AA11 - Research on Digestion Conditions of High Carbonate Bauxite to Improve Performance

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Abstract

In the process of alumina production by the Bayer process, the high concentration of sodium carbonate in the production system will cause a series of problems such as difficult operation, increase of energy consumption, decrease of output, and increase of alkali consumption. In the paper, the effects of lime addition amount, digestion temperature, digestion time and other conditions on the carbonate reaction behavior were studied for a high-carbonate bauxite from Guizhou (China). The changes of A/S (weight ratio of Al_2O_3 to SiO_2), N/S (weight ratio of Na_2O to SiO_2) and TIC (total inorganic carbon) content in red mud under different conditions were analyzed in detail. Based on the digestion performance of bauxite and the exclusion of more carbonate from the liquor, the best technological conditions for this type of bauxite were put forward, which not only can ensure efficient recovery of alumina, but also can remove carbonate from the liquor at low cost, providing guidance for the production organization.

Keywords: Carbonate, Bauxite, Digestion, Reaction behavior.

1. Introduction

With the development of the alumina industry in China, the grade of bauxite decreases rapidly, and gangue minerals in ore increase gradually, especially carbonate minerals. The carbonate species in bauxite react with alkali liquor and enter the production system, resulting in an increase in the concentration of sodium carbonate, which affects all aspects of production, especially the processes of high-pressure digestion, seed precipitation and spent liquor evaporation. The increase in sodium carbonate concentration results in reduced process flow due to sodium carbonate precipitation in the digestion flash train, which requires frequent water injection or liquid washing [1]. The water addition affects the heat balance of the leaching process and the steam consumption increases. The liquor viscosity also increases resulting in an increase of power consumption related to conveying slurry as well as the deterioration of filtration performance and the associated production capacity of vertical plate filters [2], flat plate filters, and the increase of filters downtime for cleaning. With this increase in liquor viscosity, the precipitation efficiency and alumina production also decrease. In the evaporation process, due to the increase in sodium carbonate concentration, the salt discharge pressure of forced circulation evaporator is increased, which leads to the increase of evaporation steam consumption and decrease of evaporative capacity; the evaporator operating cycles are also shortened due to more frequent cleaning.

There are three common ways to eliminate sodium carbonate from a production system: evaporation crystallization method, the causticization of the red mud washing liquor and causticization using barium salt. The evaporation crystallization method is a widely one among alumina plants but this method involves higher implementation cost and reduced evaporation capacity thus making it unsuitable for long-term operation [3–5]. The causticization of the red mud washing liquor involves utilizing a liquor stream suitable for causticization to produce sodium hydroxide from sodium carbonate reacting with lime. But the reduction of the sodium carbonate content in the Bayer process by this method is slow, and the alumina losses are high. It is therefore difficult to achieve the desired effect in a short period by applying this method [6, 7]. The liquor causticization using barium salt takes advantage of the characteristics that most barium salts are insoluble in sodium aluminate liquor to eliminate sodium carbonate. However, barium salts are expensive and regeneration cost is high, additionally, gases and dust harmful to human health are produced in the regeneration process, also impacting the environment [8, 9]. Therefore, how to use high carbonate bauxite reasonably and efficiently is an urgent technical problem to be solved.

In this paper, the existing form of carbonate in a high carbonate bauxite from Guizhou, China, was analyzed. The impact of digestion temperature, residence time, lime addition, and initial spent liquor carbonate content, on the carbonate removal from the liquor and entering the produced red mud was studied and will be discussed. The best process conditions for this type of bauxite were proposed, which not only can ensure efficient recovery of alumina, but also can remove carbonate through digestion red mud at low cost, providing guidance for the production organization.

2. Test Raw Materials

2.1 Bauxite

The bauxite was obtained from an alumina plant in Guizhou, China. The main chemical composition of the bauxite (%) is shown in Table 1, and the main mineral phases are shown in Table 2. It can be seen that this is a high carbonate diasporic bauxite, and the carbonate mineral is siderite, an iron (II) carbonate ($FeCO_3$), sometimes comprising other elements as impurities (e.g. Ca, Mg, etc.) [10].

Table 1. Chemical compositions of bauxite (wt %).

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	K_2O	Na_2O	CaO	MgO	TC	TOC	TIC
47.19	9.25	27.63	2.13	0.72	0.024	0.26	0.49	0.78	0.21	0.57

Table 2. Mineral phase compositions of bauxite (wt %).

diaspore	chlorite	illite	kaolinite	hematite	siderite	anatase	rutile
46	16	7	5	15	8	1.7	0.4

2.2 Liquor

The spent liquor was obtained from an alumina plant in Guizhou, China. The main components are shown in Table 3.

Table 3. Chemical compositions of sodium aluminate liquor.

Na_2O_T g/L	Al_2O_3 g/L	Na_2O_k* g/L	Na_2O_c* g/L	α_k
263.88	133.40	244.00	19.88	3.01

* Na_2O_k represents caustic soda, expressed as Na_2O, while Na_2O_c represents sodium carbonate also expressed as Na_2O

2.3 Lime

The lime used in the experiment was obtained from an alumina plant in Guizhou, China. After grinding, it was roasted and activated. The chemical compositions are shown in Table 4.

Table 4. Chemical compositions of lime.

Al_2O_3	SiO_2	CaO_T*	MgO	CaO_f*
0.98	2.56	91.80	1.04	85.49

* CaO_T = Total calcium oxide content in lime;
CaO_f = available calcium oxide content in lime.

3. Test Methods

3.1 Bauxite Digestion Test

The bauxite digestion test was carried out in a steel bomb digester heated by molten salt. According to the requirements of the ingredients, a proportion of bauxite, liquor and lime were added into the steel bomb, installed in the rotating steel bomb rack, at a predetermined temperature and immediately stirred. When the residence time is reached, the solution is separated from the treated solid phase, and the chemical composition of the solution is analyzed. After washing and drying, the solid phase was analyzed for chemical composition. The relative digestion efficiency of alumina (η_{AR}) is calculated with A/S (the weight ratio of Al_2O_3 and SiO_2) in the bauxite and in the red mud according to the following formula:

$$\eta_{AR} = \frac{(A/S)_B - (A/S)_R}{(A/S)_B - 1} \times 100\% \quad (1)$$

where:

$(A/S)_B$ weight ratio of Al_2O_3 and SiO_2 in the bauxite;
$(A/S)_R$ weight ratio of Al_2O_3 and SiO_2 in the red mud.

3.2 Analytical Methods

PANalytical PW2403 X-ray fluorescence spectrometer was used to analyze the contents of Al_2O_3, SiO_2, Fe_2O_3, TiO_2, K_2O, Na_2O, CaO and MgO in bauxite, red mud and lime. The contents of Na_2O_T, Al_2O_3 and Na_2O_k in sodium aluminate solution were analyzed by chemical titration. The mineral composition of the solid phase was analyzed by Nalytical X, Pert Pro MPD X-ray diffraction analyzer. The content of CaO in lime was determined by X-ray fluorescence spectrometry. The effective CaO content in lime was determined by acid-base titration method. The content of TC (total carbon) and TOC (total organic carbon) in bauxite and lime was determined by CS-2000 carbon-sulfur analyzer. The content of TIC (total inorganic carbon) was calculated from the difference between TC and TOC.

4. Test Results

4.1 Effect of Lime Addition on Bauxite Digestion Performance and Carbonate Reactions

The effect of lime addition (1, 3, 5, 7, 9 and 11 %) on bauxite digestion performance and carbonate reactions was studied under the following test conditions: Na_2O_k concentration in spent liquor of 244 g/L, temperature of 265 ℃ and reaction time of 50 minutes. Effect of lime addition on A/S and N/S (weight ratio of Na_2O to SiO_2) in the red mud is shown in Figure 1, and effect of lime additions on TIC content in the red mud is shown in Figure 2.

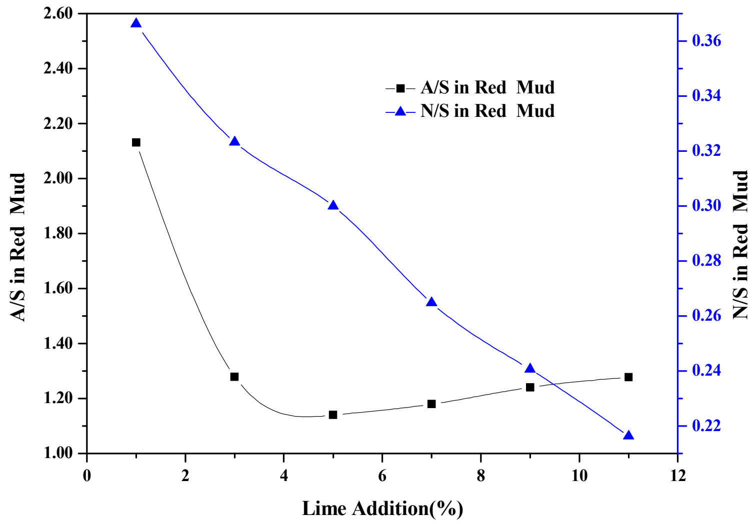

Figure 1. Effect of lime addition on A/S and N/S in the red mud.

Figure 1 shows that under the above test conditions, with the increase of lime content from 1 to 11 %, the red mud A/S decreased firstly and then increased, and the relative digestion rate of alumina increased firstly and then decreased. When the lime content is 5 %, the red mud A/S is the smallest, which means the digestion efficiency is the highest, for a relative alumina extraction of 96.62 %. With the increase of lime content from 1 to 11 %, the silicon-containing minerals in the red mud gradually changed from cancrinite to hydrated garnet, and the N/S in the red mud decreased from 0.37 to 0.22 [11].

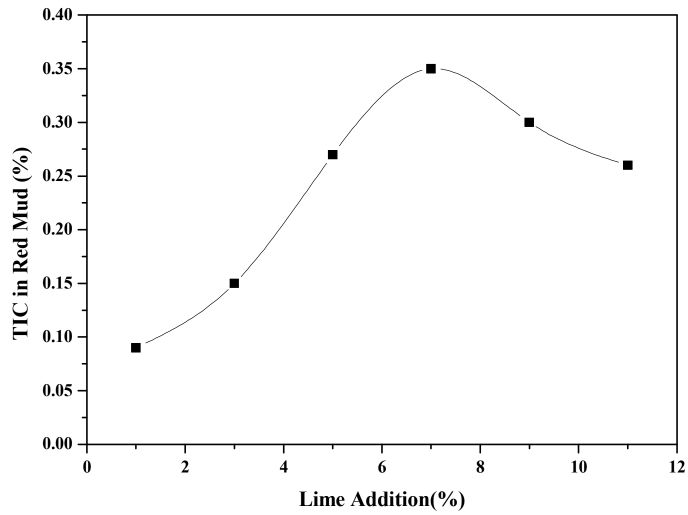

Figure 2. Effect of lime additions on TIC content in the red mud.

Figure 2 shows that under the above test conditions, with the increase of lime content from 1 to 11 %, the TIC content in the red mud initially increased and then decreased. For a lime addition of 7 %, the TIC content in the red mud is the highest, and the carbonate taken away from the red mud is also the highest. The analysis of the red mud phase composition shows that higher lime addition is beneficial to the carbonate entering the cancrinite structure, but when the lime addition amount is greater than 7 %, the silicon-containing mineral gradually changes from cancrinite to hydrated garnet, and the carbonate content of the red mud decreases [11].

4.2 Effect of Temperature on Digestion Performance of Bauxite and Carbonate Reaction Behavior

The effect of temperature (255, 260, 265 and 270 °C) on bauxite digestion performance and carbonate reaction behavior was studied under the following test conditions: Na_2O_k concentration in spent liquor of 244 g/L, lime addition of 5 % and reaction time of 50 minutes. Effect of temperature on A/S in the red mud is shown in Figure 3, effect of temperature on N/S in the red mud is shown in Figure 4, and effect of temperature on TIC content in the red mud is shown in Figure 5.

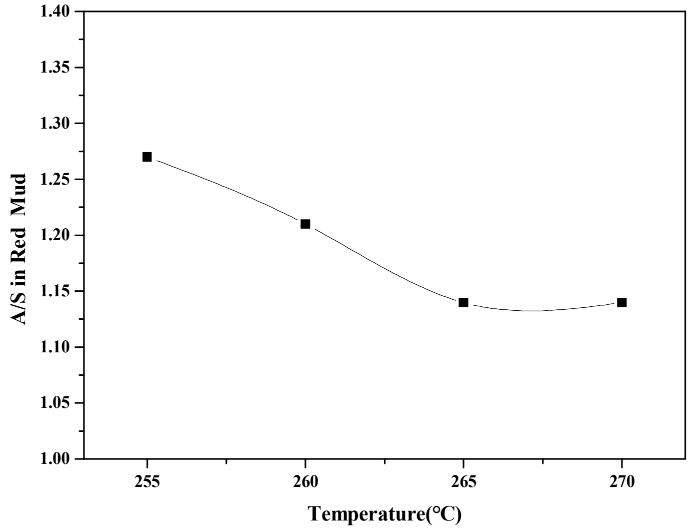

Figure 3. Effect of temperature on A/S in the red mud.

It can be seen from Figure 3 that under the above test conditions, as the temperature increased from 255 to 270 °C, the A/S in the red mud gradually decreased. At a temperature of 265 °C, the A/S in the red mud is the lowest, and the digestion efficiency is the best with an alumina extraction rate of 96.62 %.

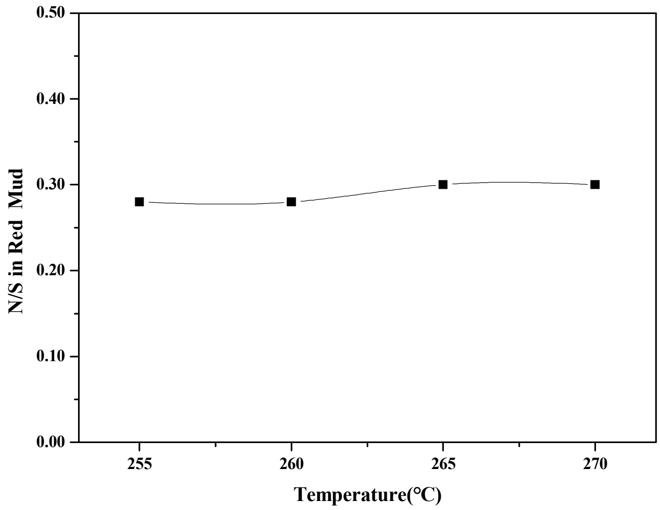

Figure 4. Effect of temperature on N/S in the red mud.

Figure 4 shows that under the above test conditions, with the temperature increasing from 255 to 270 °C, N/S in the red mud is about 0.29, and the temperature has little effect on N/S in the red mud,.

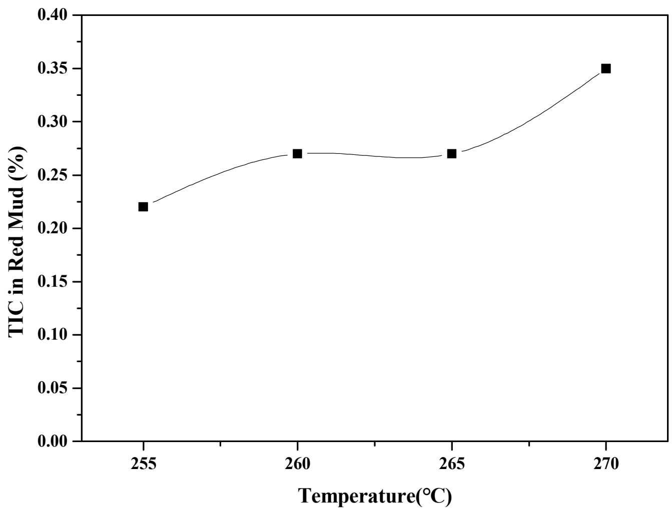

Figure 5. Effect of temperature on TIC content in the red mud.

It can be seen from Figure 5 that under the above test conditions, with the temperature increasing from 255 to 270 °C, the TIC content in red mud increased following an almost linear trend from 0.22 to 0.35 %. With the increase of temperature, the content of cancrinite increased, which was conducive to the removal of more carbonate through the red mud from the digestion process.

4.3 Effect of Time on Bauxite Digestion Performance and Carbonate Reaction Behavior

The effect of time (40 and 50 minutes) on bauxite digestion performance and carbonate reaction behavior was studied under the following test conditions: Na_2O_k concentration in spent liquor of 244 g/L, lime addition of 1 to 11 % and reaction temperature of 265 °C. The effect of time on A/S in the red mud is shown in Figure 6, the effect of time on N/S in the red mud is shown in Figure 7, and the effect of time on red mud TIC content is shown in Figure 8.

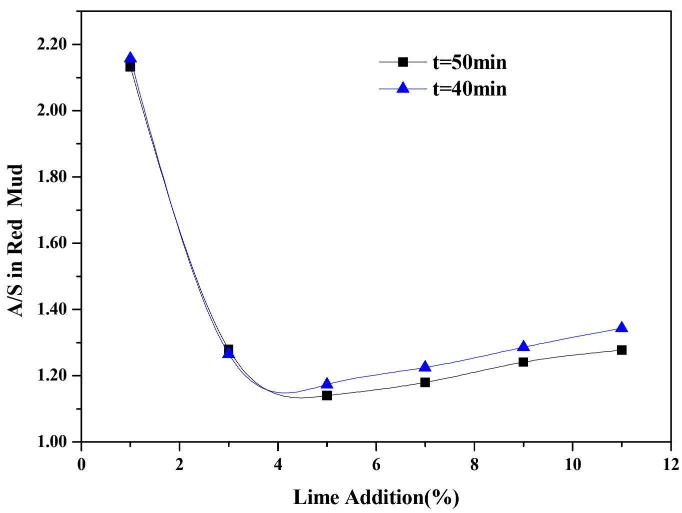

Figure 6. Effect of time on A/S in the red mud.

Figure 6 shows that under the above test conditions, when the digestion time is 50 minutes, the A/S of the red mud is slightly lower than that of 40 minutes, and the digestion efficiency of alumina is slightly higher. This is particularly true when lime addition is above 4 %.

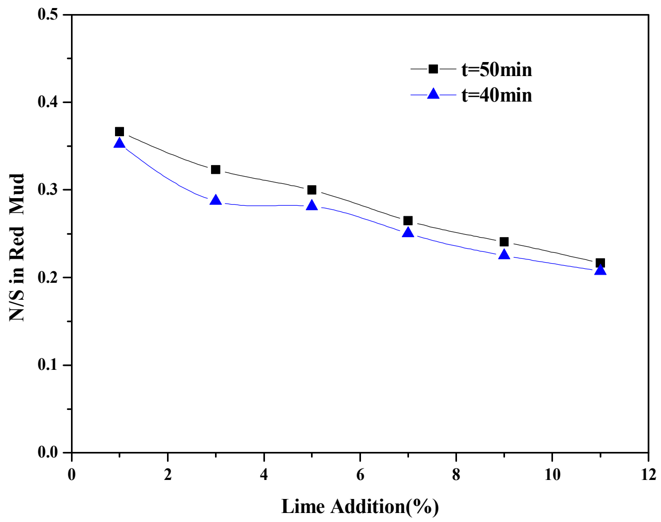

Figure 7. Effect of time on N/S in the red mud.

Figure 7 shows that under the above test conditions, when the digestion time is 50 minutes, the N/S of the red mud is slightly higher than that of 40 minutes.

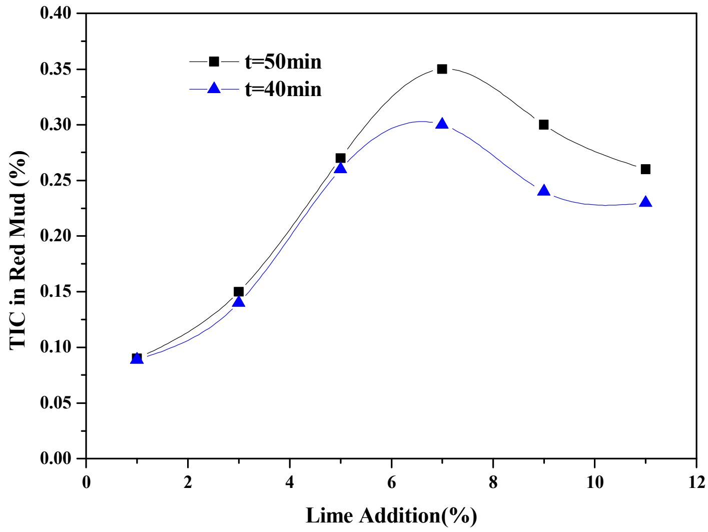

Figure 8. Effect of time on TIC content in the red mud.

It can be seen from Figure 8 that under the above test conditions, when the lime addition is between 1 and 5 %, there little difference in the TIC content of the red mud for digestion time of 50 and 40 minutes. When the lime addition is greater than 7 %, however, the TIC content in the red mud obtained with a digestion time of 50 minutes is significantly higher than that after 40 minutes. Therefore we can conclude that a longer digestion time is conducive to the removal of more carbonate through the red mud from the production process.

4.4 Effect of Sodium Carbonate Concentration in the Spent Liquor on Bauxite Digestion Performance and Carbonate Reaction Behavior

The effect of sodium carbonate concentration in the spent liquor (19.88, 25, 30, 35, 40 g/L and 45 g/L Na_2O_c) on the bauxite digestion performance and carbonate reaction behavior was studied under the following test conditions: Na_2O_k concentration in spent liquor of 244 g/L, lime addition of 5 % , reaction temperature of 265 °C and reaction time of 50 minutes. Effect of sodium carbonate concentration of spent liquor on A/S and N/S in the red mud is shown in Figure 9, and the effect on TIC content in the red mud is shown in Figure 10.

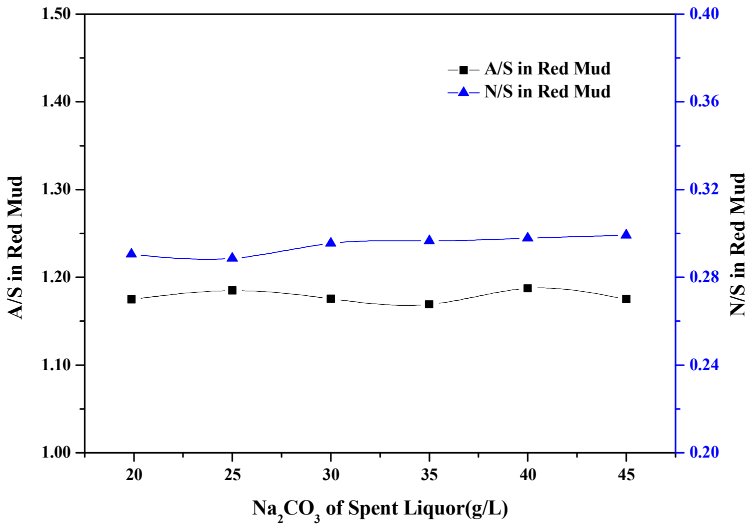

Figure 9. Na_2CO_3 concentration of spent liquor on A/S and N/S in the red mud.

It can be seen from Figure 9 that under the above test conditions, with an increase of the Na_2CO_3 concentration in the spent liquor, the A/S of the red mud is relatively stable at about 1.18, and the N/S of the red mud is also relatively stable at about 0.29. We can therefore conclude that the Na_2CO_3 concentration in spent liquor has very little effect on the bauxite digestion (alumina extraction and soda consumption), under the tested conditions.

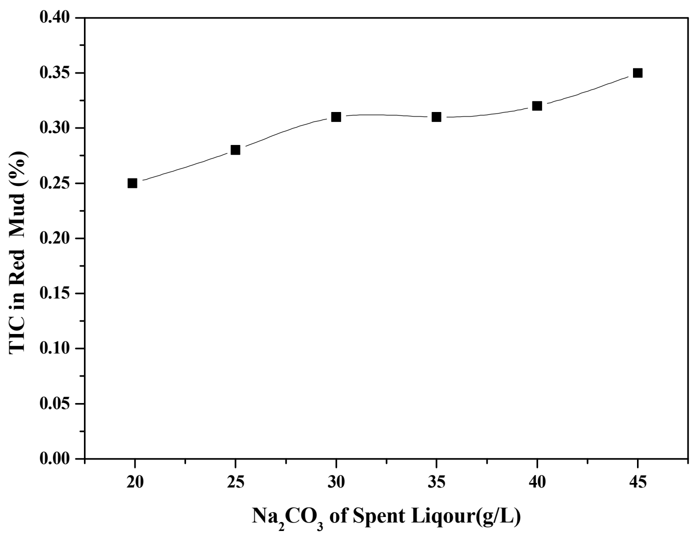

Figure 10. Na_2CO_3 concentration of spent liquor on TIC content in the red mud.

As can be seen in Figure 10, under the above test conditions, with an increase of the Na_2CO_3 concentration in spent liquor, the TIC content in the red mud rapidly increased from 0.25 to 0.35 %, and the carbonate removed through the red mud increased from the production process.

5. Conclusions

(1) The bauxite studied was from an alumina plant in Guizhou, China. It is a high-carbonate diaspore type bauxite with siderite as the carbonate mineral.

(2) The study on the bauxite digestion performance and carbonate reaction behavior determined that with an increase of lime addition, the alumina extraction and the TIC content of red mud increased firstly and then decreased. When the lime addition was 7 %, the amount of carbonate in the red mud, and therefore removed through the red mud was the highest. Increasing the digestion temperature and prolonging the digestion time is conducive to the increase of the alumina extraction and the discharge of more carbonate through the red mud. With the increase of sodium carbonate concentration in spent liquor, the carbonate removed from the red mud increased.

(3) Based on the comprehensive consideration of the bauxite digestion performance (namely alumina extraction) and the increase of carbonate carried away through the red mud, the optimal digestion conditions are a lime addition of 5 to 7 %, a temperature higher than 265 °C, and a residence time longer than 50 minutes. With these conditions, not only a better bauxite digestion can be obtained, but also the carbonate evacuated with the red mud can be maximized, creating the best conditions for the production organization.

6. Reference

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