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Beneficiation of low-grade diasporic bauxite with hydrocyclone

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Abstract: Low-grade diasporic bauxite was treated with hydrocyclone of small cone-angle. The effects of apex diameter, feed pressure and feed concentration on separation indexes were tested, and then the separation process was discussed by hydrokinetics tentatively. The results show that the increase of apex diameter changes the spacial locality of the envelope of zero vertical velocity, resulting in decrease of the ratio of Al_2O_3/SiO_2 in overflow and increase of the recovery of Al_2O_3 in underflow, while feed pressure and feed concentration have no remarkable effect on the spacial locality of the envelope of zero vertical velocity, however, the separation indexes are improved by the increase of feed pressure, but are worsened by the increase of feed concentration.

Key words: low-grade diasporic bauxite; hydrocyclone; envelope of zero vertical velocity; flow ratio; selectivity

1 Introduction

Bauxite is the main raw material to produce alumina, whose mineralogical characteristic and processing technology affect its general utilization directly. Diasporic bauxite is the major kind in China, characterized by high-aluminum, high-silicon, low ratio of Al_2O_3 to SiO_2[1], complicated mineral compositions [2] and finely disseminated associations of aluminous minerals and silicate minerals[3−4]. Presently, to produce aluminum oxide in China is usually not Bayer's process but sintering process and a combined process of sintering and Bayer. Bayer's process has remarkable economic benefit and little environmental pollution, but sintering process and the combined process are comparatively energyintensive and environmentally less friendly, incurring high alumina production cost[5].

Studies on reducing the ratio of A/S (ab. of Al_2O_3 to SiO_2) by physical separation methods become further thorough, since Mineral Processing-Bayer's process, a new technological concept, has been brought forward, especially flotation has gained great achievement. The first Chinese bauxite plant with a scale of 3 000 t annually has been built in Henan Zhongzhou Alumina Factory in 2003 [6−7], where direct flotation was adopted. For reverse flotation, which takes more technological advantage, a great deal of positive and effective researches have been made, and have also gained many theoretical fruits in such aspects of selective depressing of diaspore[8−9], strengthened collecting of aluminosilicate[10−13] and selective dispersing of slime[14−15]. However, the ore has to be ground to 80%−90% below 0.074 mm in size so as to satisfy flotation process[16], which will bring a series of technological problems such as high energy cost of grinding, a mass of subsequent slime and difficult dewatering of products. How to solve these problems makes researchers try to seek amounts of separation methods and technologies. In consideration of the difference of diaspore and gangue minerals in size and density, hydrocyclone was used to study and discuss their separation behavior in this study.

2 Experimental

2.1 Materials

The samples for tests were taken from Henan

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Changcheng Alumina Factory. They were crushed to size less than 3 mm by jaw crusher for grinding test, and some of them were ground to size less than 0.074 mm for chemical analysis. The result is listed in Table 1.

It can be seen from mineral compositions by XRD analysis given in Table 2 that, the aluminous minerals in the ore include much diaspore, little boehmite and gibbsite, and the silicate gangue minerals are constituted by kaolinite, illite chlorite and quartz.

2.2 Methods and apparatus

Grinding, particle size analysis and hydrocyclone separation were carried out respectively, according to the flow sheet shown in Fig.1. The schematic diagram of experiment apparatus of hydrocyclone separation is given in Fig.2.

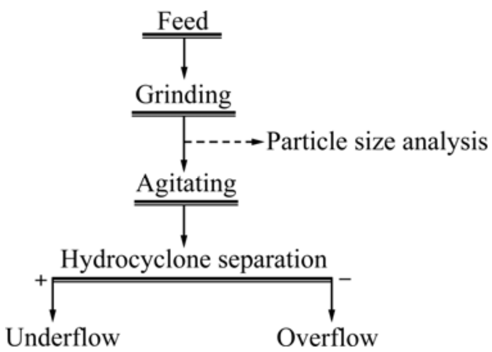

Fig.1 Test flow sheet

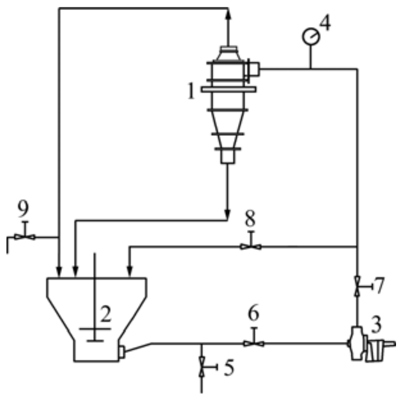

Fig.2 Schematic diagram of experiment apparatus of hydrocyclone separation: 1 Hydrocyclone; 2 Agitator; 3 Sand-pump; 4 Pressure gauge; 5 Letting valve; 6 Feed valve; 7 Discharging valve; 8 Feed sampling valve; 9 Overflow sampling valve

3 Results and discussion

3.1 Grinding

Ball milling was carried out with medium of diameters of 30, 20, 10 mm in fraction of 54%, 36% and 10%, respectively. Grinding product of 61.90% $<$0.074 mm can be prepared by controlling grinding time. Its size components and chemical analysis are listed in Table 3.

It can be seen from Table 3 that the grade of each size product differs obviously, that is, with the decreasing

Table 1 Chemical compositions of low-grade diasporic bauxite (mass fraction, %)

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	CaO	K	Na	Mg	S
59.80	13.62	5.37	3.12	1.37	1.64	0.19	0.26	0.079

Table 2 Mineral compositions of low-grade diasporic bauxite (mass fraction, %)

Diaspore	Boehmite, gibbsite	Pyrite	Hematite, goethite	Kaolinite, illite
59.47	6.57	0.22	0.10	7.89
Anatase, rutile, titanite	Clorite	Quartz	Calcite	Others
1.53	9.00	5.56	2.20	7.64

Table 3 Size components and chemical analysis of grinding products

Size component		Grinding product		
Size/μm	Fraction/%	$w(Al_2O_3)$/%	$w(SiO_2)$/%	A/S
$>$100	26.57	65.56	10.84	6.05
75−100	11.52	63.43	11.64	5.45
37−75	27.66	60.46	12.29	4.92
19−37	12.25	58.69	14.14	4.15
10−19	15.81	57.08	15.99	3.57
5−10	1.64	47.73	23.84	2.00
$<$5	4.55	43.86	29.95	1.46

of size, the grade of Al_2O_3 decreases and the grade of SiO_2 increases gradually. Therefore, it can be concluded that selective grinding between aluminous minerals and silicate minerals can be achieved as a result that they concentrate in larger sizes and finer sizes respectively. Thus this product by coarse grinding is prone to be separated by density difference effectively using hydrocyclone, in which classification according to size difference is in progress as well.

3.2 Hydrocyclone separation

A hydrocyclone with diameter of 75 mm, cone-angle of 15° was used to investigate the effects of apex diameter, feed pressure and feed concentration on separation indexes.

3.2.1 Effect of apex diameter on separation indexes

Keeping the diameter of overflow pipe 17 mm, feed pressure 0.4 MPa, and feed concentration 10%, the effect of apex diameter on separation indexes was investigated. The result is shown in Fig.3.

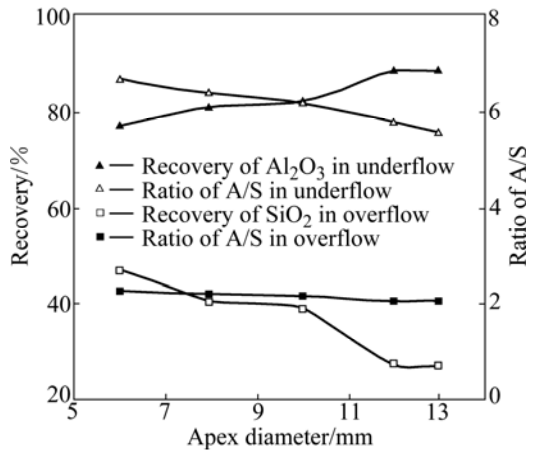

Fig.3 Effect of apex diameter on separation indexes

It can be seen in Fig.3 that with the enlarging of apex diameter the ratio of A/S in overflow decreases, but it increases a little while the apex diameter is 13 mm. Similarly the ratio of A/S in underflow decreases with the enlarging of apex diameter. The recovery of Al_2O_3 in underflow increases with the enlarging of apex diameter and reaches a maximum 88.05% at apex diameter of 12 mm, where the inflexion appears as the same of the curve of ratio of A/S in overflow. However, the recovery of SiO_2 in overflow (namely removal rate of silicate) decreases with the apex diameter enlarging.

It can be deduced by the above facts that low-grade slime is carried upwards from the overflow pipe decreasingly with the enlarging of apex diameter, while it is carried downward from the apex increasingly, as a result the ratio of A/S decreases in overflow and the recovery of Al_2O_3 increases in underflow. The inflexion that appears at 12 mm is a bourn of good separation selectivity. Hydrocyclone separation has good selectivity while the apex diameter is not larger than 12 mm. Once it exceeds this value, the separation selectivity breaks up, which can be proved by the fact that the ratio of A/S in underflow decreases at 13 mm.

It was once discussed with hydrokinetics that there exists an envelope of zero vertical velocity in hydrocyclone, whose spacial locality controls the classification size[17], and the enlarging of apex diameter can constringe it to the vertical axis of hydrocyclone[18], hence the upward inner flow, which will become overflow, reduces correspondingly. Actually, the flow ratio[19] in overflow decreases with the enlarging of apex diameter just as shown in Table 4. We can also see the trend of solid ratio in overflow accords with that of flow ratio. Therefore the solid ratio in overflow can be well controlled by flow ratio provided that other test conditions are fixed. In additional, when the apex diameter increases from 12 mm to 13 mm, the solid ratio does not decrease with the decrease of flow ratio, which may be interpreted by the fact that the time of relative motion between solid particles and flow becomes longer.

Table 4 Change of flow ratio and solid ratio in overflow with apex diameter

Apex diameter/mm	Flow ratio/%	Solid ratio/%
6	92.34	27.54
8	85.12	23.86
10	77.64	22.19
12	62.20	15.02
13	58.10	15.07

3.2.2 Effect of feed pressure on separation indexes

Keeping the diameter of overflow pipe 17mm, apex diameter 8mm, and feed concentration 10%, the effect of feed pressure on separation indexes was investigated. The result is shown in Fig.4.

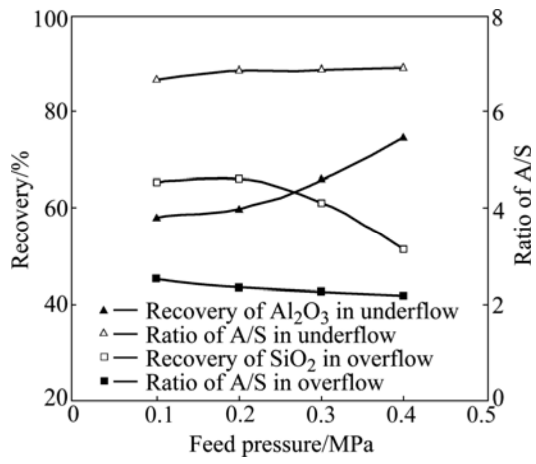

Fig.4 Effect of feed pressure on separation indexes

From Fig.4, it can be seen that the ratio of A/S in overflow decreases gradually with the increase of feed pressure, while that in underflow increases. The recovery of Al_2O_3 in underflow increases with the increase of feed pressure and the recovery of SiO_2 in overflow decreases. Based on the facts above, the separation selectivity in hydrocyclone becomes better with the increase of feed pressure. When it is 0.4 MPa, the four indexes mentioned above are 2.18, 6.88, 74.75% and 51.66% respectively.

The distribution ratios of flow and solid are shown in Table 5. It can be judged by the unobvious trend of flow ratio that the increase of feed pressure has no remarkable effect on the spacial locality of the envelope of zero vertical velocity. The solid ratio and concentration in overflow decrease with the increase of feed pressure, and the ratio of A/S decreases similarly. This occurs without the decrease of the ratio of A/S in underflow. So it can be concluded that hydrocyclone separation which works depending on density difference becomes more remarkable with the increase of feed pressure.

Table 5 Change of flow ratio and solid ratio in overflow with feed pressure

Feed pressure/MPa	Flow ratio/%	Solid ratio/%	Overflow concentration/%
0.1	91.77	47.14	5.1
0.2	91.74	46.17	5.0
0.3	89.89	40.27	4.8
0.4	86.27	30.68	4.7

3.2.3 Effect of feed concentration on separation indexes

Keeping the diameter of overflow pipe 17 mm, apex diameter 6 mm, and feed pressure 0.4 MPa, the effect of feed concentration on separation indexes was investigated. The result is shown in Fig.5.

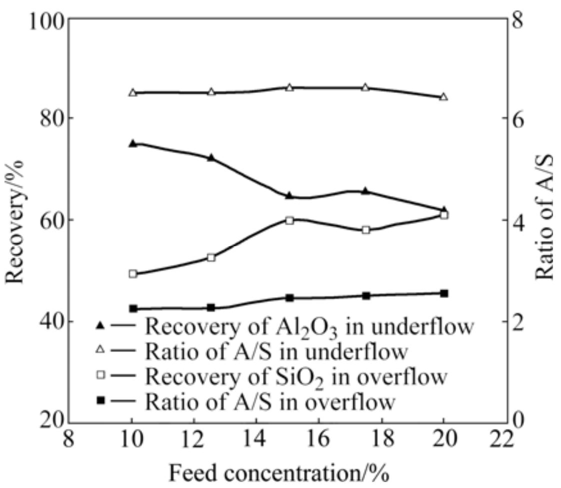

Fig.5 Effect of feed concentration on separation indexes

From Fig.5 we can see that with the increase of feed concentration the ratio of A/S in overflow is increased from 2.27 to 2.53, while the increase of the ratio of A/S in underflow isn't obvious. The recovery of Al_2O_3 in underflow decreases remarkably with the increase of feed concentration, and the recovery of SiO_2 in overflow increases meanwhile. Therefore, the increase of feed concentration is disadvantageous to the process of hydrocyclone separation, which can be interpreted by the increase of pulp viscosity[20].

The change of distribution ratios of flow and solid with feed concentration are shown in Table 6. We can find that the concentrations of overflow and underflow increase with the concentration of feed increasing, and the concentration of overflow increases more rapidly than that of underflow, which results in the increase of solid ratio in overflow. Additionally, the flow ratio does not change obviously with the increase of feed concentration. It could be inferred that the change of feed concentration has almost no effect on the special locality of the envelope of zero vertical velocity.

Table 6 Change of flow ratio and solid ratio with feed concentration

Feed concentration/%	Overflow concentration/%	Underflow concentration/%	Flow ratio/%	Solid ratio/%
10.0	3.8	68.7	93.22	30.10
12.5	4.7	72.7	93.47	33.15
15.0	7.3	77.0	93.42	40.89
17.5	8.3	74.2	91.66	39.73
20.0	9.8	76.3	91.81	43.17

4 Conclusions

1) The trend of flow ratio is a good measure to judge whether the spacial locality of the envelope of zero vertical velocity changes with experimental factors or not. The enlarging of apex diameter of hydrocyclone can change it according to the measurement, and so has effect on the separation indexes. For apex diameter, overflow with low ratio of A/S and underflow with high recovery of Al_2O_3 can be processed by controlling flow ratio.

2) Feed pressure has almost no effect on the special locality of the envelope of zero vertical velocity, but the increase of it can intensify the process of separation which works according to density difference. Overflow with low ratio of A/S and underflow with high ratio of A/S can be processed at the same time, even with a high recovery of Al_2O_3 in underflow.

3) Feed concentration also has little effect on the special locality of the envelope of zero vertical velocity, and its increase is disadvantageous to the hydrocyclone

separation process because the pulp viscosity increases correspondingly and makes the separation indexes worsen, as a result, the ratio of A/S in overflow increases and the recovery of Al_2O_3 in underflow decrease, which means more losing of Al_2O_3 in overflow.

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