

Comparison of Alumina Production Process from Low Grade Refractory Bauxite

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Abstract

The chemical composition and mineral composition of low grade refractory bauxite were studied in this research. The experimental study on the alumina production from low grade bauxite were carried out by Bayer process, chemical desilication of calcination process, (Bayer-Sintering) series process and wet series process, respectively. Under the conditions of temperature 270 °C, 75 min digested time and lime content of 10 %, red mud of bauxite was digested by Bayer method with A/S 1.16, and N/S 0.52, alumina digestion efficiency rate can reach 75.25 %. Under the conditions of calcination temperature 950 °C and 60 min calcination time, the A/S of deposition bauxite and bulk bauxite concentrates can exceed 9 after chemical desilication process, but the digestibility of concentrate is poor. As to the Bayer-digestion of red mud from low grade refractory bauxite using series process, the standard digestion efficiency of alumina and sodium oxide in clinker are 77.58 %, 92.87 %, respectively. When using wet series process, the A/S of red mud and sodium-silicon ratio N/S can reach 0.64 and 0.04, respectively. Besides, the total digestion efficiency of alumina can reach 86.35 %.

Keywords: Low-grade bauxite, Bayer process, Chemical desilication, Wet series process.

1. Introduction

A low-grade refractory bauxite, with lower alumina content and higher carbonate and organic carbon content, is difficult for alumina production [1-3]. The exploratory experimental study on the feasibility of alumina production were conducted, using Bayer process, chemical desilication of calcination process, (Bayer-Sintering) series process and wet series process[4-6].

2. Raw Materials Test

2.1. Bauxite

The chemical composition and mineral composition of low grade refractory bauxite are shown in Table 1 and Table 2.

It can be seen from Table 1 that the content of Al₂O₃, SiO₂, Fe₂O₃ and A/S in low grade refractory bauxite are 39.98%, 8.52%, 27.71% and 4.69 respectively. Compared with diasporic bauxite in other parts of China, total carbon and organic carbon content in bauxite are higher: total carbon content is 0.98%, and organic carbon content is 0.27%.

Table 1. Chemical composition of low grade refractory bauxite, %.

Al ₂ O ₃	SiO ₂	Fe ₂ O ₃	TiO ₂	K ₂ O	Na ₂ O	CaO	MgO
39.98	8.52	27.71	6.06	0.014	0.021	3.43	0.037
P ₂ O ₅	V	Ga	LOI	C _{total}	C _{organic}	S _{total}	A/S
0.17	0.062	0.0041	13.45	0.98	0.27	0.039	4.69

Table 2. Mineral composition of low grade refractory bauxite, %.

diasporic	boehmite	kaolinite	hematite	calcite	anatase	rutile
38.5	/	18.5	27.5	6	4	2

From Table 2, it can be seen that the main aluminium-bearing mineral of bauxite is diaspora bauxite; the siliceous mineral mainly exists in the form of kaolinite; the main iron-bearing mineral is hematite; the main titanium-bearing minerals are anatase and rutile, and a small amount of calcite.

In summary, the bauxite is a low-grade diasporic bauxite with high iron, high carbon and kaolinite content.

2.2. Liquor

The cycling liquor used in the test is synthetic sodium aluminate solution, whose main chemical compositions are shown in Table 3. In general, mother liquor 1# is used in the digested test in this research; the mother liquor is used in the wet series process to deal with Bayer red mud.

Table 3. Chemical constituents of cycling liquor for test.

Number	Na ₂ O _T g/L	Al ₂ O ₃ g/L	Na ₂ O _k g/L	α _k
1#	258.84	133.8	244	3.0
2#	203.45	11.39	200	28.88

2.3. Lime

Lime is obtained from one production site of an enterprise, in which the reactive CaO is 89.24% and the total CaO is 91.13%.

3. Test Methods

3.1. Digestion Test

Bauxite digested test was carried out in molten salt steel elastic stripper. Based on the ratios of aluminium to silicon in red mud and bauxite, the alumina digestion efficiency is calculated. Detailed formulas are as follows [7]. Digestion efficiency of alumina:

$$\eta_A = \frac{(A/S)_{mine} - (A/S)_{mud}}{(A/S)_{mine}} \times 100 \quad (1)$$

where:

(A/S)_{mine} mass ratio of Al₂O₃ to SiO₂ in mine

(A/S)_{mud} mass ratio of Al₂O₃ to SiO₂ in red mud

3.2. Calcinated-Chemical Desilication Test of Bauxite

According to a certain proportion of ingredients, calcinated bauxite and sodium hydroxide solution were added to the steel bullet in oil bath, and the alkali leaching desilication test was carried out in the steel bullet stripper heated by oil bath.

3.3. Raw Material Sintering

After calculating the quality of each test material according to the formula and weighing accurately, the three-dimensional moving mixer was used to mix for 30 min, after which it is made into cylindrical tablet and dried. According to the set temperature, the sintered material was sintered in the fast heating furnace. The burned material was sealed in the dryer and grinded before use.

3.4. Standard Digestion of Clinker

The standard digestion conditions are: conditioning solution concentration $N_k = 15$ g/L, carbon alkali $N_c = 5$ g/L; ratio of L/S in weight is 15, digestion time is 15min, digestion temperature is 90 °C.

After the digestion of clinker, the digestion rate of alumina and sodium oxide was calculated according to the chemical composition of clinker and red mud. Detailed formulas are as follows [7]:

Alumina digestion rate of clinker:

$$\eta_A(\%) = \frac{A_{clinker} \cdot I_{ARM} \cdot \frac{C_{clinker}}{C_{RM}}}{A_{clinker}} \times 100 \quad (2)$$

Sodium oxide digestion rate of clinker:

$$\eta_N(\%) = \frac{N_{clinker} \cdot I_{NRM} \cdot \frac{C_{clinker}}{C_{RM}}}{N_{clinker}} \times 100 \quad (3)$$

where:

η_A alumina digestion rate of clinker

η_N sodium oxide digestion rate of clinker, clinker is the content of calcium oxide in clinker

C_{RM} the content of calcium oxide in red mud

$A_{clinker}$ alumina content in clinker

A_{RM} the content of alumina in red mud

$N_{clinker}$ the content of sodium oxide in clinker

N_{RM} the content of sodium oxide in red mud.

4. Test Results

4.1. Bayer Process Digestion Test

The Bayer process of low grade refractory bauxite was studied under the conditions of digestion temperature 265 °C, digestion time of 60 min and 75 min respectively, and digestion temperature of 270 °C with digestion time of 75 min. The effects of the amount of lime added on dissolved of red mud A/S are shown in Figure 1.

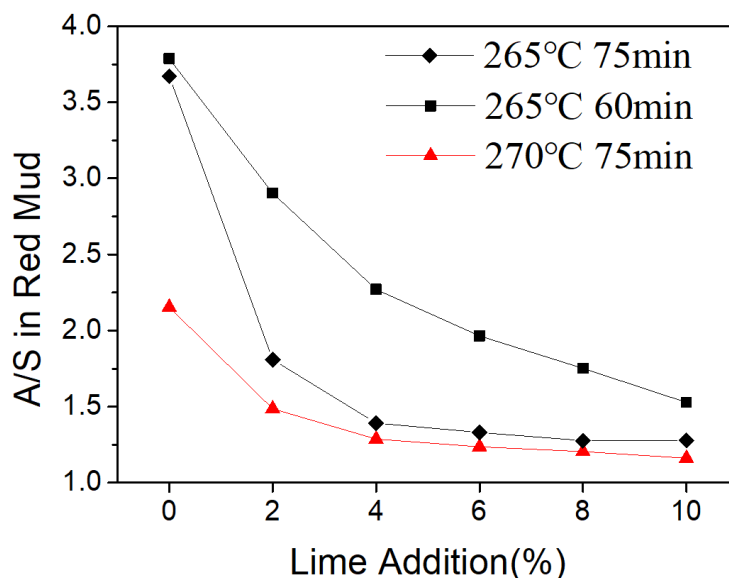


Figure 1. The red mud A/S of deposition bauxite with different lime addition amount and digestion conditions.

When the digestion time was extended to 75 min, the change of A/S in digested red mud with the addition amount of lime is basically the same as that of 60 min, but the A/S in digested red mud with the same addition of lime is lower. When the amount of lime added was 10 %, the A/S in red mud was 1.33, N/S was 0.50, and the digestion efficiency of alumina was 71.65 %.

When the digestion temperature increased to 270 °C, digestion time was 75 min, the A/S in red mud changed with the lime are basically the same with digestion temperature at 265 °C, but the digestion red mud A/S was lower when the temperature was 270 °C, amount of lime was 10 %, A/S of the digestion of red mud was 1.16, N/S was 0.52, alumina digestion rate was 75.25 %.

It can be seen from the results, when the bauxite is digested by the Bayer process, it needs relatively high digestion temperature and longer digestion time.

4.2. Calcinated-Chemical Desilication Process Test

Calcination-silica pre-removal technology is an important technical research direction dealing with low-grade refractory kaolinite ore [8-9]. The theory of this technology is that kaolinite is decomposed into alumina and amorphous silica under high temperature roasting, in which amorphous silica can be dissolving and removed using soda liquor, which can improve the grade of diasporic bauxite.

Bauxite roasting test was conducted at 950 - 1000 °C for 30 - 60 min. Alkali leaching desilication test was conducted under the condition that caustic concentration, temperature and L/S were 150 g/L, 90 °C and 3, respectively. Figure 2 shows the A/S of the obtained calcined bauxite followed by alkali liquor desilication under different calcination conditions; Figure 3 shows the concentration of SiO₂ in the solution of the calcined bauxite, which was desilicated by alkali leaching under different roasting conditions.

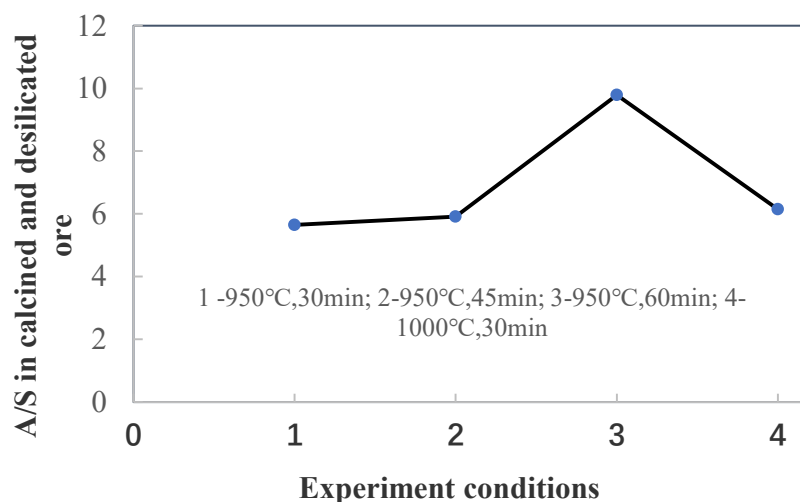


Figure 2. A/S of bauxite concentrate after calcination and desilication.

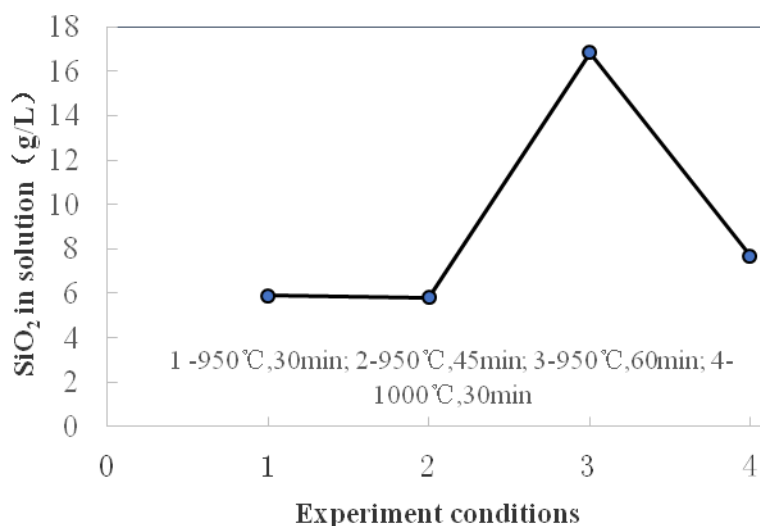


Figure 3. SiO₂ concentration in solution after alkali leaching the calcinated bauxite.

From Figure 2 and Figure 3, it shows that the best operational condition are calcination temperature 950 °C for 60 min, where the concentrate has the highest A/S. Under this condition, the A/S of bauxite can increase to 9.79 from 4.96, besides the SiO₂ concentration reached 16.85 g/L after alkali leaching. The main chemical components of low grade refractory bauxite concentrate after chemical desilication are shown in Table 4.

Table 4. The main chemical components of low grade refractory bauxite concentrate after chemical desilication, %.

Al ₂ O ₃	SiO ₂	Na ₂ O	A/S
45.99	4.70	0.15	9.79

Table 5. The molecular ratio of the dissolved solution of low grade refractory bauxite concentrate after chemical desilication under the conditions of different dissolution temperature and lime content.

Conditions	0 %	1%	3%	5%	6%	7%	9%
250 °C, 60 min	2.21	2.24	2.21	2.18	-	2.13	2.11
260 °C, 60 min	2.34	-	2.21	-	2.12	-	1.81
275 °C, 75 min	1.68	-	1.64	-	1.56	-	1.50

In order to investigate the effects of different addition amount of lime on the molecular ratio of dissolution solution, the digestion test of the concentrate after calcination and desilication was conducted under the condition of expected molecular ratio of dissolution solution 1.45, with the dissolution solution temperature were 250 °C and 260 °C, respectively. The results demonstrate that the molecular ratio of the dissolution solution was higher than 2.0 under both above dissolution conditions. While the molecular ratio of the dissolution solution was 1.56 and the red mud A/S was about 2.00, when the conditions of digestion were temperature 275 °C, lime content 6% and dissolution time 75 min. The molecular ratio of the dissolution solution of the concentrate after chemical desilication of calcining under the conditions of different dissolution temperature, time and amount of lime are shown in Table 5.

The results show that the calcinated-chemical desilication process used to treat the low-grade refractory bauxite is feasible depending on the method to solve the problem of poor dissolution performance of concentrate.

4.3. Series Process Test

The series process is that treating bauxite with Bayer method to extract most of the alumina, followed by recovering the alumina and alkali in red mud using sintering method. The series production of alumina has the advantages of high alumina recovery and low alkali consumption [10-11].

Using the digested red mud in Bayer process with low grade refractory bauxite, Sintering test of clinker was conducted, where sodium aluminate was formed by alumina, sodium calcium silicate by silicon oxide, and calcium ferrite by iron oxide (the molar ratios of iron oxide to calcium oxide F/C were 1, 1.5 and 2.0). Under the conditions of Clinker sintering temperature 1150 °C, 60 min sintering time, different ratio of F/C clinker chemical components are shown in Table 6, and the chemical composition of clinker standard red mud after digestion and the digestion efficiency of alumina clinker η_A and standard alumina digestion efficiency η_N are shown in Table 7.

Table 6. Chemical composition of clinker, %.

Number	F/C	Al ₂ O ₃	SiO ₂	Fe ₂ O ₃	Na ₂ O	CaO
QBC-1	1.00	11.17	9.34	30.43	15.61	22.87
QBC-2	1.50	10.40	8.96	28.95	15.14	26.3
QBC-3	2.00	9.64	8.62	27.90	14.05	29.97

Table 7. Chemical composition and digestion efficiency of red mud from clinker, %.

Number	F/C	Al ₂ O ₃	SiO ₂	Fe ₂ O ₃	Na ₂ O	CaO	η_A	η_N
QBC-1	1.00	3.22	10.89	39.18	1.43	29.40	77.58	92.87
QBC-2	1.50	3.26	10.37	36.74	2.99	33.16	75.14	84.34
QBC-3	2.00	2.81	9.43	34.19	4.30	35.79	75.59	74.37

From Table 7, we can see that when the clinker F/C is 1, the standard digestion efficiency of alumina and sodium oxide is relatively high: the standard digestion efficiency of alumina is 77.58 %, and the standard digestion efficiency of sodium oxide is 92.87 %.

Compared with the conventional sintering process, the digestion efficiency of alumina and sodium oxide in the clinker was lower with Bayer red mud of bauxite was treated by the series process.

4.4. Wet Series Process Test

The effects of lime addition account on the Bayer digested red mud disposed with wet process, under the conditions of digested temperature 240 °C and 250 °C, with 60 min. Detailed results are shown in Figure 4 and Figure 5, respectively.

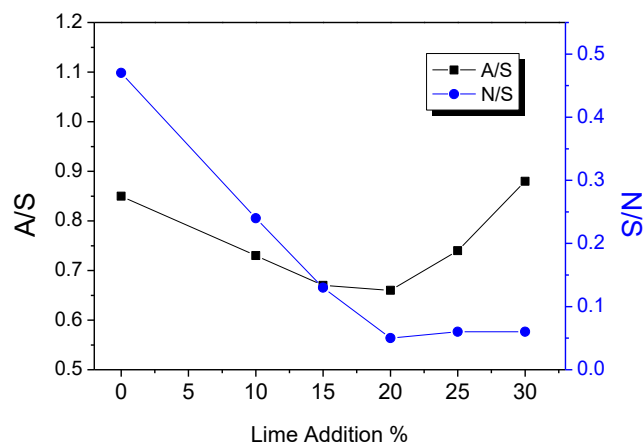


Figure 4. Effect of Lime addition on the red mud by wet process in Bayer process. (T=240 °C).

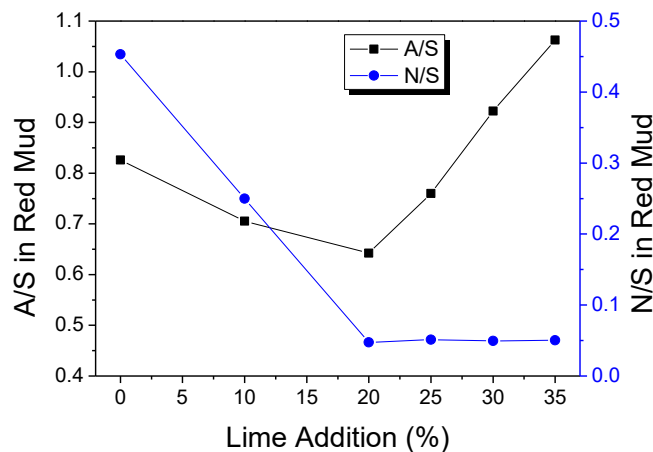


Figure 5. Effect of Lime on the red mud by wet process in Bayer process. (T=250 °C).

The A/S ratio in red mud by wet process decreases first and then increases with the increase of lime addition when the temperature is 240 °C and 250 °C. The N/S ratio of red mud by wet process decreases when the lime addition is within 0 – 20 %. The changes of N/S ratio of red mud by wet process is not obvious when the lime addition is more than 20 %. The A/S ratio and N/S ratio of red mud by wet process reaches the lowest level. The A/S ratio is 0.66, the N/S ratio is

0.05 and the digestion efficiency of alumina is 85.93 % when the temperature is 240 °C. The A/S ratio is 0.64, the N/S ratio is 0.05 and the digestion efficiency of alumina is 86.35 % when the temperature is 250 °C.

5. Conclusion

The content of alumina in low grade bauxite is 39.88 %, the silica is 8.52 %, the iron oxide is 27.71 %, and the A/S ratio in low grade bauxite is 4.69.

The main aluminum containing mineral in low grade bauxite is diaspora bauxite, the silica containing minerals is kaolinite, the iron containing minerals is hematite and the titanium containing minerals is anatase and rutile. A small account of calcite is also contained. The bauxite is the low grade diaspora bauxite with high iron, high carbon and kaolinite content.

The A/S ratio and N/S ratio in red mud are 1.16 and 0.52, the digestion efficiency of alumina is 75.25 %, the relative digestion efficiency is 95.65 % at temperature of 270 °C, with digestion time 75 min and lime addition amount 10%.

The A/S in the concentrate after chemical desilication can exceed 9 when the calcination temperature is 950 °C and the calcination time is 60 min, but the digestibility of the concentrate is poor.

The standard digestion efficiency of alumina and sodium in the sinter are 77.58 % and 92.87 % when the red mud produced by low grade bauxite in Bayer process is treated by series process.

The A/S in the red mud is 0.64, the N/S ratio is 0.04 and the digestion efficiency of alumina is 86.35 % when the red mud produced by low grade bauxite in Bayer process is treated by wet series process.

The series or wet series process has obvious advantages over the other two technical routes, according to the key technical indexes such as the digestion rate of alumina and the A/S ratio and N/S ratio of the red mud. But in order to select the appropriate technological route for alumina production from the low grade bauxite, further detailed technical and economic analysis are needed.

6. Reference

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