BX04 - Research on Comprehensive Utilization of Bauxite Resources

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Abstract

A certain gibbsite-type bauxite of overseas has complex mineral structure, and the mosaic size of gibbsite minerals in it is quite fine. The Al_2O_3 content in the ore is 54.37 %, SiO_2 content is 12.80 %, and the raw ore A/S is 4.24. The ore washing test was carried out for this type of bauxite. After the raw ore was washed, the washing concentrate A/S reached 5.79, and the washing tailings A/S was 2.06. The reverse flotation desilication experiment was continued for the washing tailings, and the influence of the flotation slurry PH, flotation reagents and separation process on the desilication effect of the reverse flotation was investigated. Finally, under the technological process of "washing classification-reverse flotation desilication", by optimizing the process parameters, the test index of final concentrate A/S 5.83, final concentrate yield 87.08 %, and alumina recovery 91.46 % was obtained, which realized the efficient use of this type of bauxite resource.

Keywords: Gibbsite-type bauxite, ore washing and classification, reverse flotation desilication.

1. Introduction

With the rapid development of China's alumina industry, the availability of high-grade bauxite resources is increasingly scarce. At present, the raw ore A/S of most domestic alumina enterprises is below (4.5), resulting in a series of problems such as increased production cost of alumina and increased amount of red mud [1, 2]. In order to solve the contradiction between the rapid growth of domestic alumina demand and the relative shortage of bauxite resources, Chalco is importing gibbsitic bauxites from overseas to produce alumina. The production process is mainly based on the low-temperature Bayer method [3]. The production of alumina by this method implies that bauxite must be dissolved in caustic soda, and the alkali consumption is one of the most important factors affecting the production cost of this process [4]. With the increasing of the reactive silica mineral in the imported ore in recent years, the alkali consumption of low temperature Bayer method also increases. Kaolinite and quartz are the main effective silica mineral in the bauxite. There is a linear correlation between the content of silica minerals and the alkali consumption. In industrial practice, the correlation is as follows: for each additional 1kg of silica minerals in the ore, the alkali consumption increases for 1 kg [5]. Therefore, if silica minerals can be fully or partially removed from the bauxite, the content of reactive silica in the ore can be reduced, which will be of great significance to the production cost of the low-temperature Bayer method.

The processing technology of monohydrate bauxite has been gradually mature after nearly 50 years of development [6]. Chalco has built mineral processing plants in Shandong and Henan province and put them into production successfully. However, there are few researches on the beneficiation technology of bauxite in China. In this investigation, desilication tests are carried out on gibbsite-type bauxite, which provides ideas for the effective utilization of this type bauxite and for reducing the production cost of the low temperature Bayer method.

2. Description of Sample

2.1 Chemical Multi-Element Analysis

Chemical multi-element analysis was carried out on the raw ore to examine the main element content of the ore, and the analysis results were shown in Table 1：

Table 1. Chemical multi-element analysis results of ore samples (%).

Element	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	K_2O	Na_2O	CaO	MgO
Content	54.37	12.80	7.25	2.94	0.019	0.049	0.059	0.068

From the analysis results in Table 1, the content of Al_2O_3, SiO_2, Fe_2O_3, and TiO_2 in the ore is 54.37 %, 12.80 %, 7.25 %, and 2.94 %, and the A/S of raw ore is 4.24. After being processed by a certain beneficiation process, the concentrate is suitable for producing alumina by Bayer process.

2.2 Mineral Composition Analysis

The X-ray diffraction analysis results of the ore sample are shown in Fig. 1, mineral composition results based on chemical analysis and X-ray diffraction analysis are shown in Table 2.

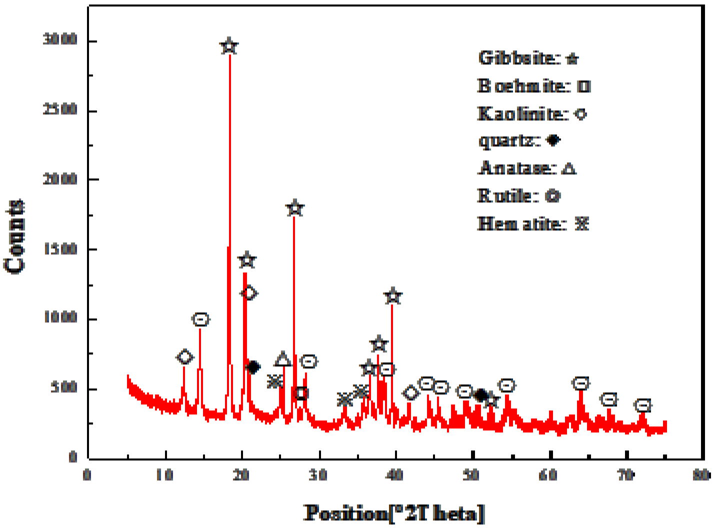

Figure 1. XRD pattern of raw ore.

Table 2. Mineral composition analysis results of ore samples (%)*.

Element	Gibbsite	Boehmite	Kaolinite	Quartz	Hematite	Rutile/Anatase
Content	53.30	18.60	9.20	8.50	7.20	2.90

*: XRD semi-quantitative analysis results

It can be seen from the XRD analysis results, the main aluminum-bearing minerals in the ore sample are gibbsite and boehmite, the main silicon-bearing minerals are kaolinite and quartz, and the others are hematite and a small amount of anatase and rutile.

2.3 Process Mineralogy Analysis

According to the particle shape, the ore sample of this experiment can be divided into unclosed pisolite, closed pisolite, irregular pisolite and ordinary pisolite, among which ordinary pisolite is mostly.

Using polarized light microscope combined with XRD diffraction, electron microscopy scanning and chemical analysis methods, a preliminary process mineralogy study was carried out on the particle morphology and ore sample of four kinds of pisolite. The results show that the main useful minerals in the ore are gibbsite and boehmite; gangue minerals are mainly kaolinite and quartz; iron minerals are hematite; titanium minerals are mainly anatase and rutile. The main microstructure of the ore is crystalline aggregate, microparticle structure, oolitic structure, vein structure, dissemination structure, etc.

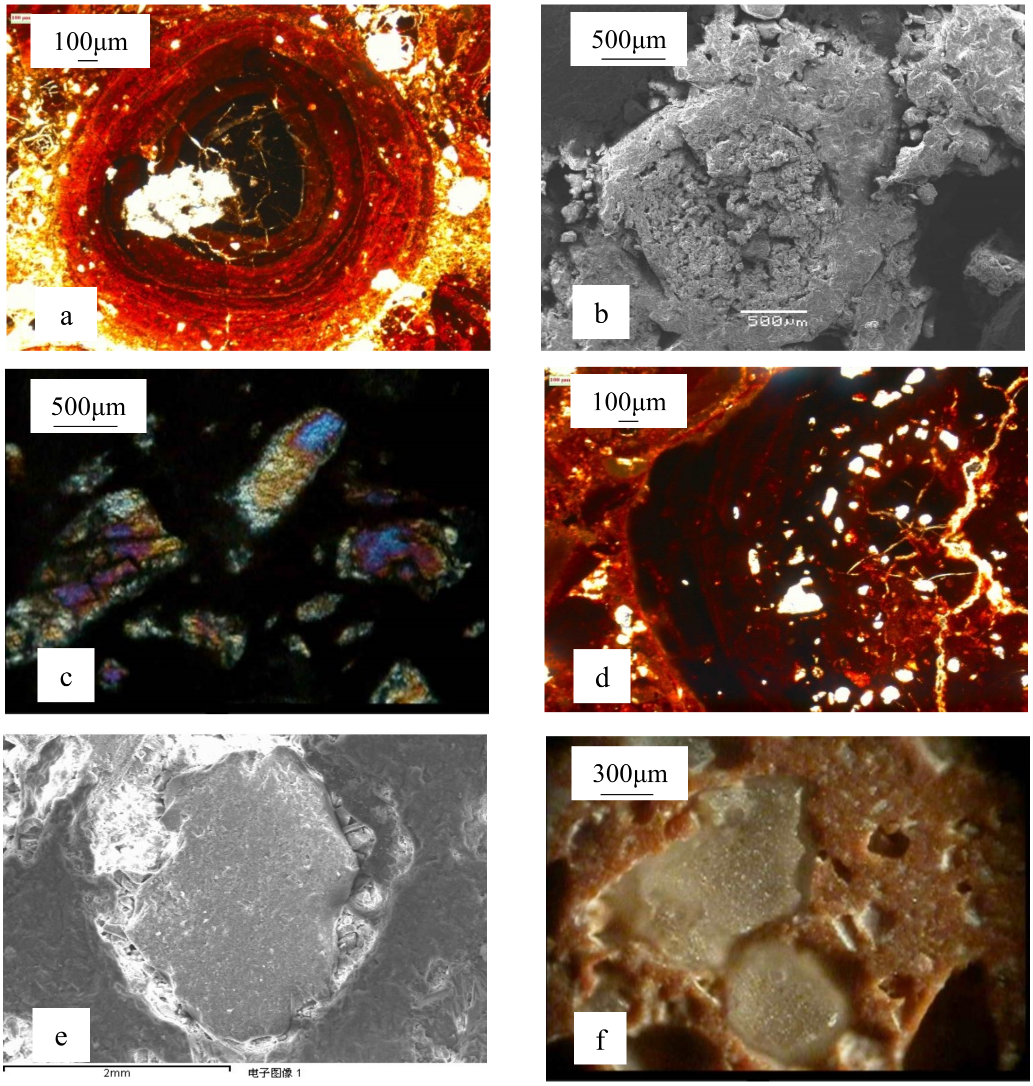

Figure 2. XRD pattern of raw ore.
a: oolitic structure of bauxite (orthogonal polarization); b: gibbsite is distributed in the core of the ore in an oolitic structure (SEM); c: gibbsite and boehmite are crossed together (orthogonal polarization); d: the gibbsite has a vein structure (single polarized light); e: granular quartz (SEM); f: granular quartz (reflected light)

It can be seen from Figure 2 that:

1. The gibbsite mainly exists in the following inlaid characteristics in the ore:
   (1) The gibbsite exists in the form of oolitic granules, the core of which is iron-impregnated gibbsite, and iron crusts are often seen in the outer layer. The gibbsite oolitic particles generally have a size of 0.05 to 3.0 mm (Figure.2 (a) and (b)), and the thickness of the iron skin is generally 0.1 to 0.15 mm.
   (2) The contact relationship between gibbsite and boehmite is often intertwined. It can be seen under the microscope that gibbsite and boehmite intersect together to form a rich aggregate of useful minerals. The size of diaspore is usually 0.02mm ~ 0.3mm – Figure 2 (c).
   (3) The gibbsite is filled in the rock in the form of veins, and the pulse width is generally 0.01 to 0.05mm - Figure.2 (d).

2. Quartz minerals
Low positive protrusion, no cleavage, colorless and transparent, complete crystal form, interference color is generally grade I off-white, hexagonal column and trigonal bipyramid or irregular granular, angular, sub-angular, smooth surface, crystal size is 0.005 ~ 3mm (Figure.2 (e), (f)).

3. Results and Discussion

3.1 Classification Test of Raw Ore

A screening test study was carried out to examine the distribution of minerals in each particle grade. The standard sieves of 3 mm, 1.18 mm, 0.5 mm, and 0.3 mm were used to screen the raw ore. The test results are shown in Table 3.

Table 3. Sieving test results.

Granularity (mm)	Yield (%)	Al_2O_3 (%)	SiO_2 (%)	Fe_2O_3 (%)	A/S
Raw ore	100.00	52.93	12.80	7.89	4.14
+3	59.33	54.96	9.83	8.72	5.59
-3+1.18	15.58	55.27	8.27	10.34	6.68
-1.18+0.5	2.95	49.74	17.81	6.58	2.79
-0.5	22.14	46.29	23.28	4.11	1.99

From Table 3, after the raw ore is washed, the A/S at the +1.18mm particle size is higher than the A/S at the -1.18mm particle size. The +1.18mm particle size yield is 74.91 %, and the A/S is 5.79, which is suitable for alumina produced by the Bayer process. The -1.18mm particle size yield is 25.09 %, Al_2O_3 content is 46.70 %, A/S is 2.06. The high A/S of tailings was not conducive to the comprehensive utilization of resources. Therefore, the subsequent desilication experiment of tailings flotation was conducted to improve the comprehensive recovery rate of alumina.

3.2 Reverse Flotation Desilication Test of Wash Tailings

3.2.1 Property Analysis of Wash Tailings

Multi-element analysis and physical-phase analysis were carried out for the wash tailings, and the analysis results were shown in Table 4:

Table 4. Multi-element analysis of wash tailings (%).

Element	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	K_2O	Na_2O	CaO	MgO
Content	46.70	22.64	4.40	3.20	0.026	0.038	0.094	0.088

Table 5. Phase analysis of wash tailings (%).

Element	Gibbsite	Boehmite	Kaolinite	Quartz	Hematite	Rutile	Anatase
Content	40.10	19.70	7.70	20.00	5.20	2.40	0.80

According to the data in Table 4 and Table 5, the main silica mineral in tailings is quartz mineral, so the reverse flotation desilication experiment can significantly improve the ore quality.

3.2.2 Effect of Pulp pH on Reverse Flotation Desilication

In order to investigate the influence of pulp pH on flotation desilication index, the pulp pH value test was conducted. The test process is shown in Figure 3, and the results are shown in Table 6.

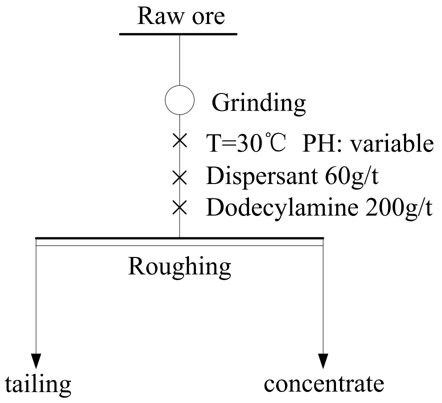

Figure 3. Test process of the effect of pulp pH on flotation index.

Table 6. Test results of the effect of pulp pH on flotation index.

pH	Product	Yield %	Al_2O_3 %	SiO_2 %	A/S	Recovery of Al_2O_3 %
4	concentrate	41.68	59.89	15.44	3.88	53.47
	tailings	58.32	37.24	27.92	1.33	46.53
	total	100.00	46.68	22.72	2.05	100.00
5	concentrate	31.42	59.23	8.72	6.79	39.85
	tailings	68.58	40.96	29.15	1.41	60.15
	total	100.00	46.70	22.73	2.05	100.00
6	concentrate	29.67	61.48	11.39	5.40	39.07
	tailings	70.33	40.45	27.53	1.47	60.93
	total	100.00	46.69	22.74	2.05	100.00
7	concentrate	30.86	60.48	14.63	4.13	39.97
	tailings	69.14	40.55	26.36	1.54	60.03
	total	100.00	46.70	22.74	2.05	100.00
8	concentrate	40.68	57.43	13.98	4.11	50.05
	tailings	59.32	39.31	28.73	1.37	49.95
	total	100.00	46.68	22.73	2.05	100.00
9	concentrate	37.24	58.41	12.35	4.73	46.56
	tailings	62.76	39.77	28.86	1.38	53.44
	total	100.00	46.71	22.71	2.06	100.00

pH	Product	Yield %	Al_2O_3 %	SiO_2 %	A/S	Recovery of Al_2O_3 %
10	concentrate	32.68	61.26	9.11	6.72	42.87
	tailings	67.32	39.63	29.34	1.35	57.13
	total	100.00	46.70	22.73	2.05	100.00
11	concentrate	33.47	60.48	9.60	6.30	43.36
	tailings	66.53	39.75	29.32	1.36	56.64
	total	100.00	46.69	22.72	2.06	100.00

From table 6 can be seen that when pH=5, 10, 11, the A/S of the concentrate is higher than other pH values. However, to increase comprehensive recovery rate of Al_2O_3 in the concentrate, the pH of the pulp 10 shall be accepted with the recovery rate of Al_2O_3 is 42.87 %. Therefore, compared with other pH conditions, the choice of slurry pH=10 can obtain relatively large economic benefits.

3.2.3 Effect of Collector Type on Reverse Flotation Desilication

In order to investigate the influence of collector types on flotation desilication effect, an experimental study was carried out to select the type of flotation desilication collector. The experimental process was shown in Figure.4, and the experimental results were shown in Table 7.

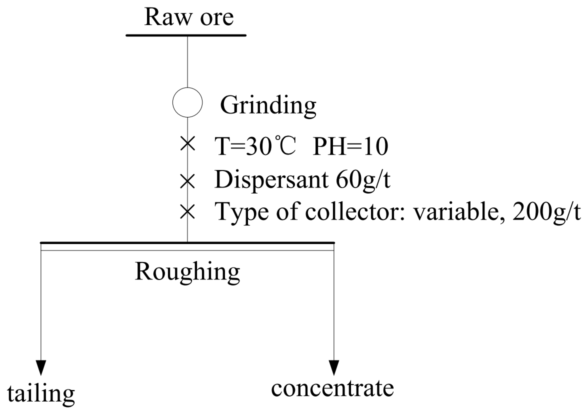

Figure 4. Test process for selection of collector types.

Table 7. Test result for selection of collector types.

Collector types	Product	Yield %	Al_2O_3 %	SiO_2 %	A/S	Recovery rate of Al_2O_3 %
Dodecylamine	concentrate	32.68	61.26	9.11	6.72	42.87
	tailings	67.32	39.63	29.34	1.35	57.13
	total	100.00	46.70	22.73	2.05	100.00
Tetradecylamine	concentrate	33.03	60.58	9.24	6.56	42.86
	tailings	66.97	39.84	29.37	1.36	57.14
	total	100.00	46.69	22.72	2.06	100.00
1231	concentrate	56.52	53.49	16.70	3.20	64.74
	tailings	43.48	37.87	30.55	1.24	35.26
	total	100.00	46.70	22.72	2.06	100.00
Dodecylamine：1231 （1:1）	concentrate	33.22	61.54	9.43	6.52	43.81
	tailings	66.78	39.26	29.35	1.34	56.19
	total	100.00	46.66	22.73	2.05	100.00

Dodecylamine, tetracylamine, 1231, and dodecylamine: 1231=1:1 were used as collectors for comparison experiments. From Table 7, under the same dosage condition, when dodecylamine or tetracylamine were used as collectors alone, concentrate A/S reached 6.72 and 6.56, respectively, but the Al_2O_3 recovery was low; when 1231 is used alone, the recovery rate of Al_2O_3 is significantly higher than that of dodecylamine and tetracylamine, indicating that 1231 has a better ability to capture Al_2O_3, but cannot achieve a better A/S; when dodecylamine: 1231=1:1, the A/S of flotation concentrate was 6.52, slightly lower than that of dodecylamine or tetracylamine alone, but the Al_2O_3 recovery rate was improved. Therefore, dodecylamine and 1231 were selected as flotation collectors at the ratio of 1:1.

3.2.4 Effect of Flotation Process on Reverse Flotation Desilication

According to the test results of the types of collectors, a pilot study of the flotation process was carried out. By adjusting the flotation process, the quality of the aluminum concentrate and the alumina recovery rate was improved. The experimental process was shown in Figure 5, and the experimental results were shown in Table 8.

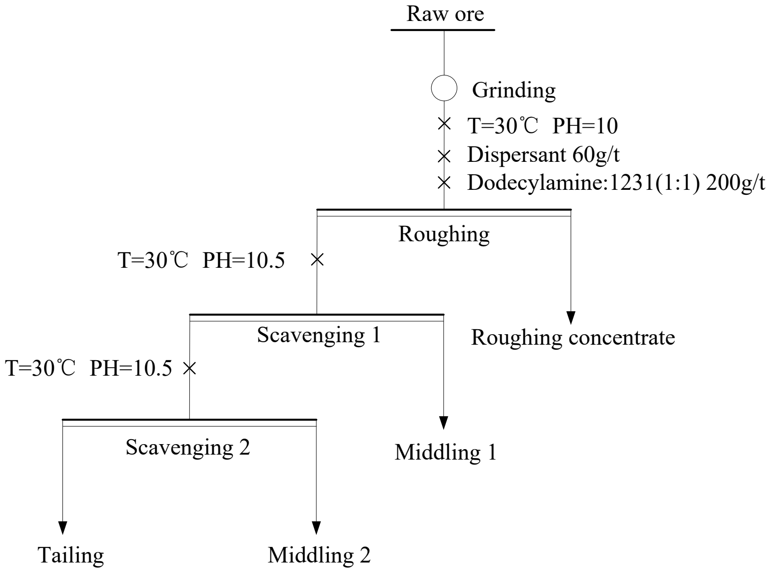

Figure 5. Test process of flotation desilication exploration.

Table 8. Test process of flotation desilication exploration.

Product	Yield %	Al_2O_3 %	SiO_2 %	A/S	Recovery of Al_2O_3 %	Cumulative yield %	Al_2O_3, %	SiO_2, %	A/S	Recovery of Al_2O_3 %
Concentrate	33.22	61.54	9.43	6.52	43.81	33.22	61.54	9.43	6.52	43.81
Middling-1	15.27	53.96	10.19	5.30	17.64	48.49	59.15	9.67	6.12	61.42
Middling-2	5.33	36.28	22.02	1.65	4.14	53.82	56.88	10.89	5.22	65.56
Tailing	46.18	34.83	36.33	0.96	34.44	100.00	46.70	22.64	2.06	100.00
Total	100.0	46.70	22.64	2.06	100.00					

From Table 8, the yield of middling-2 is 5.33% and the A/S is 1.65, there is no economic value of mineral processing for it. Therefore, the middling-2 was combined with tailings as the mineral processing tailings. Through the test process of "one roughing and one sweeping", the concentrate with yield of 48.49%, A/S 6.12% and alumina recovery of 61.42% was obtained.

3.3 Discussion

The data in Table 3 and Table 8 are integrated, and the final data are shown in Table 9:

Table 9. Test results of ore washing - flotation desilication for washing tailings.

Product	Yield %	Al_2O_3%	SiO_2 %	A/S	Recovery rate (Al_2O_3) %
Washing concentrate	74.91	55.02	9.51	5.79	77.87
Washing tailings	25.09	46.70	22.64	2.06	22.14
Flotation concentrate	12.17	59.15	9.67	6.12	13.60
Flotation tailings	12.92	34.98	34.85	1.00	8.54
Final concentrate	87.08	55.60	9.53	5.83	91.46
Final tailings	12.92	34.98	34.85	1.00	8.54
Raw ore	100.00	52.93	12.8	4.14	100.00

According to the data in the Table 9:

(1) Through the ore washing process, the aluminum concentrate with a yield of 74.91 % and A/S of 5.79 was obtained.

(2) Flotation desilication of the washed tailings was carried out to obtain the concentrate with a comprehensive yield of 12.17 %, A/S of 6.12 and the tailings with a comprehensive yield of 12.92% and A/S of 1.00 respectively.

(3) The final concentrate yield is 87.08 %, and the Al_2O_3 recovery rate is 91.46 %, realizing the comprehensive utilization of resources.

4. Conclusions

1) Through the ore washing test study, alumina concentrates with a yield of 74.91 %, and Al_2O_3 content of 55.02 % and an A/S of 5.79 are obtained.

2) Under the process of "raw ore washing - fine grain reverse flotation desilication", the yield of final concentrate is 87.08 %, Al_2O_3 content is 55.60 %, A/S is 5.83, Al_2O_3 recovery is 91.46 %. The concentrate is suitable for Bayer process to produce alumina. The new bauxite processing technology has realized the efficient utilization of bauxite resources.

5. Acknowledgement

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6. References

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