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CHINESE BAUXITE AND ITS INFLUENCES ON ALUMINA PRODUCTION IN CHINA

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Abstract

It is shown in this paper that the main bauxite deposits in China are located in such central and south-west provinces as Shanxi, Henan, Guizhou and Guangxi provinces etc. The chemical and mineralogical composition of various Chinese bauxites is reviewed to present the characteristics of the Chinese bauxites, which have great influences on the alumina production process. Key technology and equipment applied in China are also presented.

Introduction

Bauxite is the main raw material to produce alumina in the world. The bauxite grade, defined by the ratio of alumina to silica in weight percentage (A/S) and alumina content in bauxite, has a great influence on the consumption of energy, caustic soda and bauxite in the alumina production process. With the production growth the Chinese alumina industry is facing the challenges of grade reduction in the local bauxite resources, which brings out production instability and deterioration of process parameters and indexes. A common situation will happen to the bauxite mines that the grade of output bauxite is gradually reduced or there exist a large amount of lower grade bauxite resource nearby. The alumina refineries using such kinds of bauxite have to study the characteristics of the bauxite, the influences of the grade reduction on the production and how to efficiently process the bauxite.

Figure 1 shows that the alumina production in China is being developed with a great growth rate. The total alumina production in China was about 13.7 million tons in 2006, but will be more than 20 million tons in 2007, in which about one third will be produced from imported bauxite.

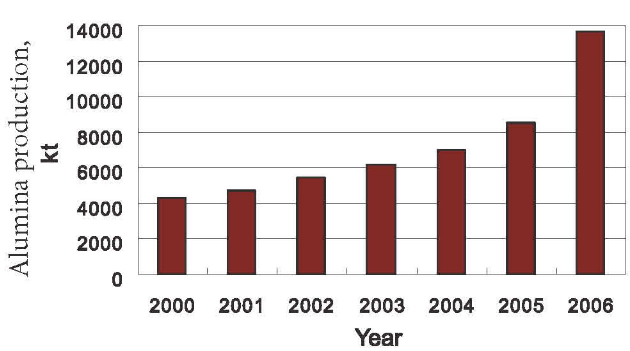

Figure1. Rapid growth of alumina production in China

Deterioration of the local bauxite grade is becoming more and more serious in some areas in China, such as Henan province where some important alumina producers are located. Compared with the bauxite grade 5 years ago, A/S ratio in bauxite has decreased by about 2-3, and alumina content has decreased by about 5%.

The Chinese alumina industry has developed a number of technologies to process middle or low grade bauxite which were a success and are widely applied in the production. Further development of new processes for enhancing the alumina production efficiency, reducing energy and caustic soda consumption is still an urgent task and a long term goal for Chinese scientists and engineers working in alumina field.

Distribution of Chinese Bauxite

A great amount of bauxite reserve has been found in China. According to the geological survey statistics in 2001, bauxite reserve is 0.539 billion tons, the basic reserve is 0.716 billion tons and bauxite resource is 1.787 billion tons, so total bauxite resource is more than 2.5 billon tons in China.

Chinese bauxite is widely distributed in the middle areas of China, especially in such provinces as Shanxi, Henan, Guizhou and Guangxi. The majority of mines are located in these four provinces and account for 90 % of the bauxite mine.

Recently some large bauxite deposits have been found and explored in Guangxi and Shanxi provinces. And a great effort is being made to explore new bauxite deposits and increase the bauxite reserve in China. It can be predicted that the Chinese bauxite reserve will be increased in the future.

More than 95% of Chinese bauxite reserve is diasporic bauxite. Only such provinces as Hainan, Fujian and Taiwan have small gibbsitic bauxite deposits, which are not used for alumina production yet. Some low grade gibbsitic bauxite deposit has been found in Guangxi province, for which a new process should be developed to reduce production cost. Up to now all the alumina produced by using local bauxite is from diasporic bauxite in China.

Figure 2. shows the distribution of the main local Chinese bauxite deposits and mines.

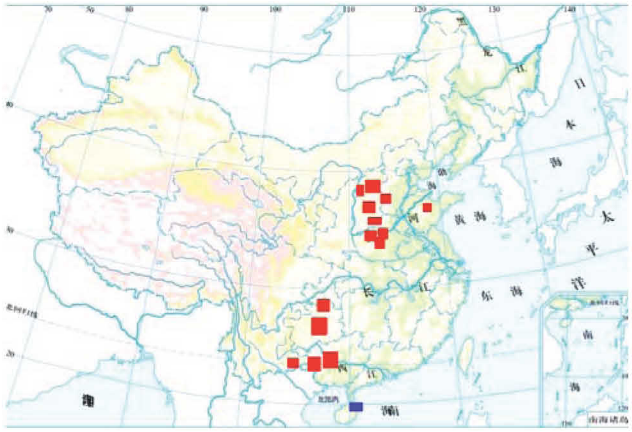

Figure 2 Distribution of main Chinese bauxite deposit and mines

Characteristics of Chinese bauxite

The typical chemical and mineral compositions of Chinese diasporic bauxite from different areas in China are shown in Table I.

Table I Typical Chemical and Mineral Compositions of Chinese Diasporic Bauxite

Items	Composition	Bauxite Location		
		Guangxi	Henan	Shanxi
Average chemical composition %	Al_2O_3	56.22	64.35	66.3
	SiO_2	6.21	9.94	13.36
	Fe_2O_3	19.15	5.93	1.02
	TiO_2	3.35	1.95	3.3
Average mineral composition %	Diaspore	60.25	69.52	65.71
	Gibbsite	2.18	/	/
	Kaolinite	4.99	2.77	25.85
	Illite	4.04	7.11	2.01
	Hematite	5.48	2.45	1.0
	Goethite	15.41	/	/
	Anatase	2.69	1.6	2.9
	Rutile	0.48	0.59	0.52

It can be seen in Table I that most of Chinese bauxite used in Chinese refineries has high alumina (usually more than 60%) and silica. Most Chinese bauxite has less than 5% Fe_2O_3 content except Guangxi bauxite. Guangxi diasporic bauxite is a very special kind of bauxite in China compared with other Chinese bauxite because it has high Goethite content (similar to most of gibbsitic bauxite) and a little lower alumina content, but also a high A/S ratio.

Table 2 shows the grade distribution of Chinese bauxite. It is found that about 80% of the Chinese bauxite reserve is low or middle grade with an A/S ratio of less than 7. Thus, most of Chinese bauxite has both high alumina and silica content.

Table II. Grade Distribution and Proportion of Chinese Bauxite

A/S	<4	4-6	6-7	7-9	9-10	>10
Reserve proportion range, %	7-8	48-49	10-11	14-15	11-12	6-7

A number of silica minerals are the main impurities in Chinese bauxite, such as kaolinite, illite, pyrophyllite and a series of aluminum silicates. Due to variations in silica minerals in different local bauxites, different processes and technologies are used in the different refineries.

Most of silica minerals in Shanxi bauxite appears as kaolinite, while the main silica minerals in Henan bauxite is illite and pyrophyllite. Guangxi bauxite contains a lot of chamosite. There is almost no quartz in Chinese bauxite.

With the rapid growth of the Chinese alumina industry, consumption of local bauxite resources has increased dramatically. As a result, shortages in bauxite supply, especially of higher grade bauxite, are emerging and the situation is becoming serious. Many bauxite mines are almost exhausted and only low grade bauxite can be mined. The average service time for some bauxite mines is even less than 10 years. The reduction in high grade bauxite supply and shortages of bauxite resources in China will greatly influence alumina production costs in Chinese refineries.

Influences of Bauxite Characteristics on Alumina Production

An acceptable digestion result can be obtained for diasporic bauxite in Bayer process only under the conditions of high caustic concentration and high digestion temperatures, which will result in the following consequences.

- High temperature difference in preheating of bauxite slurry: a more complicated preheating system will be needed and more energy will be consumed;
- Seeded precipitation at the higher caustic concentrations: lower supersaturation in the precipitation process will lead to a greater difficulty to produce sandy alumina and lower precipitation efficiency.
- Red mud settling at higher caustic concentrations: settling rate of red mud will be reduced at higher caustic concentration leading to increased flocculant uasage and costs ?.
- Higher evaporation strength due to higher concentration differences before and after evaporation: more energy will be consumed in the evaporation process.
- More serious scaling problem on the indirect preheating surfaces due to the fast reactions between liquor and the complicated silica minerals in bauxite at higher preheating temperatures and caustic concentrations: the lower heat transfer efficiency and operation cycling time will be brought about.

These five influence factors are mainly related to system energy consumption and the equipment suitability and technology optimization in the various processes for alumina production.

Due to the prescence of high amounts of silica in more than 80 % of Chinese bauxite, a great amount of DSP will be produced in the digestion process if a simple Bayer process is applied, which will lead to large loss of caustic soda and alumina from bauxite. As a result, caustic consumption will be increased, alumina recovery from bauxite will be reduced and production costs will be unacceptably high. Therefore, the typical Bayer process can not be used for lower grade Chinese diasporic bauxite for alumina production.

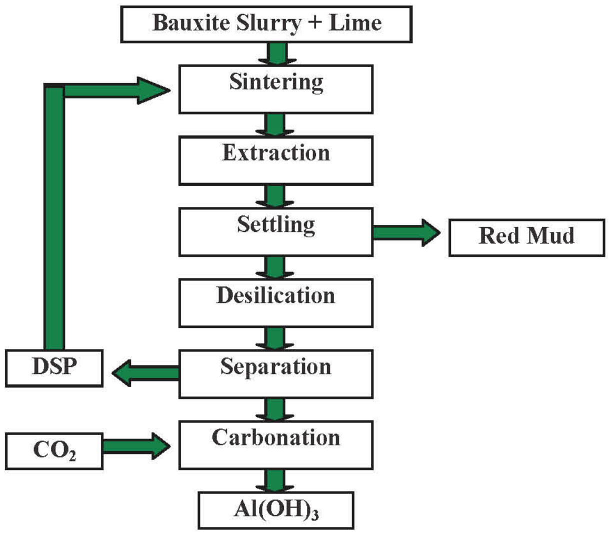

Figure 3. Schematic of the sintering process flowsheet

In order to utilize Chinese lower grade diasporic bauxite, the sintering process and Bayer-sintering combined process were developed by the production experiences in Chinese alumina industry in the past a few decades. About 60% of alumina will be produced from Chinese bauxite by these two processes this year. Figure 3 shows a brief flowsheet of the sintering process.

The major desilication reaction for the sintering process is the reaction between lime and silica minerals at the sintering temperature up to 1200°C. The main sintering product is hydro-calcium silicate with the formula of $2CaO{\cdot}SiO_2{\cdot}xH_2O$, in which x is changeable. The desilication product in the sintering process does not contain any alumina and caustic soda, so theoretically there is no loss of caustic and alumina in the red mud of sintering process. But in industrial practice some side-reactions must happen, such as, the reaction of hydro-calcium silicate formed in sintering with liquor in sinter extraction and red mud settling processes, which produces hydro-sodium aluminium silicate (so-called DSP), and the seeded desilication reaction of pregnant liquor after red mud settling for lower silica content in the liquor, both lead to some losses of caustic and alumina.

Although lime is used for desilication in the sintering process with relatively high efficiency, the ratio of alumina to silica in red mud discharged from sintering process can be reduced to less than 0.5 and ratio of caustic soda to silica reduced to less than 0.1, the sintering process will bring about huge and complicated production system, great investment and high energy consumption .

Thus, very high alumina recovery and low caustic consumption are achieved in the sintering and combined processes, while a great amount of energy must be consumed.

Compared with alumina industry in the world, the most important disadvantage for Chinese alumina production is higher energy consumption. Even though the energy consumption in Chinese alumina industry has been gradually reduced from past years, it is still as high as about 25 GJ/t Al_2O_3 in 2006, which is almost double of the average in the world. Energy cost is the most important influence factor and contributes more than 40% of operation cost in Chinese refineries.

The major energy consuming processes in a Chinese Bayer refinery are evaporation and digestion, while in the major energy consuming processes in the sintering process are sintering, desilication of sinter extraction liquor and the evaporation of carbonation liquor.

A great effort is being made in Chinese alumina refineries to reduce operation costs by lowering energy consumption while maintaing alumina recovery.

Key technologies for low grade Chinese diasporic bauxite

It is clear that Bayer process must be more widely applied instead of the sintering process in order to reduce energy consumption. But high silica content in Chinese bauxite limits the use of the Bayer process because of high caustic consumption and formation of large amount of DSP (the ratio of caustic soda to silica of which is about 0.68). Thus, to more readily apply the Bayer process with lower grade bauxites the following key technologies were developed and applied in China.

<u>Silica minerals in bauxite removal ahead of Bayer process</u>

Figure 4 shows the a brief flow sheet of a new Floatation-Bayer process. The key technology concept of this process is that some silica minerals are first removed from low grade bauxite before digestion in the Bayer process using floatation technology. The concentrates after floatation have higher grade (A/S) and can be used in Bayer process without unacceptable caustic consumption.

Floatation-Bayer process was developed at the end of last century and has been industrialized in Zhongzhou refinery of Chalco to process Henan local diasporic bauxite in China. This is a great success. And the production of Floatation-Bayer process is as high as more than 800,000 tons of alumina per year this year.

On the other hand, not all the alumina minerals can be recovered totally in the floatation process. This happens because it is difficult to separate all the alumina minerals from silica minerals only through the physical floatation and some silica minerals remained in the tails contain certain amount of alumina. The selective property of floatation additives has to be improved for higher selective separation efficiency of silica minerals. Since there are very complicated silica minerals composition in Chinese bauxite, especially high content of Kaolinite which is difficult to be removed, the floatation process has a long way to go for more satisfying results.

The important future developments in this process is to obtain high alumina recovery and less floatation additives addition in bauxite floatation which might have some negative effect on the consequent Bayer process. Therefore powerful and efficient floatation additives should be developed to improve alumina recovery and keep Bayer process efficient.

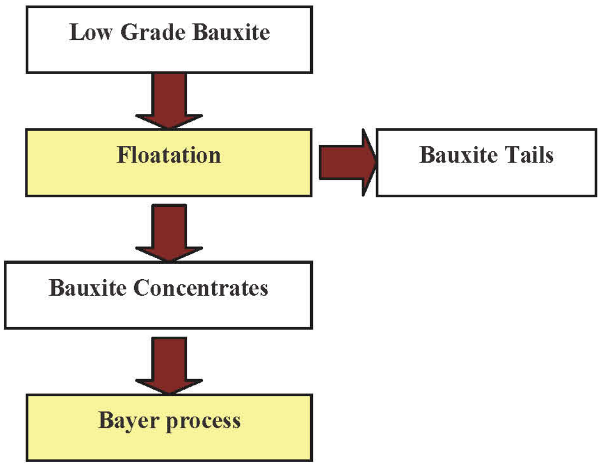

Figure 4 Schematic of Floatation-Bayer process.

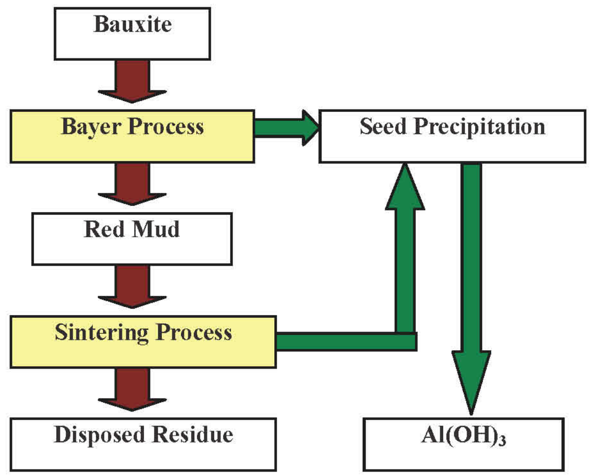

Figure 5 Schematic of the Series Process

Silica removal in Bayer process with less caustic consumption
In order to reduce caustic consumption in the Bayer process to treat lower grade bauxite the only way is addition of more lime, the main reason of which is lime can react with silica minerals in digestion process to form various types of hydrogarnet instead of general DSP. Hydrogarnet almost does not contain Na_2O, so silica is removed by extra lime addition. In this process more lime is consumed and more red mud is produced. The negative effects are the resulting red mud is more difficult to separate and thus flocculant and lime costs are higher. Suitable lime addition and better flocculant selection are the key technology improvement needs for this process.

Caustic recovery from red mud after Bayer process
There are some ways under investigations to recover caustic soda from Bayer red mud. Basically the Na_2O and Al_2O_3 in red mud can be extracted by caustic liquor under some conditions.
The recovery rate depends on the process conditions, such as the process temperatures and duration, caustic and alumina concentrations in the liquor etc.
The new processes can be developed by changing the process conditions. The best selection should be the process with higher recovery rate and lower process cost.

Bayer-Sintering Series Process
Figure 5 illustrates a flow sheet of Bayer-Sintering Series Process (BSSP). The red mud from the Bayer process is sintered by lime and caustic soda to extract Na_2O and Al_2O_3. Compared with a so-called Bayer-Sintering Combined Process (BSCP) shown in Figure 6, Bayer-Sintering Series Process has less sintering output proportion in the whole output of the refinery so less energy will be consumed on average, but this process produces less alumina than the Bayer-Sintering Combined Process because alumina content in the sinter is lower than the Bayer-Sintering Combined process and the output of the sintering process is lower as well.

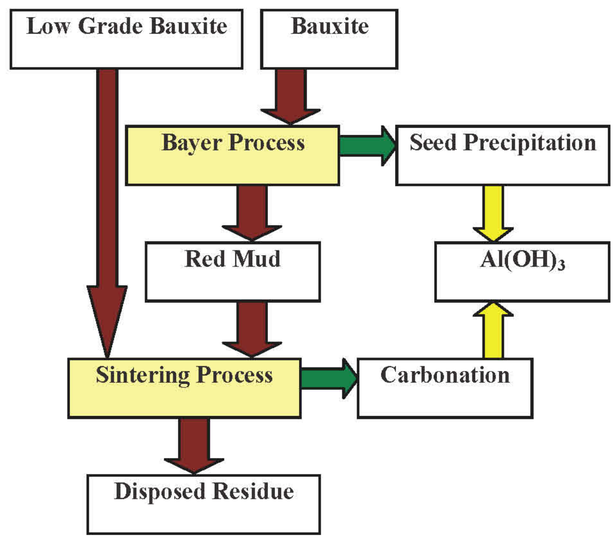

Figure 6 Schematic of Combined Process

Key technologies to save energy in Chinese refineries

The energy saving is of great importance in Chinese alumina industry because of too high energy consumption in the refineries and great potential to save energy as well.

There are a number of papers detailing efforts to reduce energy consumption in the Chinese refineries. The energy saving technologies in Chinese alumina industry can basically be classified as the following aspects:

(1) Bayer process modified. Most important for modification of Bayer process is the optimization of the concentration system in the Bayer cycle, including increasing caustic concentration, reducing the concentration difference between pregnant liquor and evaporated spent liquor and further enhancing the productivity at some stages and liquor cycling efficiency in the whole Bayer process.

(2) Sintering process modified. Increasing the cycle liquor concentration in the hydrometallurgical process of the sinter is the most promising technology to save energy for the sintering process, the main goal for which is reducing energy consumption in liquor evaporation and improve cycling efficiency. Sintering of slurry is the stage that consumes the most energy in the whole process. Reducing water content in the slurry before sintering and reducing recycling of DSP are the most important energy saving - measures for the sintering process.

(3) Application of higher efficiency equipment and control systems: Application of high efficiency equipment is essential to reducing electricity consumption, such as efficient pumps, new structure agitators and transducing fans etc. The energy utilization efficiency can greatly be raised by application of such up-to-date equipments as gas suspension calciners, falling film evaporators, fluidized digesters and efficient preheaters etc. Online inspection and automatic controls are the important measures to keep steady operation of the process, and to optimize process technological parameters and to improve process productivity as well.

(4) Better heat recovery and less energy loss: better energy recovery, higher transfer efficiency and less heat loss for all the stages in the alumina production process are the significant goals for energy savings.

Conclusions

(1) There is abundant diasporic bauxite distributed in the middle areas in China, mainly in such provinces as Shanxi, Henan, Guangxi and Guizhou.

(2) Most of Chinese bauxite is diasporic, with high alumina and high silica content. The bauxite grade used in Chinese refineries becomes lower and the Chinese alumina industry will face shortages of high grade bauxite supply.

(3) The characteristics of Chinese bauxite have great influences on the alumina production processes including high energy consumption, complicated processes and more capital investment in order to refine the alumina effectively.

(4) The key technologies to process Chinese high silica bauxite are bauxite benefication / flotation to remove silica minerals from bauxite ahead of Bayer process, silica minerals removal in Bayer process with less caustic consumption by additive addition, caustic recovery from red mud after Bayer process and Bayer-Sintering series process etc.

(5) There is a great potential to develop key technologies for energy savings in Chinese refineries using the Bayer process and combined process by applying the high efficiency equipment and control systems and better heat recovery and less energy loss in the process.

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