Light Metals 2011 *Edited by: Stephen J. Lindsay*
TMS (The Minerals, Metals & Materials Society), 2011

One Green Field Megaton Grade Large Alumina Refinery with Successful Engineering & Operation Experience

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Keywords: diaspore bauxite, alumina production, Bayer process, comprehensive energy consumption

Abstract: The Phase I alumina project (1.6million tons/a metallurgical grade alumina) of the Guangxi Huayin Aluminum Corporation Limited is a greenfield construction project with to-date, the largest disposable investment in the Chinese alumina industry. The project is based on a diasporic bauxite which is difficult to grind and dissolve, with a high aluminum & low silicon content. Two years of operational experience shows that the comprehensive energy consumption per ton alumina production is only 10.51GJ/t. This article introduces the process scheme & technical measures adopted in the engineering and operational stages of this project.

1. Introduction

Guangxi Huayin Aluminum Corporation Limited is a partnership of the Guangxi Investment (group) Corporation Limited, China Minmetals Non-ferrous Metals Corporation Limited and China Aluminum Stock Corporation Limited. The major investment is located in Mayi Town, Debao County, Guangxi Chuang Municipality, Guangxi. The construction of its phase I alumina project (hereinafter to be referred as Huayin phase I alumina project) has been targeted to produce 1.6 million tons/a of metallurgical grade alumina and is based on a total budgetary estimated investment of RMB 9.12 billion. .

The project was designed by the Guiyang Aluminium Magnesium Design & Research Institute, constructed and started up by China Aluminum International Engineering Corporation Limited as the general contractor. Construction was started in June 2005; the first production line was put into production in Dec. 2007, with all the production lines in operation in June 2008 and production & operational standards achieved in June 2009.

2. Bauxite resource and ore processing performance

Guangxi Chuang Municipality is abundant in high-quality bauxite resource reserves. The total explored bauxite reserves are 0.569 billion ton and the proven ones are 0.375 billion ton up to the end of 2005. As far as known from the ore bed investigation degree in Guangxi, the resource reserves reaching exploration degree are 28%, reaching detailed investigation are 22% and reaching general investigation are 48%, thus the bauxite investigation degree in Guangxi is high.

Guangxi bauxite contains 3 types of ore, including ancient weathering crust bauxite, accumulated bauxite and laterite bauxite. The proven resource reserves are mainly the accumulated bauxite and the ancient weathering crust bauxite, in which the accumulated diasporic bauxite is 83.5% and the ancient weathering crust diasporic bauxite is 16.5%. From the ore bed scale it is known that all ore beds in 10 large-size ore beds are accumulated diasporic bauxite and 3 ores in medium-size ore beds are accumulated diasporic bauxite. The accumulated bauxite mainly is distributed in Pingguo, Debao, Jingxi etc. in the west of Guangxi. This bauxite is characterized by medium aluminum content, high ferrous content, high alumina silica ratio, low sulfur content etc. and consists of diasporic bauxite, goethite, hematite and kaolinite being 85% content ,with lower content of other mineral, is the few high-quality bauxite resource in China can be used for producing the aluminum with Bayer process. The ore grade: Al_2O_3 is 45%-65%, generally 54%-60%; SiO2 is 3.4%-14% &, generally 5%-9%; alumina silica ratio is 4-11; Fe_2O_3 is 5%-25%, generally 10%-20%.

The bauxite in Debao and Jingxi County is the raw material for the Huayin phase I alumina project, and there is a mining division and an ore wash division respectively built in these two counties. The parameters of the mined bauxite in the first mining area are as follows:

Mining area	Al_2O_3 (%)	SiO_2 (%)	A/S	Water content of qualified bauxite (%)
Debao	≥56.64	≤5.75	≥9.84	≤7.0
Jingxi	≥55.80	≤5.94	≥9.39	≤7.0
Average	≥56.22	≤5.84	≥9.62	≤7.0

The ore processing performance test [1] result indicates that the bauxite in Debao and Jingxi is a diaspore dominated bauxite, characterized by high aluminum & low silicon content, and its performance is as follows:

- This bauxite is difficult to grind and its work index is large. The Bond rod mill work index is 20 mesh, Wi=16.02; the Bond ball mill work index is 120 mesh, Wi=22.55.
- Under the test conditions with a solid content of 320g/l in the slurry, test liquor caustic soda (Na_2O) being 245g/l and lime addition being 7%, the predesilication rate of this bauxite is close to 80% when the predesilication temperature is 90 to 100℃.
- Under the test conditions with digestion temperature being 260℃, digestion time being 40 min and lime addition

being 7%, the actual digestion rate reaches 86% and the relative digestion rate is 96%, however, with digestion time being 30 min, the actual digestion rate is 83% and the relative digestion rate is 92%. With a diluted slurry retention of 3 hours, the ratio of alumina content and silicon oxide content in the sodium aluminate liquor is always above 230. The bauxite in Debao and Jingxi is difficult to dissolve, so it requires higher digestion temperatures, higher caustic liquor concentration and finer bauxite granularity.

- After some flocculant is added to the slurry after digestion, the red mud settling speed can satisfy the industry production requirements, thus the red mud settlement performance is acceptable.

3. Process scheme and main operation indexes

The alumina refinery uses the Bayer process, based on the bauxite supply conditions. It consists of raw material plant (including bauxite storage & transportation, bauxite grinding, lime storage & transportation, lime slaking etc.), digestion shop (including high-pressure pump house, sleeve-tube preheating digestion & dilution etc.), red mud settling & washing plant (including red mud settling & washing, red mud filtration, red mud transportation, flocculant preparation, hot water station, security filtration etc.), precipitation shop (including pregnant heat exchange, seed precipitation, hydrate classification, intermediate cooling, seed filtration etc.), hydrate calcination (including product filtration, hydrate silo & hydrate conveying, calcination, alumina conveying & packing etc.), evaporation plant (including evaporation station, green liquor storage tank & water washing, test liquor storage tank, desalt, causticization etc.), circulating water shop etc.

The process flow of the whole plant is as follows: the bauxite is made into slurry after it is ground with the lime and qualified test liquor by the ball mill. The slurry after predesilication enters the digestion unit consisting of the sleeve-tube preheater and the autoclave, and the digested slurry after multi-stage self-evaporation enters the dilution tank. The diluted slurry enters the red mud settling & washing system consisting of large flat-bottomed settlers and drum filters. The red mud after washing is sent to the red mud stockyard and the settler overflow after security filtration and heat-exchange cooling, enters the seed precipitation system. The aluminum hydrate generated from the seed precipitation in converted to alumina through gas suspension calcination and the spent liquor after precipitation is fed back to bauxite grinding through the evaporation.

The technical scheme of each process section is as follows:

3.1 Bauxite grinding

A two-step bauxite grinding process is used, with the first step a rod mill open circuit and the second step a ball mill & hydraulic cyclone closed circuit.

The bauxite, being no more than 15mm from the homogenization stackpile, is sent to the bauxite silo of the bauxite grinding plant, and the lime from the lime warehouse is sent to the lime silo of the plant.

The bauxite and the lime are sent to the rod mill in proportion respectively by plant-type feeder & belt conveyor and electronic belt weigher & roller conveyor.

The test liquor required for bauxite grinding is taken directly from the evaporation station, and is added in proportion respectively from the outlet & inlet of the rod mill and the outlet & inlet of the ball mill.

The slurry ground by the rod mill and the ball mill together enter the slurry tank, and are then sent to the hydraulic cyclone for classification by the slurry pump. The underflow is sent back to the ball mill and the overflow enters the slurry storage tank through the rotary screen and becomes the qualified slurry, then sent to the high-pressure digestion by slurry pump.

This grinding scheme effectively solves the problem that the bauxite from Debao and Jingxi is difficult to grind and satisfies the digestion requirements to the bauxite granularity, which reduces the power consumption for the bauxite grinding by 6.22kw.h/t compared with the general bauxite grinding process and makes the bauxite granularity more uniform.

3.2 Predesilication

Considering the bauxite from Debao and Jingxi possesses good predesilication performance, the predesilication section is not here in the design and just requires more heating in the slurry storage tank. Fast slurry predesilication is achieved in the slurry storage tank, with 2 hours predesilication (the scaling in the single sleeve-tube preheater is very slow and the acid washing cycle of the single sleeve tube preheater is above 80 days during actual production, indicating that the predesilication effect is good and this measure is very successful).

3.3 Digestion

An eleven-stage preheating and ten-stage flash evaporation digestion device has been adopted for this plant.

The slurry from the raw material grinding section is sent to the high-pressure pump house, and to six-stage sleeve-tube preheater through a high-pressure diaphragm pump, and heated to 170 °C, with the secondary vapour generated by the self -evaporator. It then enters 4 autoclaves heated to 220 °C with secondary vapour, and is heated to the digestion temperature being 260 °C in a follow-up reaction autoclave with fresh 6.1MPa steam. It then enters an insulated autoclave for insulated retention for 40 min. The slurry after high temperature digestion, is sent to the dilution tank after the temperature reduces to below 126 °C through a ten-stage self-evaporation, and sent to the after tank by the pump, after it is diluted with the primary washing liquor from the red mud settling & washing and remains for some time. It is then sent to the red mud settler by pump. The feeding pump of this digestion device is a triple cylinder single action diaphragm pump.

There are many improvements in the utilization of digestion fresh steam condensate secondary vapour, the pore plate structure of the flash evaporator, heating pipes of the autoclave, continuous emission of non-condensing gas from autoclave, utilization of high-pressure digestion secondary condensate etc. in this engineering design compared with before. These make the steam consumption of the digestion system more reasonable.

3.4 Red mud settling & washing

A reverse washing system is adopted, consisting of red mud settlement by settler, triple settling & washing and primary washing by drum filter.

The solid-liquor separation of digestion slurry (concentration of caustic soda Na_2O being 172g/l) after dilution in the settler, the overflow (coarse liquor) is sent to security filtration and the underflow is sent to red mud washing system by pump. In this washing system, the red mud is treated using hot water addition through triple settling & washing. The washing water flows along the reverse routing of red mud and its concentration is gradually increased, finally being used for diluting the slurry after digestion.

The settler is a large flat-bottomed settler of 40m diameter. Some flocculant is added during operation so as to ensure the solid content of the settlement overflow is controlled within the specified limit.

The red mud slurry after triple washing is sent to drum vacuum filter by the pump so it is washed and filtered with water injection for the last time. The red mud after washing is sent to mixing reaction tank; the filtrate is back to red mud washing settler through the filtrate tank by pump.

The filtration area of the drum filter is $100m^2$, being equipped with water injection device. It can simultaneously carry out red mud filtration and washing. The alkali content in the residual liquor of the red mud after filtration, is reduced to 0.32% (dry basis) and the water content is adjusted to about 40% (wet basis). Finally the red mud is transported by a diaphragm pump to the red mud stockyard being 2 km away for dry storage.

3.5 Security filtration

The large double-star vertical leaf filter of the filtration area being $308m^2$ is adopted to filter the coarse liquor from the red mud settling & washing. It is characterized by light weight, less occupation area, higher automatization, being convenient for maintenance and high capacity. The solid content of filtrate is no more than 15mg/l.

The refined liquor(pregnant) from security filtration is sent to the pregnant heat exchange section by pump.

3.6 Pregnant heat exchange

This section is for simultaneously satisfying the seed precipitation temperature requirements and recycling the heat resource. The two mediums of heat exchange are respectively the pregnant liquor (inlet temperature being 100-105 °C and outlet temperature being 60-62 °C) from the security filtration and the spent liquor (inlet temperature being 45-48 °C and outlet temperature being 80-82 °C) from the product filtration.

The equipment for this section is a plate-type heat exchanger.

3.7 Seed precipitation

The seed precipitation system consists of large mechanical agitation precipitators of diameter 14m, intermediate cooling unit and classifier (hydraulic cyclone).

The sodium aluminate pregnant liquor after cooling is sent to the precipitation system where hydrate seed is added, and then the hydrate is generated by the precipitation over 45-50 hours.

Guangxi is in semi-tropical area in south of China, with a hot climate and high humidity. This limits the natural drop in temperature during precipitation and the increase in precipitation output rate. So intermediate cooling unit is added for higher precipitation output rate (the output of pregnant liquor can reach more than $88kg/m^3$).

Moreover, some crystallizing agent is added so as to intensify the precipitation of aluminum hydrate and also increase its granularity.

3.8 Seed filtration

This section has the function of seed supply for seed precipitation. The aluminum hydrate in the slurry from the last precipitator of the precipitation system is subjected to liquor-solid separation so as to obtain the aluminum hydrate seed; the spent liquor (caustic alkali Na_2O concentration being 181g/l) generated after filtration is sent to evaporation section for carrying out mother liquor evaporation, so as to obtain the test liquor

3.9 Recycle of aluminum hydrate in spent liquor

In the spent liquor obtained after seed filtration and product filtration, the aluminum hydrate content is about 2g/l. The existence of aluminum hydrate in the spent liquor increases the pipe blocking risk index of the evaporator heating pipe and reduces the circulating efficiency of the caustic alkali. So this project is equipped with an aluminum hydrate recycling section and a vertical leaf filter is the main device for this section.

The underflow from the spent liquor conical tank in the seed filtration section is sent to the vertical leaf filter for filtering out the aluminum hydrate in the liquor. The filtrate is sent back to the spent liquor tank in the seed filtration section, and the filter cake (aluminum hydrate) is sent to the overflow tank in seed filtration and is finally sent to the precipitation section as seed.

3.10 Evaporation and desalt

The super-concentrated desalting technology with a 6-effect falling film evaporator and forced circulating evaporator has been adopted. It is characterized with maturity & reliability, low energy consumption (steam ratio <0.27) and high efficiency desalting.

The spent liquor being 80 °C from the heat exchange is respectively sent to the 6th and 4th evaporator unit.

The liquor entering the 6th evaporator unit reaches the requirements after it is concentrated through the 6th effect evaporator and the 5th effect evaporator.

The liquor entering the 4th evaporator unit is concentrated through the 4th evaporator, the 3th evaporator, the 2nd evaporator and the 1st evaporator, and enters 2-stage flash evaporation, then respectively enters the 3th stage flash evaporation and super-concentrated evaporator in proportion.

The concentration of the evaporation liquor after 3-stage flash evaporation reaches the plant requirements; the concentration of caustic alkali Na_2O in the liquor after concentration through super–concentrated evaporator reaches 320g/l. The sodium carbonate crystals are removed from the slurry with salt grain discharged from the super-concentrated evaporator through the settler and filter, the overflow from the settler and the filtrate from the filter as well as the liquor from 5-effect evaporator and 3-stage flash evaporation converge to become the mother liquor.

Mother liquor, liquor after causticization, less evaporation green liquor and liquid caustic soda with alkali addition are mixed to be the test liquor with caustic alkali concentration being 245g/l,

and then it is sent to the bauxite grinding by pump after circulation through the liquor storage tank.

3.11 Product filtration & washing

The underflow from the hydraulic cyclone classifier flows to an aluminum hydrate slurry tank and the secondary condensate from the evaporation section enters a hot water tank, and the hydrate slurry and the hot water respectively are sent to a horizontal pan filter for hydrate separation & washing.

The spent liquor obtained through filtration is sent to the spent tank in seed filtration by pump. The washing liquor is sent to the red mud washing settler by pump and the filer cake is sent to the calciner or hydrate silo through a belt conveyor.

This section is mainly equipped with a large horizontal pan filter. Separation and 2-stage reverse washing of the aluminum hydrate is carried out in this filter. Some dehydrating agent is added so as the water content in aluminum hydrate is below 3%.

3.12 Calcination

The aluminum hydrate calcination uses a gas suspension calciner. The aluminum hydrate from the product filtration & washing or the aluminum hydrate silo, is sent to a small silo before the calciner, through the belt conveyor.

The aluminum hydrate in the small silo is sent to a gas suspension calciner through the feeding weigher and screw feeder, being burned to the required alumina specification.

There are two heat exchange stages in calcination: heat exchange between the aluminum hydrate and the exhausted gas generated through coal gas burning and between alumina and air required for coal gas burning.

The exhausted gas, with dust generated during calcinations, is discharged after passage through electrostatic filters to meet discharge standards.

The utilization of calciner waste heat has been greatly improved in later stage of this project, so RMB 10 million economic benefits per year can be gained.

4 Actual production conditions

The first production line of this project was put into production in December 2007; it took only 33 hours to go through the whole alumina production process flow. The second and third production line were successively finished in March and April 2008, and the commissioning of the fourth production line in May 2008 indicated that Huayin phase I alumina project was fully finished.

However, due to the international finance crisis coming, the China aluminum product was overstocked heavily and the alumina price declined significantly and continuously. So Guangxi Huayin Aluminum Corporation Limited had to reduce the output to limit loss, and ran at only 50% production before May 2009.

Guangxi Huayin Aluminum Corporation Limited checked the performance of Huayin phase I alumina project with the technical guidance of China Aluminum International Engineering Corporation Limited in June 2009. The checking results indicate that various indexes reached or exceeded the designed value, thus the performance checking was qualified.

The four production lines ran under full load in the last month of 2009 along with the recovery of the alumina market. The technical & economic indexes were obviously improved and the production cost is reduced, being below RMB 1100, thus the profit was achieved in July to December 2009.

Production statistical indexes of Guangxi Huayin Aluminum Corporation Limited in July to December 2009 are indicated below.

No	Item	Unit	Production statistical indexes in July to December 2009
1	Bauxite component		Al_2O_3 53.86% A/S 8.504
2	Output	kt/a	827.3 (converted into 1654.7 for whole year)
3	Product		Sandy Al_2O_3
	One-class product percent	%	99.78
4	Comprehensive energy consumption	GJ/t (kg standard coal/t)	10.51 (358.8)
4.1	Steam	t/t	2.438
4.2	Electrical power	kWh/t	246.3
4.3	Coal gas	Nm^3/t	617.1
5	Alkali (converted into Na_2CO_3)	kg/t	118.7
6	Bauxite	t/t	2.26
7	Lime	kg/t	243.8
8	Fresh water	t/t	2.97
9	Compressed air	m^3	39.93
10	Relative digestion rate	%	93.4
11	Pregnant liquor output	kg/m^3	87.63
12	Alumina recycling rate	%	81.01

5 Conclusions

Huayin phase I alumina project is a green field project with the largest disposable investment and construction scale in the Chinese alumina industry. It achieved the target of full commissioning in three years, and production & standards achieved after 1 year's commission, and thus establishes a new record in China alumina construction history.

Guangxi Huayin Aluminum Corporation Limited as a new plant can get away from the difficult position in the international finance crisis, because this plant possesses the right technical guidelines, excellent engineering design, better construction quality and strong production management, thus various indexes are at international advanced levels, especially comprehensive energy consumption per ton alumina production, being only 10.51GJ reaches the international leading standard.

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