of anglesite was over 0.4% in treating massive copper-pyrite ore of secondary enrichment, the flotation performance deteriorated with copper recovery 85% max. Afterwards, when loess is used as adsorbent, the negative effect of anglesite is eliminated and the copper recovery has gone up to 93%.

2. Reagent Regimes

In order to improve the performance of mineral processing, considerable efforts regarding reagent usage have been made in a number of copper mills.

2.1 Mixed collectors

At Shitouzui Mill, Hubei Province, treating copper ore of higher oxidation rate, a mixed collector of butyl xanthate and sodium hydroxamate (ratio 3:1) is used instead of single butyl xanthate, which has raised not only copper recovery, but copper grade by 3% as well. At Luoxue Mill, treating copper ore of 20-30% oxidation ratio, a mixed collector of sodium butyl dithiophosphate and butyl xanthate (ratio 1:2) is used to replace single butyl xanthate, which has raised copper grade by 2.85% and copper recovery by 0.75% while reducing consumptions of collectors, frothers and sodium sulphide. Another example is Jingxi Copper Mill, treating arsenate type oxide ore. Among its copper minerals tennantite accounts for 14%, and various copper arsenates 73%. No satisfactory results can be gained by flotation with sodium sulphide and xanthate. However, flotation of such ore can be improved by a combination of butyl xanthate, fatty acid with C₅₋₉ and diesel oil, and further improved by adding benzothiazole. The latter reagent regime has gone into commercial experiment, giving a 70% Cu recovery, and already been used in operation.

2.2 Mixed-base xanthate

At Tongkuangyu Mine, Shanxi Province, mixed-base xanthate prepared from isopropyl, butyl and isopentyl alcohols was tested in copper flotation process. Such mixed-base xanthate exhibits higher collective power than butyl xanthate offering the same metallurgy at its consumption 20% less than that of butyl

xanthate. The mixed-base xanthate now is used in production, resulting in lower reagent cost.

2.3 Flotation at lower alkalinity of pulp and lower consumption of xanthate

At Baiyin Co. higher alkalinity of pulp and higher consumption of xanthate were practised to treat single disseminated copper sulphide ore, which led not only to higher reagent consumption but also to considerable loss of pyrite to the tailings. Later the flotation regime is shifted to lower alkalinity of pulp and lower consumption of xanthate. As a result, on the premise of maintaining copper grade at 26%Cu and its recovery at 95%Cu consumption of reagents has been reduced while pyrite also recovered.

2.4 Improvement of flotation performance by ethylenediamine phosphate

At Luoxue Copper Mine, Yunnan Province, addition of ethylenediamine phosphate (56 g/t) has been able to increase total copper recovery by 2.25% at the same concentrate grade (24%Cu) compared with the circuit without addition of such phosphate. Among others, recovery from oxides has been raised by 9.26%Cu and that from sulphides by 0.42%Cu; consumption of sodium sulphide and xanthate reduced by 20-30% and 10-20%, respectively. Similar results have also been recorded in other copper mills such as Yinmin and Tangdan.

2.5 Using ammonium sulphate as sulfidization promotor

At Langtianba Copper Mine, Yunnan Province, where copper ores exhibit a 70% oxidation ratio, ammonium sulphate is used as sulfidization promotor, resulting in increases of concentrate grade by 2%Cu and recovery by 5%Cu respectively.

2.6 Depressing carbonaceous gangue by ferrochrome lignin

At Hujiayu Copper Mill, Shanxi Province, where ores treated contain fine-grained carbonaceous gangue minerals, leading to a copper concentrate with higher silicon content and a sticky froth, when 40 g/t ferrochrome lignin is added in the cleaning stage as gangue depressant, concentrate grade is gone up from 25%Cu to 26.6%Cu and moisture in copper concentrate also reduced.

2.7 Upgrading copper concentrate by sodium humate

Copper ores treated at Lanniping Mine are oxidized in a 23% ratio. Depressing gangue minerals by 148 g/t sodium humate has upgraded the concentrate by 3%Cu.

3. Combined Methods

Some difficult copper ores, refractory or even unacceptable to single beneficiation method, can be more effectively treated by combined methods of beneficiation with pyro- or hydro-metallurgy. A few examples are cited as below.

3.1 Single stage segregation-flotation

Copper ores treated at Shilu Copper Mine, Guangdong Province, contain 40-50% cemented copper, which disseminated in clay, ferro-manganese nodule, etc., and are high in calcium and magnesium. As a result, such ores are difficult to treat by single beneficiation or acid leaching method to recover copper values. Since the 70s a process of single stage segregation followed by flotation has been used to recover copper. After treating a feed of 2.8%Cu at segregation temperature 750-850°C for 20-25 min., a concentrate of 30%Cu is floated at a 82%Cu recovery.

3.2 Acid leaching-extraction-flotation

Copper ores treated at Yongping Mine, Jiangxi Province, are oxidized in a 13-30% ratio, with copper oxidation rate in slime reaching 44%. A process of ore washing before separate treatment of sand and slime is adopted to recover copper minerals, i.e. sand is directly sent to flotation while slime to acid leaching-dewatering-flotation circuit. The leach liquor is extracted with Y-510 extractant to recover copper values, which are then stripped before electrowinning. This technology now is in trial production stage.

3.3 Recovering copper from converter slag

Flotation process is practised at Guixi Smeltery, Jiangxi Province to recover copper values from its converter slag. Two stage grinding is used for the 4.5%Cu converter slag after slow cooling for 60-90 min. The feed is ground to 90%-325

resh while middlings ground to 50 μ -20 μ . A 35%Cu concentrate is obtained at a recovery of 92%Cu.

3.4 Flotation of anode slime

A flotation process is used at Yunnan Smeltery to treat copper anode slime. The anode slime is first treated with sodium chlorate to remove copper and selenium, then repulped to acid level and sent to a flotation column to recover precious metals by adding xanthate as collector and sodium hexametaphosphate as depressant for gangue and lead. The recovery of gold and silver reaches 95-97%. In addition, a 40%Pb concentrate is gained from the gold & silver flotation tailings at a recovery of 80%Pb. The total recovery of Au+Ag is 99%.

4. Flotation Machines

Apart from the revamping and modification of out-of-date A type cells as well as the development and introduction of flotation columns, a number of new types of flotation cells have been studied, manufactured and put into operation.

4.1 CHF-X14 type air-blowing mechanical flotation cell with 14 m³ active volume

Compared with 6A type cell, CHF-X14 type cell can raise copper recovery by 1-2%, and reduce energy consumption and floor space by 15% and 61%, respectively. Its variations include CHF-7(7 m³), and CHF-3.5(3.5 m³). Similar types are XJC-80(8 m³), XJC-40(4 m³) and XJC-20(2 m³). At present 400 and more single CHF-X14 cells have been put into operation in China.

4.2 JJF-20 type self-aerating mechanical flotation cell with 20 m³ active volume

It offers an increase of 0.95-3.76%Cu recovery, and reductions of energy consumption, wear parts and floor space by 39%, 60% and 42%, respectively, compared with 7A type cell. Modifications are JJF-16(16 m³), JJF-8(8 m³) and JJF-4(4 m³) cells, and similar types are XJQ-160(16 m³), XJQ-80(8 m³), XJQ-40(4 m³) and XJQ-20(2 m³). For the time being there are 500 and more JJF type cells operating at China's mines.

4.3 KYF-16 type air-blowing mechanical flotation cell

With an active volume of 16 m^3 , it is capable of increasing copper recovery by 1.22%Cu, reducing energy consumption by 44%, and prolonging the life of spare parts by three times, compared with 6A type cell. Its family members include KYF-38(38 m^3 , now in trial production), KYF-8(8 m^3) and KYF-4(4 m^3). And BS-KJF type is a similar one.

4.4 SF-10 type self-aerating mechanical flotation cell with 10 m^3 active volume

Compared with 6A type flotation cell, it can raise copper and zinc recoveries in the bulk Cu-Zn concentrate by 1.27%Cu and 1.26%Zn, and reduce the energy consumption by 11.6%. Combined units with SF type cell for suction and JJF type cell for direct flow have been in operation. Its variations include SF-8(8 m^3) and SF-4(4 m^3).

4.5 LC4-X5 type air-blowing mechanical flotation cell with 5 m^3 active volume

Compared with 6A type cell, it can increase copper recovery by 3% and reduce energy consumption by 16%.

4.6 Cyclo-jet type flotation cell

With an active volume of 2.7 m^3 , it can upgrade a copper concentrate by 1%Cu when cell volume needed is only 30-60% that of 5A type cell.

PROCESSING OF BAUXITE RESOURCES

China's aluminium resources encompass a large proportion of diasporite-kaolinite type bauxite ores with Al/Si ratio of 4 or 6:1, containing higher silica. The major aluminium minerals are diasporite and kaolinite. Flotation tests were run on such bauxite ores. The diasporite shows good flotability and considerable difference in flotability from kaolinite; it is also easy to separate it from quartz. Results of flotation tests on bauxite ores ground to 95-97%-200 mesh, using oxidized paraffin wax soap and tall oil as collector and sodium hexametaphosphate or ammonium humate as depressant, are given in the following table

Table — Flotation Results on Samples of Bauxite Ores

Sample	Al ₂ O ₃ , %			SiO ₂ , %			Al:Si		Al ₂ O ₃ Recovery in Concentrate
	ore	conc.	tail.	ore	conc.	tail.	ore	conc.	
Xiaoyi, Shanxi	66.04	76.25	55.96	13.07	7.85	23.17	5.10	8.41	71.12
Xiaoguan, Henan	64.27	71.34	50.23	13.97	7.73	26.35	4.60	9.23	73.81
Pingguo, Guangxi	52.33	56.13	34.40	9.06	6.13	22.81	5.78	9.13	88.50
Shanrong, Zhejiang	66.80	70.49	55.80	12.23	8.71	23.10	5.47	8.09	79.61

Figures in the above table demonstrate the possibility of processing bauxite ores, since the Al/Si ratio can be enhanced from about 5:1 to 8 or 9:1, and the recovery of Al₂O₃ can reach 71-88%. However, due to the presence of large quantity of kaolinite, high alumina tailings result. Therefore, comprehensive utilization of such tailings should be put on the agenda. Studies have shown that such tailings may go into making refractory material, building material, cement ingredient, bricks, etc. The additional problem is the difficulty with concentrate dewatering, caused by fine grinding. As a result, processing of bauxite ores is now still in a stage of further investigation and comparison.