TECHNOLOGY IMPROVEMENT OF SANDY ALUMINA PRODUCTION FROM DIASPORIC BAUXITE IN CHINA

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Abstract

China has the second largest annual output of alumina in the world, and CHALCO is the largest alumina producer in China, whose major products were middle state alumina and powder alumina in previous years. As the technology of large pre-bake anode electrolytic cells blossomed, the requirement was for the quality level of smelter grade alumina to also improve. With the support of Ministry of Science and Technology of China, CHALCO has put up a series of fundamental studies, pilot experiments and industrialization technology for the technology breakthrough for producing sandy alumina since the year 2000. A technology system which has the characteristics of sandy alumina production from diasporic bauxite in China was developed. The technology and methods of CHALCO for producing sandy alumina were also realized by Bayer Process and Sintering-Carbonation Precipitation Process. It fully realized the upgrade of smelter grade alumina, and satisfied the demands of large pre-bake anode electrolytic cells. The technology improvement of sandy alumina production from diasporic bauxite in China will be discussed in this article.

1 Introduction

The alumina industry in China is developing rapidly with the annual alumina output exceeding 6.8mt pa. With the booming demand for alumina for aluminum production, CHALCO possesses nearly all of the alumina refineries and supplies approximately 70% of all alumina products consumed in China. It has a total of 6 alumina refineries in 5 provinces of China. Table1 shows the alumina refineries of CHALCO and their alumina capacities and production process being used (CHALCO, 2005, Song Peikai, 2000).

Table 1. Annual capacities of alumina refineries of CHALCO in 2004

Refineries	Annual capacities (10,000 tons/year)	Production process
Henan	147.5	Mixed combined process
Zhongzhou	111.6	Mixed combined process
Shangdong	103.9	Sintering process, Bayer process
Shangxi	140.3	Mixed combined process
Pingguo	91.7	Bayer Process
Guizhou	85.1	Mixed combined process

Although bauxite is abundant in China, 99% are diasporic bauxite which is not as easily digested as gibbsite, and most of them are low grade ores with A/S<7 (alumina to reactive silica). Therefore, high temperature and high caustic concentration Bayer digestion process is necessary for Chinese diasporic bauxite, which leads to a complex preheating and digestion system and many difficulties in the subsequent process (Songqing, 2002).

Traditionally, the diasporic bauxite were treated by Sintering Process or Mixed Combined Process. As the technology of large pre-bake anode electrolytic cell blossomed, the requirement was for the quality level of metallurgy grade alumina to also improve. If the traditional process was adopted, there would be many difficulties such as problems of digestion, energy consumption, product quality and construction cost etc. In order to overcome these difficulties, many new technologies focusing on the characteristic of bauxite in China have been developed.

2 Technology improvement of sandy alumina production from diasporic bauxite in China

There are three alumina production processes in China: Bayer Process, Sintering Process and Mixed Combined Process which combines Bayer process and sintering process. In fact, there are only two systems in these three processes: Bayer system and sintering system, our research is focused on developing the technology of these two systems.

2.1 *Technology improvement in Bayer system*

2.1.1 *Technology of bauxite dressing*

The grade of bauxite in China is rather low with high silica content. This kind of bauxite is not easy to process by Bayer Process directly. In order to meet the demand of Bayer Process, the bauxite was pre-treated by an ore dressing process. That means adding a flotation stage in front of the traditional Bayer Process to remove a part of the silica and enhance the grade of the bauxite (Yuehua, 2003).

With years of research, CHALCO has developed a full series of Bauxite Flotation Process including specific reagents, facilities and processes. The process was verified by laboratory experiments, pilot experiments and industrial test. A part of the results are shown in the Table 2 (CHALCO, 2001).

From the data of Table 2, the original A/S of bauxites less than 7 can be enhanced to above 11 by flotation. The bauxites pretreated by flotation can fully meet the demand of Bayer Process.

Table 2: A part of results of Bauxite flotation test

	A/S of bauxite sample	A/S of concen-trate	Ratio of concen-trate effi-ciency/%	Ratio of Al_2O_3 recovery/ %	Moisture of concen-trate/%
Small scale	~5.9	>11	>80	~90	16
Pilot test	~5.8	>11	>82	~90	14
Industrial test	5.9	11.39	79.52	86.45	11-12

2.1.2 *Intensified Digestion Technology*

Diaspore is much more difficult to digest than gibbsite, the digestion temperature and the caustic concentration needed for diaspore is much higher than gibbsite. This causes many difficulties in traditional Tube Digestion Process, such as temperature and caustic sustainability of digestion facilities and scaling problems.

The Tube Digestion Process was introduced to Chinese Refineries in the 1990's and it has been improved all the time since then to adapt to the digestion characteristics of Chinese diasporic bauxite.

The technology of Tube-Preheater with Autoclaves or Retention Tanks (Figure 1), and newly improved Bi-stream Digestion Process have been successfully developed on the basis of fundamental research results and industrial experiences and they have passed the long term pilot test.

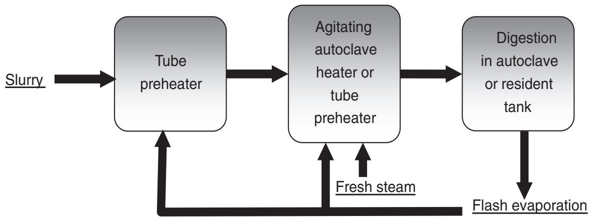

Figure 1 Schematic flow sheet of Tube-Preheater with Autoclaves or Retention Tanks

The technology of Tube-Preheater with Autoclaves or Retention Tanks successfully solved the problem of corrosion for high caustic concentration and high temperature; however, the scale problem may occur for continuously precipitation of silica and titanium content during the process. The bi-stream process may solve the problem. In the bi-stream system, the high solids slurry and the spent liquor are preheated separately, the preheating temperature of high solids slurry can then be controlled to reduce the precipitation of silica and titanium content.

The scale-cleaning systems including hydraulic power cleaning, acid cleaning with new type of anticorrosive additives and caustic cleaning have been also developed and put into operation, which is very important to enhance heat transfer efficiency and extend operation cycles.

2.1.3 *Pregnant Liquor Diffluence Precipitaion Technique*

For the special properties of bauxite and the corresponding unique technology in mineral dressing and digestion, the caustic concentration of the pregnant liquor for precipitation is relatively high while the supersaturation is relatively low compared with other processes. The physical chemistry properties of the pregnant liquor then is not the same, which effects the precipitation process. The yield of the liquor produced from the CHALCO process is relatively high, but the particle size of the product is much finer than liquor with lower concentration. In order to conquer this difficulty, CHALCO organized the research groups of many branches to solve the problem, based on the fundamental research of agglomeration and growth stage, and studies on the change of granularity and intensity of precipitation product. A new precipitation technology focus on the liquor with characteristics of high caustic concentration and low supersaturation were developed (CHALCO, 2004). The technology is to produce coarse hydrate by proper diffluence of the pregnant liquor and make the solids agglomerate at relatively higher temperature and lower solid content (Figure 2). The pregnant liquor is separated into two streams, and mixed with fine seed and relatively coarse seed respectively. The mixed slurries are added into different precipitation tanks with different temperatures to create conditions to agglomerate or grow. The solids content, concentration, supersaturation and particle size distribution of the seeds are different between the two streams of the slurry.

2.1.4 *Model prediction of Crystal Size Distribution*

Because of the characteristics of the pregnant liquor, the precipitation process to obtain high quality hydrate without sacrificing unit output is a rather difficult problem. The instantaneous control and adjustment of the production conditions is a method to reach the objective. In previous years, the adjustment was mainly based on experiences collected during the production process, it was sometimes delayed and the effect was always unsatisfactory. Therefore, a model for prediction based on the knowledge of kinetics of each fundamental precipitation stage has been developed for the industrial control (Pingmin, 2001). The model is based on the concept that coarse particles come from fine particles of the previous term by complex kinetic influence of various fundamental precipitation stage (Eqn.1). By studying the characteristic of fine particles generated in the precipitation and its transformation rules, the future particle size distribution can be predicted (Pingmin 2001, Sweegers 2001). Studies on the kinetics of each basic stage of precipitation are also needed in model construction.

$$\lambda_1 - \frac{\lambda_2}{T} = \ln\left[100 \cdot \Delta\phi(-10um)\right] - 2\ln\frac{\chi}{130} - \ln\frac{\alpha_k}{\alpha_{k,eq}} + \left(1 - \frac{\phi(-45um)}{0.6}\right)^2$$

The model controlled the difference of particle volume ratio of fine particles between the given two precipitation tanks (Ψ) by adjusting the precipitation temperature in the corresponding tank, the particle size distribution of the product then can be controlled (Figure 3). Figure 3 shows that the characteristic parameter $\psi(10\mu m)$ can be controlled in a given range by temperature adjustment predicted by the model, and the particle size distribution of the products $\psi(-10\mu m)$ can then be controlled.

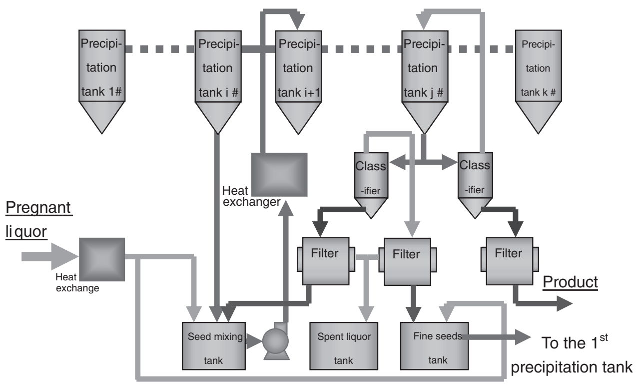

Figure 2 Schematic flow sheet of the pregnant liquor diffluence process

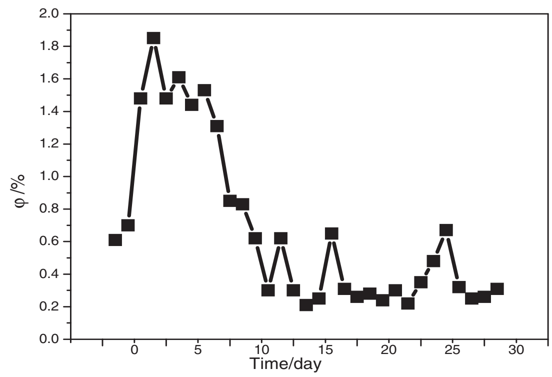

Figure 3 The characteristic parameter controlled by temperature adjustment

2.2 *Technology improvement in sintering-carbonation precipitation process*

2.2.1 *The intensified sintering technology*

The sintering process is a unique process developed to process bauxite with low A/S, the key point of the process is to convert the silica content in the bauxite into β-$2CaO \cdot SiO_2$, and to make the separation of aluminum and silicon easy . The traditional sintering process is ideal to treat low grade bauxite but the high energy consumption and low yield limit the utilization of the sintering process. So the major objectives of technological development in the Chinese Sintering Process are to intensify the process by raising A/S of bauxite, to increase cycle efficiency and reduce energy consumption.

Table 3 Comparisons of indices between traditional and intensified sintering process

	A/S of the bauxite inflow the grinder	Ratio in sintered material (t/t)	Unit energy consumption (Kg/t-AO)	Unit alkali consumption (Kg/t-AO)	Electric consumption (Kwh/t-AO)	Gas consumption (t/t-AO)
Traditional sintering process	7.5	3.5	1410	80	440	3.40
Intensified sintering process	10.0	2.5	994	73	350	1.25

Intensified sintering technology has been developed (CHALCO, 2001) to utilize bauxite with A/S>6 as the input. In traditional sintering process, the A/S in sinter is relatively low therefore, the unit cost of sintering process is high. In intensified sintering process, the alumina content in the sinter can be enhanced by temperature control during the sintering process and the alumina concentration in hydro process is also enhanced. As a result, the productivity and yield of sinter are increased and energy consumption is proportionally reduced (Table 3). At the same time, the application of rapid test and control technology of the sinter feed assures the accuracy and steadiness of sinter composition and makes the operation of the sinter kiln more efficient.

2.2.2 *Continuous Carbonation Precipitation Technology*

The traditional Carbonation precipitation technology is a unique technology to process pregnant liquor with high caustic concentration produced from the sintering process. It has advantages of a high decomposition rate and high hydrate yield, but the particle size of the product can't meet the quality requirement. In order to produce a coarse crystallization product by the carbonation precipitation process, the continuous carbonation precipitation process was developed. The traditional carbonation precipitation is a batch process without seed addition. The Continuous Carbonation precipitation is a continuous process with seed charge (Figure 4). It raises the production efficiency and plays an important role in achieving steady production and improving product quality. The particle ratio below 45 can be controlled under 15% by the Continuous Carbonation precipitation process during a relatively long period (Figure 5), the index of which the traditional carbonation process can't reach.

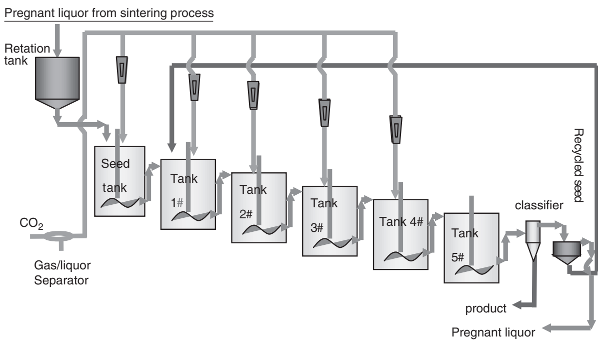

Figure 4 Schematic flow sheet of Continuous Carbonation Precipitation Technology

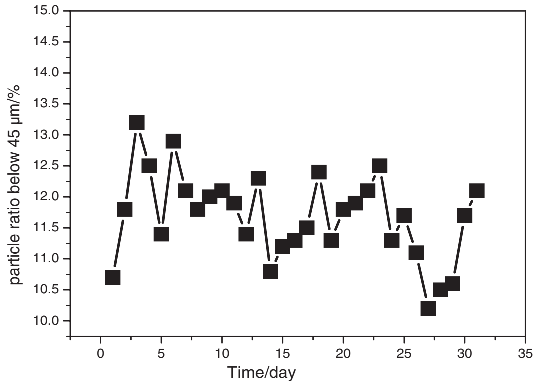

Figure 5 The indices of product by Continuous Carbonation precipitation Technology

3 The improvement of alumina production by technology development

By the technology development mentioned above, many indices in the alumina production have been improved. Firstly, the energy consumption has been reduced and the unit cost of alumina production has been decreased (Table 4).

Table 4 Unit energy consumption of the process before and after technology development

	Before technology development	After technology development
Bayer process	14	13
Sintering process	37	32
Mixed combined process	32	26
Average	32.2	22

The physical properties of the alumina products has been also improved, as shown in Table 5.The indices of alumina products have

Table 5 Indices of alumina products from different refineries

No.	Refineries	Detection results					
		+150μm/%	–45μm/%	Attrition index/%	BET	Angle of repose/°	Bulk density (g/cm³)
1	Henan Branch	5.9	14.1	10.6	63.2	31.6	1.07
2	Guangxi Branch	0.4	12.4	26.8	85.3	30.5	0.98
3	Guizhou Branch	0.5	14.5	29	72.8	31.7	1.08
4	Shandong Branch	4.5	15.2	22.9	71.9	32.0	0.94
5	Shanxi Branch	0.6	14.9	10	76.5	32.0	0.94
6	Zhongzhou Branch	4.5	15.6	17.4	78.4	32.0	0.93
7	Worsley	1.5	8.1	5.7	79.5	33.2	0.98
8	NALCO	0.8	15.7	25.1	64.8	32.6	0.98
9	Kwinana	1.3	10.1	9.8	84.9	33.1	0.98

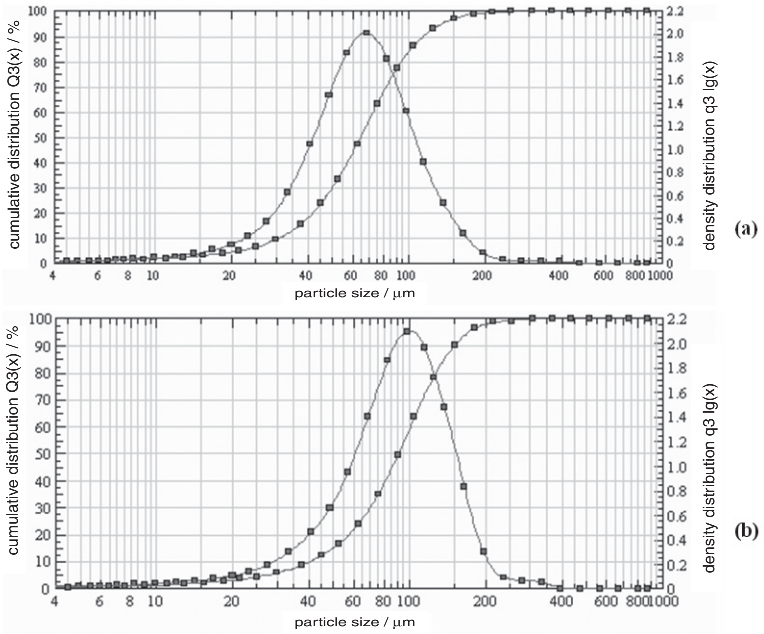

Figure 6 Comparison of particle size distribution before and after technology development
(a) before technology development (b) after technology development

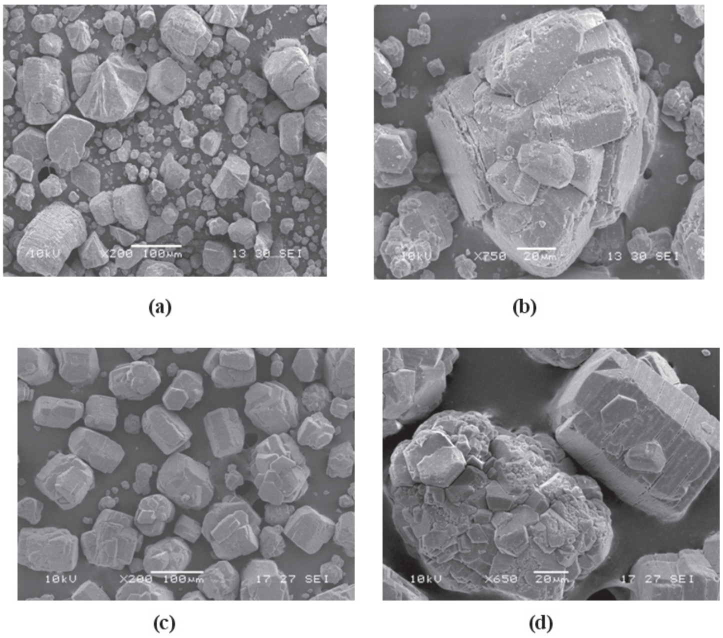

Figure 7 Comparisons of SEM images of products before and after technology development
(a) (b) before technology development (c) (d) after technology development

reached or exceeded the indices of sandy alumina. The particle size distribution (Figure 6) significantly improved. It was shown in Figure 7 that the fine particles were significantly decreased by employing new technology (Figure 7(a), (c)). Figure 7(b), (d) indicate that before the technology improvement, particles are agglomerated by large particles, while after the technology improvement, particles are agglomerated by relatively fine particles which are proved to have high intensity and not easily broken in the subsequent process.

4 Conclusions

After several years of research, CHALCO has developed a series of technologies to produce sandy alumina from diasporic bauxite in China. It has made great progress in the following aspects:

a) Bayer process has been successfully improved to produce sandy alumina by developing bauxite dressing, tube digestion, diffluence precipitation and model prediction technique.
b) The sintering process has been reconstructed by intensified sintering process and continuous carbonation precipitation process, and sandy alumina was produced by the new innovative process.

Acknowledgement

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