Influence of important factors in industrial debugging of desilication of diaspore by flotation

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Abstract. The beneficiation of diaspore with a low ratio of A/S can be realized by desilication using gradient flotation. The concentrate water can be reused in the flotation process after treating with BXF flocculant. Industrial tests of six months of continuous operation were conducted, and the results show that the concentrate with Al₂O₃ recovery of 83.04% is obtained, and the ratio of A/S increases from 4.46% in the raw ore to 9.57% in the concentrate. Moreover, the comprehensive reuse rate of the waste-water is 75%.

1. Introduction

The bauxite ore in China is mainly diaspore-kaolinite deposited ore with the characteristics of high content of Al and Si, low ratio of A/S, and complex composition. At present, the bauxite ore is used for alumina production mainly through Bayer process, which requires the A/S ratio of the bauxite ore to reach above 8. Based on this situation, a new beneficiation technology of fine grinding--flotation desilicication for the bauxite ore with low A/S ratio has been developed in China, and the obtained concentrate can be used to economically produce Al₂O₃ [1-5]. In 2003, the first dressing plant of bauxite ore in the world was built in Jiaozuo, Henan province, confirming the reliability of this technology by practice [6,7]. In addition, great progress have been made in theoretical researches through these years of hard work [8-11].

The bauxite reserve in Pingdingshan is very abundant, however, it is unfavorable to use the existing Bayer process due to the low A/S ratio. Therefore, the technology of flotation desilicication was investigated through bench-scale experiments and pilot-scale experiments, and good flotation results were obtained. According to the properties of this bauxite ore and flotation results, a dressing plant with the processing capacity of 1000 t/d was built, and industrial experiments are indispensable in order to obtain a consistent flowsheet and qualified concentrates. Unlike bench-scale experiments, many other factors should be considered in industrial practice, especially the water. In view of the environmental protection and water cost saving, the treatment and reused of the concentrate water in flotation process were designed. In this paper, the specific technologies of flotation and waste water treatment are discussed, and the setting of parameters in every process was introduced in detail, finally the stable process and concentrate products are obtained.
2. Materials and methods

2.1. Materials
Results of multielement analysis and mineral composition of the raw ore are shown in table 1 and table 2. The grade of Al$_2$O$_3$ is 55.81% with a A/S ratio of 4.67%, the valuable minerals is diaspore, and the gangue minerals are illite, montmorillonite, pyrophyllite and kaolinite, followed by a small number of rutile and quartz.

| Table 1. The multielement analysis results of the raw ore. |
|-------------|-------------|-------------|------------|-------------|-------------|-------------|------------|-------------|
| Composition | Al$_2$O$_3$ | SiO$_2$ | A/S | TiO$_2$ | Fe$_2$O$_3$ | K$_2$O | Na$_2$O | CaO | MgO | H$_2$O |
| Content/% | 55.81 | 11.95 | 4.67 | 2.53 | 12.84 | 1.98 | 0.089 | 0.66 | 0.11 | 11.84 |

| Table 2. The mineral composition of the raw ore. |
|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Minerals | Diaspore | Kaolinite | Illite | Montmorillonite | Pyrophyllite | Anatase | Quartz | Goethite |
| Content/% | 60.9 | 3.9 | 11.3 | 8.8 | 3.7 | 1.8 | 1.0 | 8.6 |

*Note: The samples were purchased from the surrounding mining areas, after crushing and mixing, the samples of -3 mm size were obtained and used in the following grinding and flotation process.

2.2. Reagents and equipment
The reagents used in this study are regulator Na$_2$CO$_3$, depressant PL (the mixture of metaphosphate, industrial pure), and the mixed collector of fatty acid and chelating agent.

The main equipments used in this study include the ball mill, the high weir spiral classifier, hydrocyclone, flotation machine, thickener and filter separation.

2.3. Technological process
According to condition tests, laboratory closed-circuit tests and pilot continuous tests, the suitable reagent system and the process with a flowsheet of one fine grinding-three roughing-one scavenging-two cleaning was determined and designed, shown in Figure 1. Based on these results, the industrial experiments were carried out in order to obtain stable process and qualified concentrate products. The targets of industrial tests are as follows: the A/S ratio should be increase from 4.0-4.5 of the raw ore to 7.5-8.0 of the concentrate, and the Al$_2$O$_3$ recovery of the concentrate is 80%.

![Figure 1. The process used in the laboratory experiments.](image-url)
3. Results and discussion

3.1. Grinding tests
The small-scale tests results showed that the suitable grinding fineness was 90% - 0.074 mm. For the properties of low grade bauxite ore, two stage continuous grinding was adopted in industry. In the first stage grinding and classification operation, the Φ 2700×3600 grate ball mill and Φ 2000 high weir spiral classifier were used, while the Φ 2700×3600 overflow ball mill and Φ 350 hydrocyclone were used in the second stage grinding and classification operation. Through parameter adjustment, the grinding fineness was finally determined as 88%-90% - 0.074mm in industrial tests, shown in Figure 2.

![Figure 2](image_url)  
Figure 2. The grinding process in industry practice of diaspore.

3.2. Flotation tests
Unlike the bench-scale experiments, the industrial process is continuous, and the throughput is up to 1000 t/d. Therefore, in order to ensure the connectivity of the process, the flotation process parameters should be satisfied gradient matching.

First, the pulp concentration should be matched. In the first stage of roughing, the middlings were not recycled to maintain the high pulp concentration and the flotation efficiency. The pulp concentrations in the following operations were adjusted to a reasonable decrease, the specific values are listed in table 3.

| Operation       | Roughing 1 | Roughing 2 | Roughing 3 | Scavenging | Cleaning 1 | Cleaning 2 |
|-----------------|------------|------------|------------|------------|------------|------------|
| Pulp concentration/% | 36         | 20         | 15         | 10         | 20         | 22         |

Table 3. The pulp concentration of every flotation operation.

Second, the speed of flotation machine should be matched. Researches have shown that the turbulence intensity of tank pulp has great influence on flotation process. When the speed of flotation machine is high, the fine mineral particles are easy to float, but the coarse particles are easy to float with a low speed[12,13]. In order to optimize the flotation process, flotation machines used in roughing and scavenging operations use frequency control equipment to control the speed. Generally, the frequency of the first tank in every operation is adjusted to 45~50 Hz (90%~100% speed rate) to guarantee the smooth process and good floatability of fine mineral particles, and the frequencies of other tanks were adjusted to 30~35 Hz (60%~70% speed rate) to well float the coarse particles.

Third, the concentrations of reagents should be matched. The first stage of roughing is very important for the high recovery of diaspore, since the content of diaspore greatly decreases with flotation proceeding, the concentrations of reagents should be properly decreased in the following operations, shown in Figure 1. In addition, the reused waste water contains a certain concentration of reagents, resulting in the decrease of the added concentration of reagents.
3.3. The treatment and reuse of waste water

In China, the comprehensive discharge of waste water and the reuse rate of industrial water have the strict standard and requirements to avoid the harm to natural environment. This mining area belongs to the water shortage area in central China, the amount of water supplied from the outside is limited every day, and the price is relatively higher. Therefore, the reuse of waste water is the hard target at the beginning of project design. Because the yield of concentrate reaches up to 74%, the treatment and reuse of the waste water produced by the concentration and filtration of the concentrate are mainly designed, shown in Figure 3.

![Figure 3. The process for the treatment of the waste water to be reused.](image)

In the concentration operation of the concentrate, a suitable flocculant is required to increase the sedimentation rate. Since a small amount of flocculant can remain in the waste water, with the prolonging of the cycle time of the waste water, the concentration of the flocculant gradually increases, it will inhibit the flotation of aluminium minerals. In addition, due to the poor selectivity of flocculation, the gangue minerals and diaspore will be flocculated and then float together, resulting in the decrease of A/S ratio [14,15]. So the selection of flocculant and its dosage are very important. Therefore, the effect of flocculant on flotation results with the reused water was investigated through a large number of condition tests, and the results show that BXF flocculant with a dosage of 70 g/t (dried concentrate) is effective in the treatment of the waste water which is then reused in flotation process. BXF flocculant mainly consist of the modified anionic polyacrylamide, which can aggregate the fine particles and accelerate the settlement through adsorption bridging and electroneutralization, thus increasing the speed of solid-liquid separation. When the flocculant is added in the water, it is first fully dispersed and reacted with particles, then the flocculation occurs and the flocs will gradually grow with the increase of the concentration of flocculant, shown in Figure 4 [16,17].

In industrial tests, the overflow water and filtered water can be completely reused. The results with and without the reused water are shown in table 4, it is clearly shown that the reuse of the treated waste water of concentrate has little influence on the beneficiation index, and a diaspore concentrate with 64.79% Al₂O₃ and a A/S ratio of 9.57 is obtained with a Al₂O₃ recovery of 83.04%, well realizing the beneficiation of diaspore and the reuse of waste water.
Figure 4. The process of flocculation.

Table 4. Results of industrial tests with and without the reuse of waster water.

| Conditions          | Products  | Yield/% | Grade/% | Recovery/% |
|---------------------|-----------|---------|---------|------------|
|                     |           |         | Al₂O₃   | SiO₂       | A/S        | Al₂O₃     |
| Without reused water| Concentrate| 72.33   | 65.37   | 6.61       | 9.89       | 82.54     |
|                     | Tailings  | 27.67   | 36.14   | 30.63      | 1.18       | 17.46     |
|                     | The raw ore| 100.00 | 57.28   | 13.26      | 4.32       | 100.00    |
| With reused water   | Concentrate| 74.09   | 64.79   | 6.77       | 9.57       | 83.04     |
|                     | Tailings  | 25.91   | 38.03   | 29.71      | 1.28       | 16.96     |
|                     | The raw ore| 100.00 | 57.96   | 13.00      | 4.46       | 100.00    |

For the waste water in tailings, due to the high content of slimes, silicon suspended solids and high pH value, the direct reuse can affect the flotation results of desilicication. At present, the tailings are stored in tailing pond, and the clarified water was reused in the production of aluminium oxide. The total reused rate of the waste water is 75%.

4. Conclusions

(1) The industrial experiments of flotation desilicication of a bauxite ore in Henan province were conducted to obtain a connected process and the qualified concentrate products, the reuse of the waste water after treatment was also investigated to avoid the hard to environment and decrease the water consumption, and the main results are as follows.

(2) For the raw ore with a low A/S ratio of 4.67%, it is necessary to realize the beneficiation of diasporie for the further production of aluminium oxide through flotation.

(3) The waste water of the concentrate can be reused in flotation process after BXF treatment, and the clarified water of the tailing is used in the production of aluminium oxide, the total reused rate of the waste water is 75%.

(4) A connected process is obtained after a half yeas of continuous operation, and a diasporie concentrate containing 64.79% Al₂O₃ is obtained with a high A/S ratio of 9.57, meeting the requirements of the further production process of aluminium oxide.

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