22 August 2013

Joint Australia China Aluminium Industry Technology Symposium 2013

Book of Abstracts
JOINT AUSTRALIA-CHINA ALUMINIUM INDUSTRY TECHNOLOGY SYMPOSIUM 2013
Swinburne University of Technology
22 August 2013, Melbourne, Australia

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Prof Geoffrey Brooks

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Published in Australia by: Faculty of Engineering and Industrial Sciences, Swinburne University of Technology

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JOINT AUSTRALIA-CHINA ALUMINIUM INDUSTRY TECHNOLOGY SYMPOSIUM 2013
Swinburne University of Technology
22 August 2013, Melbourne, Australia
Joint Australia-China Aluminium Industry Technology Symposium 2013
22 August 2013, Swinburne University of Technology, Hawthorn Campus, Melbourne, Australia
Swinburne University of Technology - China Non-Ferrous Metals Industry Association

Opening formalities

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<td>8:30 – 9:00</td>
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<td>9:05 – 9:15</td>
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<td>Welcome address by Vice President of CNIA – Professor Pan Wenju</td>
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<td>9:35 – 9:40</td>
<td>Professor Geoffrey Brooks to introduce the signing of the agreements</td>
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<td>Signing of SUT-CNIA working plan</td>
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Session 1 – Chaired by Mr. BIAN Gang - Director, International Cooperation Department, CNIA

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<td>11:30 – 11:50</td>
<td>Mr Li Liangang – Vice President, Minmetals Group</td>
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<td>11:50 – 12:10</td>
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<td>12:10 – 13:30</td>
<td>Lunch</td>
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<td>Mr. Zhang Henghai – President, Shanghai Hengyang Co.Ltd.</td>
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<td>13:35 – 13:55</td>
<td>Dr Peter Smith – CSIRO Minerals Down Under</td>
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<td>13:55 – 14:15</td>
<td>Dr Mark Cooksey – CSIRO</td>
</tr>
<tr>
<td>14:15 – 14:35</td>
<td>Mr. BIAN Gang – Director, International Cooperation Department, CNIA</td>
</tr>
<tr>
<td>14:35 – 14:55</td>
<td>Mr. Ren Baifeng – Vice President, Antaike Information Co., Ltd</td>
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<tr>
<td>14:55 – 15:20</td>
<td>Afternoon coffee/tea</td>
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<th>Time</th>
<th>Session</th>
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<td>Introduction by Session Chair</td>
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<td>15:25 – 15:45</td>
<td>Professor Xinhua Wu, Monash University</td>
<td>Australia-China Research Centre for Light Metals – Its Mission and Activities</td>
</tr>
<tr>
<td>15:45 – 16:05</td>
<td>Mr. Yi Xiaobing, Vice President of GAMI Chinalco, China</td>
<td>‘Five Cycle Control (FCC)’ Technology for Aluminium Reduction Cells in China</td>
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<td>16:05 – 16:25</td>
<td>Mr. LIAO Xinqin, Principal Engineer of Chinalco, China</td>
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</tr>
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<td>16:25 – 16:45</td>
<td>Gregory Smith, Calsmelt Pty Ltd</td>
<td>Carbothermic Smelting of Aluminium</td>
</tr>
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<td>16:45 – 17:00</td>
<td>Close of symposium by Professor Geoffrey Brooks</td>
<td></td>
</tr>
<tr>
<td>17:15 – 18:00</td>
<td>Tour of SUT facilities</td>
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Campus Map – Swinburne @ Hawthorn, Melbourne

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Joint Australia-China Aluminium Industry Technology Symposium 2013
Swinburne University of Technology
Brief Introduction of the Primary Aluminium Industry of China

YI Xiaobing

CHALIECO GAMI Guiyang Guizhou, China 550081

Keywords: Bauxite, Alumina production, Primary aluminium production, High alumina coal ash, Al-Electric joint venture, abroad strategy

This paper analyses the main problems faced in the development of China primary aluminium industry recently, based on the present situation of Chinese bauxite, alumina and primary aluminium production chain. These are related to two key elements of bauxite and electricity supply which effects its development. The author puts forward some constructive opinions on the developing trends and direction.

Bauxite

The report[1] forecasts that in China the total bauxite resource at 1000m underground is 16.7 billion ton, and the proved bauxite resource is 3.753 billion ton, among which bauxite reserve being 2.855 billion ton and basic reserve being 0.897 billion ton. The Chinese bauxite is widely distributed in 20 provinces in the middle of China, but mainly concentrated in Shanxi, Henan, Guizhou and Guangxi Zhuang Autonomous Region, with being about 90% of total bauxite reserve in China. The distribution of Chinese bauxite is shown in Figure 1, and the typical chemical and mineral compositions of Chinese diasporic bauxite are shown in Table 1.

| Table 1 Typical chemical and mineral compositions of Chinese diasporic bauxite |
|-------------------------------|-------------------|-----------------|-----------------|
| Items                         | Composition       | Guangxi         | Henan           | Shanxi          |
| Average chemical composition (%) | Al₂O₃             | 56.22           | 64.35           | 66.3            |
|                               | SiO₂              | 6.21            | 9.94            | 13.36           |
|                               | Fe₂O₃             | 19.15           | 5.93            | 1.02            |
|                               | TiO₂              | 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            |

The Chinese bauxite is featured by high aluminium content, high silicon content and low iron content (also some kinds of bauxite have high iron content), and the most is of diasporic bauxite, only the few is of gibbsite with low grade and being associated with other mine.
Alumina production

The Chinese alumina capacity was about 54.49 million ton in 2012, with annual growth being 5.97% and further increased concentration rate. The alumina capacity of Chalco was still in the top, but with the proportion in total of China falling to 30% from 90% in 2005. The alumina capacity of both of Shandong Weiqiao Aluminium Industry Group and Shandong Shiping Huayu Alumina company was more than 5 million t/a, stepping into the world leading ranks. The alumina capacity of the top five enterprises accounted for about 65% of total of China, up 5 percentage points compared with 2011.

The actual Chinese alumina production in 2012 was 37.7 million ton, with annual growth rate being 10.6% and capacity utilization rate being 69.2%. Chinese alumina production is mainly distributed in Henan Province, Shandong Province, Guangxi Zhuang Autonomous Region, Shanxi Province, Guizhou Province and Chongqing Municipality, among which about 60% in Henan Province and Shandong Province. The distribution of Chinese alumina production in 2012 is shown in Table 2 [3].

<table>
<thead>
<tr>
<th>Location</th>
<th>Henan</th>
<th>Shandong</th>
<th>Guangxi</th>
<th>Shanxi</th>
<th>Guizhou</th>
<th>Chongqing</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alumina capacity</td>
<td>11416</td>
<td>10940</td>
<td>6722</td>
<td>5086</td>
<td>2700</td>
<td>831</td>
<td>37696</td>
</tr>
<tr>
<td>Annual growth (%)</td>
<td>9.6</td>
<td>0.1</td>
<td>27</td>
<td>1.5</td>
<td>32.8</td>
<td>110.1</td>
<td>10.6</td>
</tr>
<tr>
<td>Proportion</td>
<td>30.3</td>
<td>29</td>
<td>17.8</td>
<td>13.5</td>
<td>7.2</td>
<td>2.2</td>
<td>100</td>
</tr>
</tbody>
</table>

At present, there are 7 large alumina refineries to use foreign bauxite for alumina production in China, with alumina capacity being about 20 million t/a in total. These alumina refineries mainly are concentrated in Shandong Province, in which Shandong Weiqiao Aluminium Group, Shandong Shiping Huayu Alumina Company, Shandong Branch of Chalco and Nanshan Group have more than 90% of total imports in China. In May 2012, Indonesia announced the tightening of bauxite export, so many Chinese alumina refineries (including
Chalco) consider reducing the production, with total quantity being close to 5 million t/a as predicted. However, what is worrying is that the Chinese alumina capacity expansion is still strong. Excluding the alumina capacity expansion of the alumina refineries with domestic bauxite, only Shansong Weiqiao Aluminium Group plans to expand 4 million t/a alumina capacity, is moving into 10 million t/a capacity in total.

Since this century, the Chinese alumina production technologies have made great progress along with the fast development of the Chinese alumina industry. The alumina production technology with imported gibbsite developed at the same time as the alumina production technology with domestic low-grade diasporic bauxite, forming the coexisting situation of various alumina production technologies. The equipment for alumina production has gradually becoming larger more efficient and automatic, reaching the international advanced level, so as to improve significantly the alumina quality. The sandy alumina production technology with the diasporic bauxite as the raw material can, under the high alkali concentration conditions, ensure the requirements of modern large prebaked cells to physical & chemical properties of alumina. High energy consumption sintering processes are gradually being eliminated while new energy-saving technologies and equipment are being continually used, so as to continually reduce the energy consumption with significant energy-saving and slurry reduction effect. The semi-dry technology and the dry technology for red mud are gradually promoted while the technology of iron recovery from the high iron red mud is promoted and used in the industry, achieving good economic and social benefits.

Primary aluminium production

Since the beginning of this century, the Chinese electrolytic aluminium production and consumption has secured first place in the world for 11 years due to the strong growth in demand, becoming the leading force of global aluminium industry development. It is a statistical fact by China Nonferrous Metal Association that the Chinese aluminium capacity in 2012 reached 20.27 million ton, with distribution for 21 provinces as followed in Table 3[3].

<table>
<thead>
<tr>
<th>Rank</th>
<th>Province</th>
<th>Production</th>
<th>Annual growth rate</th>
<th>Rank</th>
<th>Province</th>
<th>Production</th>
<th>Annual growth rate</th>
<th>Rank</th>
<th>Province</th>
<th>Production</th>
<th>Annual growth rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Henan</td>
<td>3841.6</td>
<td>-2.13%</td>
<td>9</td>
<td>Guizhou</td>
<td>1014.6</td>
<td>15.34%</td>
<td>17</td>
<td>Chongqing</td>
<td>191.7</td>
<td>62.86%</td>
</tr>
<tr>
<td>2</td>
<td>Qinghai</td>
<td>2032.5</td>
<td>15.96%</td>
<td>10</td>
<td>Xinjiang</td>
<td>932.0</td>
<td>216.69%</td>
<td>18</td>
<td>Hebei</td>
<td>190.0</td>
<td>0.29%</td>
</tr>
<tr>
<td>3</td>
<td>Shandong</td>
<td>1826.6</td>
<td>0.29%</td>
<td>11</td>
<td>Sichuan</td>
<td>807.3</td>
<td>1.88%</td>
<td>19</td>
<td>Zhejiang</td>
<td>153.4</td>
<td>0.23%</td>
</tr>
<tr>
<td>4</td>
<td>Mongolia</td>
<td>1933.0</td>
<td>5.42%</td>
<td>12</td>
<td>Guangxi</td>
<td>664.9</td>
<td>2.14%</td>
<td>20</td>
<td>Fujian</td>
<td>150.0</td>
<td>2.29%</td>
</tr>
<tr>
<td>5</td>
<td>Ningxia</td>
<td>1523.5</td>
<td>27.67%</td>
<td>13</td>
<td>Hunan</td>
<td>335.9</td>
<td>2.25%</td>
<td>21</td>
<td>Jiangsu</td>
<td>112.5</td>
<td>2.30%</td>
</tr>
<tr>
<td>6</td>
<td>Gansu</td>
<td>1820.8</td>
<td>49.54%</td>
<td>14</td>
<td>Hubei</td>
<td>286.3</td>
<td>-10.26%</td>
<td>22</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>Shanxi</td>
<td>1043.1</td>
<td>-2.23%</td>
<td>15</td>
<td>Shandong</td>
<td>270.0</td>
<td>-8.43%</td>
<td>23</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>Yunnan</td>
<td>1059.7</td>
<td>11.41%</td>
<td>16</td>
<td>Liaoning</td>
<td>263.2</td>
<td>24.40%</td>
<td>-</td>
<td>National totals</td>
<td>2026.75</td>
<td>12.21%</td>
</tr>
</tbody>
</table>

The Chinese primary aluminium industry has completed the development stages from Soderberg to heat dissipation prebaked cells, then to heat-insulation energy-saving cells. The Soderberg cells with high energy consumption/high pollution and small prebaked cells at 100KA or below had been or are being eliminated while the large (400KA above) cells with low energy consumption (DC consumption less than 12500kwh/t-Al) are developed. Compared with 2005, the greenhouse gas emission of electrolytic aluminium has been reduced by 21.17%. Chinese technical equipment for primary aluminium production already
matches the advanced world level and is leading the development direction of world aluminium industry, being capable of exporting and occupying part of the international market.

**Analysis on development trend of Chinese primary aluminium industry**

In 2012, in the case of that the world economy weakened and the Chinese economy growth slowed down, the Chinese primary aluminium production increased smoothly and the investment enthusiasm for primary aluminium industry was still high, however, the economic benefit of primary aluminium industry reduced significantly due to the declining aluminium price and increasing costs. Changes in alumina production and the aluminium production from 2007-2012 are shown in Figure 2[4].

At present, except the condition of resources, raw materials and power supply, regarding to the construction industry chain, transportation, water supply and labour costs also are effecting the development of the Chinese primary aluminium industry. Among of them, bauxite and power supply are also key factors.

![Figure 2 Alumina and aluminium production in China](image)

**Effect of the change in supply and conditions of bauxite on the alumina production**

China has per capita proved bauxite reserves which represent only 14.2% of world production. The bauxite consumption for Chinese alumina production was about 94.29 million ton in 2012, among which foreign bauxite 39.61 million ton and domestic bauxite supplied 54.68 million ton. The dependence on foreign bauxite was 42.0%, down by 10.5% compared with 2011, mainly due to the change in bauxite export policy of Indonesia. China imports the bauxite from only a few countries, with almost 80% from Indonesia and the rest from Australia and other countries. Therefore, Chinese alumina refineries are required to look for the other foreign bauxite resource, which is forced by the current situation and it is inevitable choice for avoiding risk. At present, A/S (ratio of alumina to silica in weight percentage) of 70% of bauxite in China is only 4~6, and the insoluble diaspore deposits accounts for more than 98% of total while the soluble and easy-exploited gibbsite only accounts for 1.6%, that brings the huge pressure on alumina production process selection and production costs. The Chinese alumina industry faces a big challenge along with declining bauxite grades and the increasing energy and caustic alkali prices in China.
For the major issue for achieving the sustainable development of alumina industry, the main work in progress is follows:

1) Technical innovation according to Chinese bauxite status

   To fully exploit the potentials and advantages of Chinese bauxite resource and high-temperature Bayer process, enhance the output rate and cycle efficiency of key sections in Bayer process and reinforce the Bayer process for technical innovation, thus improve obviously the technical level and core competence of Chinese alumina production. Specifically, the different main technologies and development directions are adopted based on the different resource conditions, so as to achieve the relevant development goals[^5], shown in Table 4 in details.

   **Table 4 Technologies adopted based on different resource conditions**

<table>
<thead>
<tr>
<th>Resource conditions</th>
<th>Main technologies</th>
<th>Development direction</th>
<th>Development goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-grade bauxite A/S&gt;5.5</td>
<td>Bayer process</td>
<td>High-efficient reinforcement</td>
<td>Energy-consumption, material consumption and production cost reach the advanced world level.</td>
</tr>
<tr>
<td>Medium-grade bauxite 5.5&gt;A/S&gt;4.5</td>
<td>Bayer process; Ore-dressing Bayer process; Lime Bayer process</td>
<td>High-efficient reinforcement; Beneficiation of optimization</td>
<td>Energy-consumption, material consumption and production cost reach the good world level.</td>
</tr>
<tr>
<td>Low-grade bauxite A/S&lt;4.5</td>
<td>Wet series technology; Dry sintering technology</td>
<td>Reinforcement for improving efficiency; Process simplification; Heat recovery</td>
<td>Energy-consumption, material consumption and production cost reach medium world level.</td>
</tr>
</tbody>
</table>

2) To seek alternative resource and adhere to scientific and technological innovation

   Inner Mongolia and Shanxi province have abundant high alumina coal ash. The research on the alumina extraction from the high alumina coal ash has become a hot research topic of coal, power and aluminum industry of China. Such research is carried out by many enterprises, universities and institutes, so as to obtain many effects, and some of these enter the industrial research stage.

   The chemical composition of coal ash mainly depends on its mineral composition. 15%-35% alumina, 30%-50% SiO₂ and some metal oxide including iron oxide, calcium oxide and titanium oxide are contained in the coal ash. For the coal ash in Inner Mongolia and Shanxi Province, more than 38% alumina is contained in it. The coal ash from some power plants has 45%-53.5% alumina, which is considered as the high alumina coal ash and has the same alumina content as the bauxite, being a kind of potential resource for Chinese aluminum industry.

   At present, for the alumina production with high alumina coal ash, many problems are required to be solved, but also there have been successful industrial tests[^6] as follows:

   - Predesilication – soda lime sintering process

     The predesilication – soda lime sintering process for alumina extraction from high alumina coal ash is improved based on the limestone sintering process of 70’s last
century. The coal ash is treated through predesilication before entering the alumina production system, in this case, much of SiO₂ in the coal ash reacts with proper concentration of caustic soda under certain conditions to generate sodium silicate solution which is used to produce the white carbon black, active calcium silicate and other silicone products, while the coal ash with significantly increasing A/S after predesilication is used to produce the alumina by a sintering process.

- Acid process

The acid process is to mix the high alumina coal ash with the acid in proportion and react with each other under certain conditions to generate the aluminum salt solution. After purification, the aluminum salt solution is evaporated to obtain the intermediate product of aluminum salt. The aluminum salt is calcined to obtain the alumina, while the calcining gas is reused after acid-making.

3) To adjust production organization mode based on the ore source

In recent years, the advanced Bayer process is adopted for all the Chinese newly-built alumina production lines along with the increasing bauxite import and improving technologies, with more than 86% of alumina capacity produced lines using the Bayer process. Due to the change in the bauxite export policy of Indonesia, the alumina refineries using the Indonesian bauxite as the raw material will consider adjusting the production organization mode, which is that the original raw materials proportion of low-temperature Bayer production line is adjusted. For instance, one aluminum company uses the Australian gibbsite and boehmite. Australia has gibbsite and boehmite which is mainly from Weber mining area and Gove mining area. The Australian ore has relatively stable quality, with A/S being more than 7, but most is of high-iron ore which is required to be separately ground and digested as well as be mixed after settlement. Moreover, one aluminum company is demonstrating the feasibility of conversion from a low-temperature Bayer process to a high-temperature Bayer process and also plan to build new high-temperature Bayer processes.

Effect of change in power supply conditions on primary aluminium production

The smelters constructed in the progress of abroad primary aluminium industry development mainly sign the long-term power supply contract for reasonable price, or consider the power plant into the smelter’s investment by “Al-Electric joint venture”. The power cost of large smelter is generally considered as 25%-30% of total cost at maximum, so as to improve the product competence and anti-risk capability.

In recent years, especially since this century, the power price of smelters has shot up along with the rapid development of Chinese primary aluminium industry. To eliminate the backward production lines and limit the high energy consumption industries (especially smelters), the government has adjusted the power price of most of the smelters for several times since 2005, so that the average power price of the Chinese smelters is much higher than that of the primary aluminium industry of developed & developing countries, with comparison between China and other countries shown in Figure 5.

The power consumption of Chinese primary aluminium industry accounted for about 6% of national total generation in 2012, and the most is the thermal power distributed for the power
grid. The number of the smelters by “Al – electric joint venture” is relatively less, with captive power rate being only about 1/3.

The low proportion of reproducible clean energy results in a high power price and high indirect carbon dioxide emission of primary aluminium production and also brings about huge pressure for energy-saving and emission-reduction in the Chinese primary aluminium industry, moreover the RMB exchange rate is appreciated faster, which makes the international competitiveness of Chinese primary aluminium industry reduce significantly. Therefore, the smelters undertake the activities on cost-decreasing & benefit-increasing and energy-saving & emission-reducing while the national government and regional government take some steps. It should be noted from Table 3, aluminium production in middle and west of China accounted for respectively 40.58% and 47.62% and that in east accounted for only 12.64% in 2012. Due to the effect of the regional difference of resource price, the primary aluminium production and the newly-added capacity in China have been transferred from east to west.

![Figure 5 Power price comparison of primary aluminum industry](image)

**Suggestions**

1) **Intensified efforts for bauxite exploration**

   To increase the investment in bauxite exploration, increase the proportion of conversion from total bauxite resource to proved reserves, basic reserve and bauxite reserve and prolong the guarantee period of bauxite resource.

2) **To fully tap the potentials of existing alumina refineries and smelters for cost-decreasing & benefit-increasing by the following methods:**

   a. Technology upgrading
   
   b. “Al-Electric joint venture”
   
   c. Product extension etc.

3) **To speed the technical development of alumina production with high alumina coal ash, so as to reduce the external dependence of alumina industry.**

   As predicted, the high alumina coal ash in China can support the alumina industry for more than 100 years. So it is recommended that the government should give more attention to the research & development and industrialization of alumina production with high alumina coal ash, so that the demonstrative base of economic alumina production available for industrial application can be formed as soon as possible, being the dominant technology for supporting the sustainable development of the Chinese alumina industry.
4) To increase properly the import of primary aluminum and aluminum scrap, so as to achieve the dual goals of energy-saving & emission-reducing and control total production from electrolytic aluminum.

It is recommended that China would import 3-5 million t/a primary aluminum and 6 million t/a aluminum scrap from 2015, so as to realize the direction CO2 emission reduction by 54% and the total emission reduction by 44% up to 2020, and with recyclable aluminum amount being 50% of total consumption up to 2030.

5) To fully use renewable resources and clean energy, so as to optimize the aluminum industry structure.

It is recommended that 3 main production bases of aluminum industry are formed in China based on the comprehensive advantage analysis regarding location, resource and energy, namely:

- An aluminum industry based on imported bauxite or alumina and supported by wind energy or nuclear energy;
- An aluminum industry based on alumina production with high alumina coal ash and supported by rich thermal power and wind energy;
- A aluminum industry based on rich bauxite as the raw material for alumina production and supported by rich hydroelectric resource;

6) To support the abroad strategy of large aluminum group – to newly-construct the large bauxite mines, alumina refineries and smelters by joint venture & equity participation or sole investment.

As China has joined WTO and as world trade deepens continually, the Chinese aluminum industry has gone to the world, especially cooperating with Asia and Australia, which will be further developed and extended.

References


Biography of Presenter

Yi Xiaobing
CHALIECO GAMI Co. Ltd.
Deputy Engineer & Professor

Mr. Yi has been involved in the design and research works for primary aluminium industry about 30 years after graduating from the Centre South of University of China, and took part in the engineering and construction works for several large aluminium smelter projects as chief designer in the domestic and foreign countries. He is an specialist in the area of smelter process technology also, and has been involved with technology exchange with more than 10 countries. He has published 20 papers in journals and international conferences.

易小兵 ——
中铝国际 贵阳铝镁设计研究
院有限公司主管副总工程师
教授级高级工程师

易小兵先生自中南大学毕业至今，在铝工业从事设计和研究工作已经30余年，曾作为项目总设计师先后成功参加了数个国内外大型铝电解工程的设计和施工建设。他还是一个铝电解工艺技术专家。到现在为止，他去过十几个国家进行技术交流并发在国内外期刊杂志和国际会议上发表了20余篇文章。
An Overview of the Australian Aluminium Industry

Miles E Prosser
Australian Aluminium Council

Keywords: aluminium, alumina, bauxite, industry, policy, Australian dollar

Australia is a significant player in global aluminium supply chains in the bauxite, mining, alumina refining and aluminium smelting sectors. These sectors have a particular export focus with approximately 80% of production destined for overseas markets. Australia also retains a downstream aluminium industry but this has a greater focus on domestic markets and faces competition from a significant level of imports.

Recent investments and announcements describe the quite different current trends within each sector:

Aluminium smelting
The Kurri Kurri smelter closed in September 2012, leaving five smelters operating in Australia at an approximate annual production of 1.7 million tonnes. The Point Henry smelter and the Bell Bay smelter were both subject to viability reviews by their owners. Both smelters remain operating in the short term, albeit with the assistance of a Government package in the case of Point Henry. All smelters, including Portland, Tomago and Boyne Island are subject to significant cost restraint.

Australia’s aluminium smelting sector is showing declining production levels in the face of increasing operating costs.

Alumina refining
There have been recent expansions in the Australian alumina refining sector in both greenfields facilities (such as Yarwun) and expansions of existing sites (Worsley and Yarwun). These expansions have built on Australia’s relative strengths of: bauxite availability; energy resources; and stable political and investment environments.

With a high Australian dollar and rising energy and project costs - and the Yarwun and Worsley expansions now completed - there are not expected to be further expansions or new facilities in the immediate short term. The Gove refinery is currently seeking to switch from fuel oil to gas as a means of reducing production costs.

Bauxite mining
There have been steady increases in the rate of bauxite mining over the last decade along with recent increases in the quantity of bauxite exported. This trend is expected to continue, if not increase, with the development of the South of Embley project and the current process to allocate and develop the Aurukun resource.
Whether the current trends of declining aluminium production, stable alumina production and increasing bauxite exports continue will depend on the future path of a range of market and policy factors.

Key market factors include the value of the Australian dollar, energy (electricity and gas) costs, the aluminium price, and any differing trajectory for alumina and bauxite prices.

Key policy factors include carbon pricing (or other emissions reduction policies), the Renewable Energy Target, energy market reform and regulatory approval processes.

**Conclusion**

The Australian industry will remain a significant global player in the bauxite mining, alumina refining and aluminium smelting sectors. The coming years are likely to see a shift up the supply chain to greater levels of bauxite mining, lower levels of aluminium smelting and an uncertain trend for alumina refining. These macro trends will be influenced by market and policy factors with the most significant in each sector being:

- **Aluminium smelting**: Australian dollar, renewable energy target, carbon pricing, electricity costs;
- **Alumina refining**: Australian dollar, gas costs;
- **Bauxite mining**: Regulatory approval processes.

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**Biography of Presenter**

**MILES PROSSER**

Miles Prosser is the Executive Director of the Australian Aluminium Council, the peak association for the bauxite mining, alumina refining and aluminium smelting industry sectors. Miles has twenty years experience in industry policy issues. He has previously worked for the pulp & paper and forest industries on a range of issues relating to resource allocation, sustainability and climate change. Miles has experience in the development and implementation of policy from the perspective of Government, resource suppliers, major processing companies and industry associations. The priorities of the Australian Aluminium Council include an effective response to climate change, energy policy and the reputation of the aluminium industry and its products.
Overview of Australian Research into Aluminium Production

Professor Geoffrey Brooks
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Keywords: aluminium research Australia, Cluster of Breakthrough Technology for Primary Aluminium

Australia has a strong tradition in primary Aluminium research, through activity at industrial laboratories and at CSIRO (the government industrial laboratories). In the case of Universities, most of the primary Aluminium research has historically been at University of New South Wales, where Professor Barry Welch and Professor Maria Skyllas-Kazacos have established an international reputation. In recent years, other Universities, who are strong in pyrometallurgical research, have become active in primary Aluminium research.

In 2009, a cluster of five Australasian Universities was formed to address the significant challenges facing the Aluminium industry. The partners are CSIRO, Swinburne University of Technology (SUT), University of Auckland (UoA), University of New South Wales (UNSW), University of Wollongong (UoW) and University of Queensland (UoQ). Over twenty researchers at the six institutions have been heavily involved in various projects, including: Professor Peter Hayes (UoQ) (pyrometallurgical fundamentals), Professor Eugene Jak (UoQ) (pyrometallurgical thermodynamics), Professor Maria Skyllas-Kazacos (UNSW) (electrochemical reactions), Associate Professor Jie Bao (UNSW) (advanced control systems), Professor Brian Monaghan (UoW) (high temperature experimentation), Assoc. Professor Sharon Nightingale (UoW) (industrial refractories), Professor Geoffrey Brooks (SUT) (modelling of high temperature processes), Professor Yos Morsi (SUT) (applications of fluid mechanics to pyrometallurgy) and Dr Akbar Rhamdhani (SUT) (fundamentals of metal refining).

A suite of ten projects across three broad themes were developed through extensive discussion with CSIRO personnel and reference to major industry reports. The three major themes were:

**Cell Design and Operations** – optimising the existing electrochemical process through the development of new materials for the cell and better understanding of chemistry of the Hall Heroult process

**Alternate Processes and Breakthrough Technology** – developing and assessment of new routes to produce Aluminium including both pyrometallurgical and low temperature routes

**Process Control** – improving control of the existing process via improve human interfaces, using advanced control techniques and better understanding of the bubbling phenomena between anodes and cathodes.
The cluster operated on an $8-million budget over three years, of which approximately 50% coming from the CSIRO collaboration fund and the rest from the University partners. All projects were formally reviewed by written and oral reports every four months. The projects were designed against a milestone structure and progress was measured against the agreed milestones. The cluster has been a success, with the following notable achievements:

- Two new cells materials have been successfully developed, one of them, developed at the University of Auckland used a novel densification technique to improve existing Silicon Carbide sidewall materials, the other, developed at the University of Wollongong has demonstrated that dense spinel based ceramics can survive the extreme conditions of aluminium smelting.\(^1\)

- A novel technique for monitoring cell performance against a process model was developed by Associate Professor Jie Bao (UNSW) and his team and tested at an industrial site with an industrial partner.\(^2\)

- Novel routes to Aluminium production have been evaluated. The chloride route was thoroughly investigated, including technical and economic evaluation of the process. A novel technique for separating chloride was proven at the laboratory scale. A new approach to forming the sulphide from alumina has been successfully established at the Swinburne University of Technology after thermodynamic and experimental evaluations of various alternate routes were carried out.\(^3\)

- A new approach to physical modelling of Hall-Heroult cells has been established by researchers at CSIRO and Swinburne University of Technology.\(^4\)

- Excellent collaboration has developed between the partners and good industry engagement achieved.

In summary, the research capability of Australian Universities in Aluminium smelting and refining has grown in recent years and Australia has several leading international researcher associated with primary Aluminium production and refining.

References


Biography of Presenter

Professor Geoffrey Brooks, B.Eng.(RMIT), B.A. (SUT), PhD (Melb.), F.I.E. Aust

Professor Brooks has been a Professor of Engineering in the Faculty of Engineering and Industrial Sciences at Swinburne University of Technology since 2006, where he leads the High Temperature Processing research group. Previously, he was a Senior Principal Research Scientist at CSIRO (2004-2006), an Associate Professor in Materials Science and Engineering at McMaster University (2000-2004) and a Senior Lecturer at the University of Wollongong (1993-2000). In the 20 years since completing his PhD at University of Melbourne, he have established an international reputation in the field of materials processing, publishing over 130 papers and running large research projects with funding from many major companies and government agencies from three countries. The great majority of these studies have concentrated on high temperature processing, including research into steelmaking, aluminium and magnesium production. Professor Brooks was the leader of the Cluster for Breakthrough Technology in Aluminium Production 2009 to 2012, which was an $8-million research consortium built around the activities of five Australasian Universities and CSIRO. He is currently active in work on limiting heat losses from Aluminium production, dross formation in aluminium processing, development of new routes to aluminium production, development of sensors for bubbling in high temperature operations, modelling of injection processes, modelling of steelmaking, use of thermal solar energy production of materials and controlling impurities in the recycling of aluminium. Professor Brooks is Fellow of the Institute of Engineers (Australia) and in 2013 received the John Elliott Lectureship from the AIST, acknowledging his contribution to the international steel industry.
The Overview of China’s Aluminium Industry

LI Liangang
Vice General Manager
China Minmetals Non-Ferrous Metals Co., Ltd

Keywords: primary aluminium, output and consumption, alumina, bauxite, market

This paper describes the overview of China’s aluminium industry. Since 2000, China’s aluminium industry has been expanding rapidly and this trend is still going on in the next three to five years and later will slow down. Building and construction, transportation and durable goods are the main fields of consumption. With the acceleration of China’s urbanization and the change of consumption pattern, China’s aluminium consumption will remain high growth rate in the next five to ten years, but averagely lower than that in the past decade. Although China has become the biggest country in aluminum output and consumption, it still needs to strengthen the ability in downstream production.

The expansion of China’s aluminum industry puts forward a new challenge to the resources and the energy. The situation of domestic bauxite is not optimistic and the political risk of Indonesia export ban is still existing. But in the long term, the exploitation overseas and alternate resources like coal ash will meet the demand. Chinese new government has focused on the “capacity cut” and this will help restraining the rapid expansion of the aluminum industry, and thus improving the supply-demand balance. This encourages the exploitation of bauxite and building of aluminum smelting plants overseas. The “integrated coal-power-aluminum” mode is promoted. Mergers and acquisitions from aluminum enterprises in different regions are also promoted. Overall there are optimistic views of China’s and global aluminum industry.

Biography of Presenter

Liangang LI
Vice General Manager, China Minmetals Non-ferrous Metals Holding Company Limited
Chairman, Minmetals Aluminium Co. Ltd.
President, Sino Mining International Limited

Liangang Li has over twenty years natural resources experience across a range of commodities, in both a technical and managing capacity. Liangang has managed and worked on due diligences, feasibility studies and reviews on worldwide mining projects including Australia, Jamaica, Southeast Asia and China. Over the last ten years Liangang spent his time in aluminium sector and his experience includes marketing, valuation, strategic planning and optimising business performance.
Overview of Bauxite and Alumina Economics and Trade

Bill Dalton
CM Group

Keywords:

Biography of Presenter

Mr Bill Dalton
CM Group

Bill Dalton is a degree qualified Metallurgical Engineer and comes to the CM Group with over twenty years experience in the metallurgical industry, initially as an engineer and then as a business analyst. Bill is based in Adelaide as the Principal Analyst. Bill’s background equips him well to form an in depth understanding of the critical issues for each project, both technical and business.
Development of Anode Baking Furnace New Materials and Structure

ZHANG Henghai
Shanghai Hengyang Co Ltd

This paper explains the progress of the development of the anode baking furnace materials and structures. The major developments are explained below:

1. Applications of high strength, high thermal conductivity and energy-saving flue walls in the anode baking furnace (HY-MAC high thermal conductivity flue-wall). The high thermal conductivity flue walls include the new processing technology of MgO sintering, where the main materials includes Magnesia-Alumina-Chrome spinel, and chromium concentrate material and agglutinant. This has main characteristics of the followings:
   - The thermal conductivity is 3-4 times higher than traditional bricks or flue walls and high speed increasing temperature
   - High thermal utilization efficiency, high temperature resistance, high compressive strength, high erosion resistance.

2. Applications of control and vacuum leakage prevention, exhaust and blast for the anode baking furnace flue-wall (HY-2 multi-functional cross wall unit (or headwalls). This has been implemented in the anode baking furnace of Qingtongxia Smelter since two years ago. A number of improvements were observed: good stability of negative pressure, sealing and heat loss reduction. This has provided saving of energy, prolonged the life of furnace by 2-3 years, easier operation and reduced the labor time.

3. Application of a new hole cover made of cast iron (HY-1 type cover / seat of square hole). This has decreased the heat loss from the surface of the cover, and avoids easy deformation and difficulties in insertion of board.

4. Applications of serial interface control components to prevent or decrease the heat loss in the top surface of anode baking furnace
Biography of Presenter

**Zhang Henghai**
Shanghai Hengyang Co Ltd

Mr. Zhang Henghai is the chairman and manager of Shanghai Hengyang Instruments Technology CO., LTD. He has research and developed the energy-saving devices in anode baking furnace and have obtained patents in China, such as for: the portable quick measuring thermocouple, thermocouple assembly designed for anode baking furnace, the devices of carbon baking furnace’s surface, HY-2 new type energy-saving multi-functional control device for headwall (cross wall), and HY-MAC high thermal conductivity brick for flue walls. Mr. Zhang Henghai received an award of China Nonferrous Metals Industry Labor Model.

张恒海 先生

张恒海 先生为上海恒洋仪表科技有限公司董事长、总经理，组织研发了手持式快速热电偶、阳极焙烧炉专用热电偶、炭素焙烧炉炉面接口测控组件、新型HY-2型多功能横墙装置、新型HY-MAC快速导热火道墙砖等铝用阳极炭素焙烧炉节能设备，并取得专利。荣获“中国有色金属工业中国有色金属工业劳动模范”称号。
Alumina Production Research at CSIRO

Peter Smith
CSIRO Minerals Down Under – Perth

Research into the refining of bauxite to alumina is conducted by the CSIRO Hydrometallurgy group mainly based in Perth, Western Australia with additional engineering expertise based in Clayton, Victoria. In total, about 15 full time researchers are involved in Alumina Production research.

There are two sub-groups in Perth, concentrating on the “Red side” and “White side” issues of the Bayer process. These are supported by a solid/liquid separation group and a process engineering group, the latter specialising in aspects of slurry flow in vessels and pipes. Our engagement mechanisms with government and Industry are of four types:

- **Strategic** – funded by the government or through quasi-government sources, generally for National Priority issues related to the Industry. Note that due to a decline in real funding, these activities have, and will continue to shrink in coming years.

- **Precompetitive** – Large projects. Often conducted over multiple years, and with several Industrial sponsors, on topics of general and common interest to the Industry. These projects may also involve other research providers outside of CSIRO, and are sometimes brokered through organisations such as AMIRA.

- **Collaborative** – Generally 1:1 projects conducted with a single Industrial sponsor. Costs and outcomes are shared, and the work is confidential to the sponsor.

- **Consultative** – Where the outcomes of the project (especially IP) are retained by the sponsor, and the work is performed strictly “commercial-in-confidence.” Full cost (or above) is born by the sponsor.

Bayer Redside projects at CSIRO include: (i) bauxite characterisation and “processibility” studies to underpin greenfield bankable feasibility studies and brownfield expansions (ii) impurity control, especially liquor organics mitigation by wet oxidation (iii) residue studies including trace metal deportment and a database for comparing existing storage technologies.

Bayer Whiteside projects at CSIRO include: (i) fundamental studies of gibbsite precipitation including the development of kinetic parameters for nucleation, agglomeration and growth (ii) the influence of oxalate co-precipitation on gibbsite precipitation (iii) calcination models to describe the transformation of gibbsite to smelter grade alumina (iv) the strength of smelter grade alumina and its relation to gibbsite precipitation parameters.

The solid-liquid separation group have conducted kinetic studies of flocculation in the flowing regions of a feedwell, examined the shape and density of aggregates and their relation to hindered settling, as well as issues of bed compaction and rake action. They currently have full CFD model which includes aspects of these studies to describe the full action of a working thickener. The engineering group have looked at vessel design, especially digesters, as well as mixing of slurries in predesilication and the development of innovative precipitator agitators (Swirl Flow Technology).
Biography of Presenter

Dr Peter Smith
Dr. Peter Smith is a stream leader within CSIRO’s Minerals Down Under flagship. He currently leads a team of 10 professionals engaged in Alumina Production research. Peter has a 25 year history with the Alumina industry and has worked with all of the Australian and most of the world’s Alumina producers. Peter has also supervised many students from undergraduate up to PhD level over this period. Peter is a regular contributor to Alumina production forums including TMS Light Metals, AQW and ICSOBA, for which he is a Council member.
Aluminium Research at CSIRO

Mark A. Cooksey

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Keywords: aluminium production, modelling, autonomous vehicles, ionic liquids

CSIRO’s mission is to deliver innovative solutions for industry, society and the environment through great science. Primary metal producers already have substantial in-house research and development (R&D) capability, but cannot afford to possess every possible relevant R&D capability. Therefore the opportunity for CSIRO is to provide R&D capability that no single metal producer can afford. This almost always involves a capability that can be applied to multiple fields. This means that CSIRO typically delivers the most value when it finds a niche between industry and universities, in an area in which it can be a global scientific leader.

The minerals industry is extremely important to Australia, and CSIRO (with its partners) has invested over $50m in aluminium research in the last decade, covering the value chain from aluminium smelting through to aluminium products. With over 6,500 staff, CSIRO is fortunate to possess a wide range of research capabilities that can be applied to aluminium production, including metallurgy, modelling, materials science and information technology.

CSIRO has a role in enhancing the competitiveness of existing processes, but also to develop new processes with a step-change improvement in performance. Two examples of each type will now be described for aluminium production.

The Hall-Héroult process for aluminium production is extremely well established, and most major primary aluminium producers have substantial in-house capability for modelling the thermal, electrical and magnetic performance of aluminium reduction cells. However, one aspect of cell operation that cannot be modelled using these approaches is the flow of gas, electrolyte and metal in the cell. These phenomena can be modelled using computational fluid dynamics (CFD), for which CSIRO began developing significant capability in the 1980s and 90s. In 2004, in collaboration with partners, CSIRO began CFD modelling of aluminium reduction cells. This allows the gas, electrolyte and metal flow in a reduction cell to be predicted, which can be used to optimise various aspects of cell design performance.

A different type of improvement to the Hall-Héroult process is autonomous systems. There are large material flows in an aluminium smelter (e.g. liquid and solid metal, carbon anodes) and much of the labour requirement is a consequence of these material flows, such as people to drive vehicles. Autonomous vehicles would ultimately be cheaper to construct and operate, and be safer. CSIRO has been developing autonomous vehicles for over 20 years, and we have implemented these in applications such as underground mines. The aluminium smelter is an even more challenging environment, because of indoor/outdoor operations, high temperatures, magnetic fields and the presence of people and other obstacles. Beginning in 2005, CSIRO has developed autonomous vehicles for transporting molten aluminium from
the potlines to the casthouse in a smelter. This involved the development of a number of technologies; camera- and laser-based localisation and objection detection systems, and navigation systems. These component systems have been tested at a smelter.

CSIRO has also invested heavily in potential replacements for the Hall-Héroult process. An example is electrolysis in ionic liquids; salts that are molten at <100 °C, compared to ~950 °C for the cryolite electrolyte used in the Hall-Héroult process. We have developed significant understanding of many of the fundamental aspects of producing aluminium via electrolysis using ionic liquids, such as solution chemistry, the structure of the ionic liquid in the bulk and at the electrode interface, and the impact of impurities. Ionic liquids are also being considered for a range of other applications, such as electrodeposition, batteries and CO2 capture. As CSIRO is also conducting research in these fields, it is developing a critical mass of expertise in ionic liquids that can be applied to metallurgy. The research has also involved extensive collaborations with a number of universities.

A challenge for developing new processes is that both the Bayer and Hall-Héroult processes are extremely well established, and most alternatives consider replacing just one of these in isolation, i.e. a new process for alumina production, or a new process for aluminium production. A better concept may be to replace both processes in their entirety. One option being considered is bauxite chlorination followed by electrolysis of aluminium chloride. This route could allow more value to be captured from bauxite, in the form of the chlorides of silicon, titanium and iron. Furthermore, a number bauxite deposits are currently uneconomic because of high silica, and the proposed process may make these deposits viable. CSIRO has commenced investigation of this process in collaboration with universities.

CSIRO continues to be positioned to have a major impact on the economic and environmental performance of aluminium production.

References
**Biography of Presenter**

**Dr Mark Cooksey**

Dr Mark Cooksey is Stream Leader – Light Metals at CSIRO, where he manages a portfolio of research projects in light metals production. He is also Program Leader – Process Measurement and Design.

Mark has previously worked at Comalco Research Centre and GE Plastics. He joined CSIRO in 2004 as a project leader for multiple research projects in aluminium and magnesium production. While at CSIRO, Mark has completed a PhD in Chemical and Materials Engineering, developing a technique to directly measure ohmic resistance in aluminium reduction cells.
The Development of Recycling Aluminium Industry in China 2012

Gang BIAN
Internal Cooperation Department CNIA

Keywords: recycling aluminium industry, aluminium scrap, aluminium industry characteristics and prospects

China is a big country in nonferrous metals industry, which has a biggest output for ten years and a biggest consumption for consecutive nine years. Meanwhile, China’s nonferrous metals industry is facing some important challenges such as increasing pressure in resources and environment, metals recycling and reuse. Thus, secondary metals industry is getting more focus and support.

In 2012, the output of recycling aluminium was about 4.8 million tons, a 9% year-on-year increase. Also in 2012, China imported aluminium scrap of total of 2.59 million tons, a 3.7% year-on-year decrease, a total amount of $4.13 billion, down 10.8%. However, from domestic sector, scrap aluminium was 2.7 million tons, an increase of 22.7% that achieved a substantial increase, which met the needs of fast development of secondary aluminium industry in China.

Significantly, the primary aluminium industry and secondary aluminium industry have become two pillars to support the development of modern aluminium industry. Along with the development of scrap aluminium collection, pre-treatment, melting, processing and utilization, the share of primary aluminium industry and secondary aluminium industry is changing with economic development. Primary aluminium industry has developed rapidly – it promotes aluminium consumption, and increases the accumulation of social aluminium scrap, which provides plenty of raw materials for recycling aluminium industry. In the meantime, the secondary aluminium industry has been greatly developed. Recycling aluminium industrial expansion is reducing dependence on resource and energy and alleviating environmental pressures. Recycling aluminium industry represents the development direction of modern aluminium industry in the future that is the most vitality part of modern aluminium industry.

It is notable that every tons of secondary aluminium alloy by using aluminium scrap equals to save 3.4 tons of standard coal, 14 cubic meters of water, reduced 20 tons of solid waste emission. In 2012, recycling aluminium industry in China saved 16.32 million tons of standard coal, 67.20 million cubic meters of water, reduced 96 million tons of solid waste emission and reduced carbon dioxide emissions by 57.60 million tons. This has made a positive contribution to achieve the goal of energy conservation and emission reduction for nonferrous metals industry in China.

Through the analysis on industrial characteristics, the aluminium scrap processing centres concentrate in the areas such as Pearl River Delta, Yangtze River Delta, Circum-Bohai-Sea, and Chengdu-Chongqing Economic Zone. The scale based on the actual annual output over 50,000 tons records 20 companies in 2012 from 2 companies in 2003.
Looking forward, resources from wastes provide advantageous conditions to the sustainable development of the industry. It is believed that there is enormous room for improvement of technical equipment of recycling aluminium. Furthermore, the recycling aluminium industry’s layout in China is optimized and the industrial concentration is improved gradually.

Biography of Presenter

Mr. Bian Gang  
Chairman of International Lead and Zinc Study Group, United Nations  
Director General of China Non-Ferrous Industry Association

Mr. Bian has been a state official since 1992 working with China National Nonferrous Metals Industry Corporation and the State Administration Nonferrous Metals Industry after 3 years working as one of the leaders of China Tungsten Industry Association. Bian is now Chairman of International Lead and Zinc Study Group and Vice Chairman of International Copper Study Group, United Nations, Lisbon Portugal. Bian is a post graduate of the Beijing Normal University. China Nonferrous Metals Industry Association officially came into existence in April 2001 as a result of China’s institutional reform of its industry ministries. All of the 10 industry ministries became industry associations with CNIA as one of them by the end of 2000. CNIA is a national, non-profit, industrial economic social organization and a cooperate body, which was registered under the State Administration for Industry and Commerce after the State Council authorized.

CNIA has over 1000 member companies including Chinese nonferrous metals enterprises, institutions, associations and universities.
Chinese transportation sector, the broad prospective market for aluminium products application

REN Baifeng
Antaike Information Co Ltd

As the second-largest aluminium user after building and construction, the transportation sector accounts for around 16%-17% of the total aluminium consumption in recent years. High speed, heavy load, weight lighting, energy saving, safety, comfort, and pollution reduction are the trends of global transportation sector which provides a good opportunity for the improving aluminum application.

Aluminium demand from China’s transportation sector in 2012 totaled at 4.27 million tons. Three major aluminium users in the transportation sector include automobile, motorcycle and bike, while the percentage of automobile industry in the aluminium demand structure will exceed 70%.

China became the globally-largest automobile manufacturer in 2009, with its automobile output in 2012 surpassed the all-time-high record ever achieved by America. But China’s average aluminium content in passenger cars and commercial vehicles is still much lower than those levels both in North America and Japan. This means a great improvement potential for aluminium application in the automobile industry.

The aluminium demand from automobile industry has always been and will still be the key driving force behind the aluminium demand growth in transportation sector. The aluminium demand from China’s automobile industry was estimated to be 2.85 million tons in 2012.

As the second and third-largest aluminium users, the motorcycle and bike industries have remained relatively stable, whose aluminium consumption has become basically saturated. Although the unit aluminium content is relatively less, the huge production volume has separately made the motorcycle and bike industries become the second and third-largest aluminium users after the automobile industry.

In railway goods transportation, the biggest advantage to using aluminium alloy made train body is the reduction of the dead load of the train body and transfer it into effective load. Urban rail transit also develops very rapidly. Aluminium has been applied to above 80% of urban rail vehicles, 6-12 vehicles/km are needed for the urban rail transportation

There is also a great potential for aluminium products to be widely applied in container and ship building. The aluminium demand from aerospace sector, as a high-end aluminium products consumption sector, represents a rather small percentage of the total demand, but it is recognized as having potential for increased aluminium consumption in transportation sector.
It is far away from being accepted by all walks in regards of its application prospect, the economic benefit and energy saving and emission reduction effect. Its design, development and production for its application in transportation sector are just beginning; the preliminary production capacity has not been formed. It requires government’s related department to strengthen directive guidance and effective publicity and to give supporting policy with regards of the wide application of aluminium in transportation sector.

Biography of Presenter

Mr. Ren Baifeng
Deputy General Manager of Beijing Antaike Information Development Co., Ltd.

He is mainly responsible for the event business development and corporate strategic planning. He graduated from China Northeast University in 1989 with a bachelor degree of engineering in Mineral Processing Engineering and then Graduated from Wuhan University of Technology in 1992 with a master degree of engineering in Mineral Processing Engineering. After graduation from the university, he engaged in the nonferrous metals production, nonferrous metals minerals trade in different companies. After entering Antaike in 1998 he mainly involved in the information research and market analysis of lead, bismuth, silver and aluminium. He published over twenty market research reports and engaged in more than thirty large nonferrous metals market research consulting programs. He has worked as the person in charge of 50 nonferrous metals market conferences or international forums responsible for the event planning, sponsor inviting, conference promotion and conference organization.
Australia-China Research Centre for Light Metals

Xinhua Wu
Monash University

Keywords: Light metals, Australia-China collaboration

Australia-China Joint Research Centre for Light Metals is co-funded February 2013 by Department of Industry, Innovation, Science, Research and Tertiary Education (DIISRTE), Australia and Ministry of Science and Technology (MoST), China, under the initiative of Australia-China Science and Research Fund (ACSRF). In Australia this Centre is led by Monash University on behalf of six University partners in the ARC Centre of Excellence for Design in Light Metals and 4 Australian companies and one European company, EADS. In China, this Centre is led by Central South University, including partners: Beijing University of Technology, Southeast University, Baosteel, COMAC, Chalco, Alnan and some other industrial partners.

The joint research centre will bring together world experts from industry and academia in the fields of light alloy development and processing and:

1. Carry out impact-driven blue-sky research into the development of revolutionary, new light metal materials and manufacturing processes for CO₂ emission reductions and energy savings through the reduction of weight, and by extending the lifetime of engineering structures in transportation.

2. Enhance industry competitiveness by undertaking industry-relevant research and servicing their development needs, including implementing new light metals/processes and improving existing manufacturing processes through the characterisation of their products and the modelling of the processes to meet required standards initially for the demanding aerospace sector, but ultimately also for land-based transport systems.

3. Expand the high-value-add manufacturing capabilities in Australia and China via the underpinning of world-class research with new, close interactions with global endusers, and the establishment of Australia as a global destination for aerospace research and manufacture.

4. Create a platform and opportunities for researchers from Australia, China and other international partners to meet and interact with each other, suppliers and endusers. In this regard, the Centre will enable the exchange and secondment of personnel between Australia and China, and in particular between industry and academia, thereby creating an extensive network of ambassadors for Australian culture and industry in an area of mutual strategic importance to both countries.

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Biography of Presenter

Professor Xinhua Wu

Professor Xinhua Wu is the Research Director of the Australian Research Council Centre of Excellence for Design in Light Metals. The Centre consists of more than 100 researchers and academics from six universities and was formed to coordinate internationally-competitive research strengths to establish a strategic fundamental research platform for expansion of the light metals industry.

Professor Wu completed her Bachelor of Science at the South-Central University, China and Masters in Science at the Institute of Metal Research, Chinese Academy of Sciences. She then undertook a PhD at the University of Birmingham.

With research interests in Aerospace Materials, Professor Wu works on projects aimed at improving current materials and developing new materials simultaneously to develop their processing and the influence of processing on microstructure and properties. Her research is also on Ti alloys and near net-shape manufacturing processes.
“Five Cycle Control”(FCC) technology for Aluminium Reduction Cells in China

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Keywords: Electrolysis aluminium production, MPPIC and FCC technology

The advanced multivariate process parameters intelligence control (MPPIC) technology[1], developed by CHALIECO GAMI, had been used in many large domestic and abroad green-field built or modernized smelters. In this paper, the new concepts and development contents with MPPIC technology named “Five Cycle Control”(FCC) technology will be discussed. The successful application of this new technology, resulting in significantly higher current efficiency and reduced energy consumption in several pilot and section’s cells of two large domestic smelters, will also be discussed. The original MPPIC technology is currently being upgraded toward FCC technology.

Introduction

Based on several cell control technologies research and application achievements in recent years, especially original “MPPIC technology” developed by GAMI, with reference to and learning a lots of successful experiences from the theoretical research and practices of the cell intelligent control systems at China and abroad and taking the in-depth research of cell control technology software and hardware as the core subject, this technology is a set of more high-efficient, energy-saving and emission-reducing control technology system for aluminium reduction cells, namely “Five Cycle Control” (FCC) technology developed by CHALOECO GAMI. As to further achieve the obvious economic and social benefits based on the existing conditions for Chinese primary aluminium industry, through the practice and continuous improvement on the large CWPB pilot cells, which of it had been demonstrated in several large CWPB potlines now.

Over the past decade, the original “MPPIC technology” and device with independent intellectual property rights developed by GAMI has reached the international advanced level and achieved great reputation in China and abroad (the special software for the system is the internationally original), which is widely applied in China and abroad with excellent product quality and technical service. However, with the rapid development of world primary aluminium industry, especially the Chinese primary aluminium industry during this decade, it injects the fresh energy to the world primary aluminium industry, but also raises the more and more intensive competition of the area to the higher point, and facing the world economic recession and more intensive energy shortage in China, some aluminium smelters in China have approached loss. Therefore, how to reduce further the production cost becomes the one of the key tasks for each aluminium smelter to face and deal with. At present, the average
power cost of Chinese primary aluminium industry exceeds total cost by 44%, and is about 16% higher than the rest of the world average level[2], so how to reduce the energy consumption of unit product by varied measures becomes the priority for the aluminium smelters in China.

The “Five Cycle Control”(FCC) technology is the latest generation of intelligent control technology for cells researched and developed based on the above basis and situations to ensure each large CWPB reduction cell achieving best technical and economic index with high efficiency and low energy consumption under the stable production conditions of least personnel interruption, which is not only the development direction of intelligent cell control system for primary aluminium industry but also the research and development trend of energy saving and emission reduction for aluminium reduction.

The concept of “Five Cycle Control”(FCC) technology

The FCC technology is the expansion and deepening of the original MPPIC technology, which not only improves the original MPPIC for single cell but also brings the monitoring and control for material and energy circulation in primary aluminium production process flow to the system, as well as the hardware of corresponding control systems is upgraded.

Besides being related with some parameters such as designed current intensity, anode current density, work voltage depending on the voltage balance, etc; the “static balance” of cells is also impacted by other factors like the materials selection and installation during the construction period and the process control level in preliminary stage of baking, etc. Especially for various complicated bath systems of cells in Chinese aluminium smelters, the best “static balance” of cells can only be realized by well controlling the “dynamic balance” parameters (including alumina concentration, AlF3 excess and voltage balance); in particular, high current efficiency requires the ideal “cell cavity shape”, and the “static balance” is the basis of ideal “cavity shape” via the basic condition for good cell integral performance. “Superheat” is a bridge between the “static balance” and the “dynamic balance”, and the most important parameter for regulating such 2 balances.

Figure 1 shows the relationship between the “Five Cycles” for aluminium reduction process. How to treat such mutual relationship is the key to reach the excellence in high efficiency, energy saving and emission reduction. As shown in figure 1, “superheat” as bridge is the key in “Five Cycle”.

The bath has a liquidus temperature (or melting-point temperature) which is the function of its compositions and impacted greatly by the concentrations of AlF3 and alumina [3]. The sum of such temperature and the superheat is called as the bath temperature. The bath melting-point temperature is impacted greatly by both cell material balance and energy balance. The energy balance is to impact and change the superheat by forming and melting the side ledge profile of molten cryolite, and impact the total molten cryolite amount in bath so as to change the concentrations of AlF3 and alumina.

The superheat is mainly the reaction result of cell energy balance, but they are impacted mutually by the impact of material balance on energy balance. It shall be indicated especially
here that the cell energy balance is impacted by current efficiency, bath and metal level and liquidus temperature.

![Figure 1: Relationship among “Five cycles”](image)

**Figure 1: Relationship among “Five cycles”**

**Upgrade of Control Model**

The main characteristic of the original MPPIC technology is to make analysis and deduction on the measuring data of cell and the data generated during cell control, realizing the identification of “superheat” and on-line control of AlF3 excess at “dynamic balance” in the first time for Chinese cell control technology, with its original control model as the following Figure 2. Such control model can be applied in the basic computer network control platform as the following Figure 3.

![Figure 2 Control model of MPPIC technology](image)

**Figure 2 Control model of MPPIC technology**

**Upgrade of Control Model**

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assessment” function in the control model of the original MPPIC technology as per each newly-added computer feedback, thus realize the more accurate “alumina concentration control” and “AlF3 feeding control”. Moreover, this technology also covers the whole set of process control on “fume treatment plant (FTP)” and “alumina circulating conveyance system” affecting directly the “energy balance” and “material balance” during reduction process flow, which not only reduces greatly the unit DC consumption but also the comprehensive AC consumption of unit aluminium and the total fluoride emissions in the system, so as to achieve the sustainable high-efficiency, energy-saving and emission-reduction. The control model of upgraded FCC technology is as the following Figure 4.

![Figure 3 Basic computer network control platform](image3)

![Figure 4 Control model of upgraded FCC technology](image4)

The control model of upgraded FCC technology can be applied in the Computer Network Control Platform designed for plant as the following Figure 5.
Key points of the research and development

1) Cell conditions analysis system
   - Intelligent tapping device
     - Improving the tapping accuracy for better control of the “energy balance”;
     - Coordinating with the high-accuracy anode stroke measure device to achieve the cell cavity identification;
   - High-accuracy measure anode stroke device;
     - High-accuracy double-pulse generator (resolution of 0.125mm as figure 6 above), instead of the original pulse generator and rotary counter;
     - Working with the intelligent tapping device to achieve the cell cavity identification.

2) Temperature measure system
   - On-line intermittent bath temperature measure system;
   - Coordinating and connecting with the cell conditions analysis system;

3) Control software development for “dynamic balance”[4]
   - Multi-mode AlF3 feeding control;
   - Double-tracking alumina feeding control;
   - Cloudy superheat identification;
   - Voltage balance control;
   - Cloudy tapping amount deduction;
   - Cell conditions analysis;
4) Aluminum reduction double-recycle optimization
   - Establishment on the energy recycle for single cell and the system;
   - Adding some equipment and materials for the system improvement, with the corresponding adjustment and modification for electrical control system required;
   - The corresponding improvement on the interior of dust filter and fume pipes[5];
   - Research on the relationship between materials recycle and alumina fluidity;
   - The regulation of reduction production operation system.

Figure 6 - High-accuracy double-pulse generator

Figure 7 Topologic figure of cell conditions analysis system
Contents and purpose of research and development

1) The contents of Technology Research and Development and Application
The contents of the complete set of “Five Cycle Control” (FCC) technology upgraded based on the research and development and upgrade of original MPPIC technology are as follows:

- Research and development and application of cell “FCC” software;
- Research and development and application of aluminum reduction management-control integration system;
- Research and application of the 8th generation of new-type “cell controller” (GAMI-VIII);
- Research and development and application of aluminum reduction fume energy recycling;
- Research and development and application of aluminum reduction material recycling optimization;
- Research and development and application of cell multi-parameter precise detection technology;
- Research and application of identification technology for cell cavity dynamic change;

2) Technology research and application team
Utilizing the technology combination advantage of the participant companies, and in the principle of “coordination, management reinforcement, research reinforcement and high efficiency and high quality”, a competent technical project research and application team is organized as required to ensure successful implementation of project and achieving the expected effect.

![Diagram of technology research and application team organization]

Figure 8 The organization structure of technology research and application team

3) Technical and economic index of demonstration cell line
This research aims at achieving the following technical and economic index at the world
advanced level after developing all the above technology contents.

- Current efficiency 94-95%
- Comprehensive AC consumption ≤13000Kwh/t-Al
- Gross anode consumption ≤495kg/t-Al
- Anode effect coefficient 0.05±0.03 times/cell/day
- Unit AlF3 consumption 16±2kg/t-Al
- Fluorides emission concentration at stack 1.5±0.5mg/m³

The whole research contents about FCC technology are planned to be completed within 2-3 years.

Current achievements on research and development

At present, the research and development of the FCC technology has been applied respectively and gradually in 160KA, 200KA, 240KA, 300KA and 420KA potlines of 2 Chinese aluminium smelters according to the plan, obtaining the stage achievements, in which the average current efficiency of the best potline applied early with this technology reaches 94.5%, and the comprehensive AC consumption is below 13200Kwh/t-Al. The Figure 9 is the multi-dimensional data electronic account results comparison of cell 715# on the 300KA line before and after using the FCC technology.

![Figure 9 The multi-dimensional data electronic account results comparison of cell 715# on the 300KA line](image)

Acknowledgements

With the assistance and support from CHALIECO GAMI and the cooperated aluminium smelters for the research and development of the New FCC technology, Thanks to everybody in the scientific research, production and management staff who participating in the project.

Reference


Biography of Presenter

Yi Xiaobing
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Deputy Engineer & Professor

Mr. Yi has been involved in the design and research works for primary aluminium industry about 30 years after graduating from the Centre South of University of China, and took part in the engineering and construction works for several large aluminium smelter projects as chief designer in the domestic and foreign countries. He is an specialist in the area of smelter process technology also, and has been involved with technology exchange with more than 10 countries. He has published 20 papers in journals and international conferences.
Innovation of Traditional Series of Combination Process for Alumina Production

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Keywords: series combination process, Bayer process, mixed combination process, innovation, yield rate of alumina, energy saving and decreased consumption;

When the Bayer process is applied to the middle/low grade bauxite with A/S <5, the production flow is simple and energy consumption is low, but the yield rate and resource availability are low as well. However if a series of combination process is used a high yield rate can be high, but the energy consumption is also high and Bayer process system is affected. In this paper an innovative series combination process to minimize the energy consumption, and to reduce the negative effects caused to Bayer process system is proposed for optimal production of alumina from middle/low grade bauxite with SiO₂ mainly existing in the form of kaolinite.

Up to the end of 2012, there were 14 alumina refineries (among the more than 40 in China totally) with the capacity of 2000kt/a or more, and the total capacity in China was 55,000kt/a. The output in 2012 was 37,700kt, and the alumina capacity and output in China both stand first on the list. However the bauxite deposit in China is not rich and does not meet the demand for alumina production. In Shandong province with the capacity the third largest in China, alumina is produced with the imported bauxite mainly, and in Shanxi and Henan provinces the domestic bauxite used is mainly with A/S 4-6 of the supplied ore. SiO₂ in the bauxite in Henan province mainly exists in the form of illite, pyrauxite and kaolinite and the chemical alkali loss with the red mud is relatively low. SiO₂ in bauxite in Shanxi province exists in the form of kaolinite and the chemical alkali loss is high, and Na₂O/SiO₂ in red mud is above 0.5.

Main technical and economic indexes of different processes for low grade bauxite treatment
As Fe₂O₃ content in most bauxite in Shanxi province is relatively low, and the excess liquid phase shall not be produced during sintering. It is appropriate to sinter and to apply a series of combination process for this unique raw material [1]. Even if the series combination process is applied to the bauxite with high Fe₂O₃ content, the sintering of mud furnace charge with low A/S can be accepted so far as changing the sinter formula and adopting the corresponding measures [2]. The operating practice in Pavlodar refinery in Kazakhstan is an example: in the refinery the series combination process is used to treat gibbsite with A/S=4, and A/S is about 1.45 and Fe₂O₃ content is above 17% of the sinter. As the suitable sinter formula is selected, the quality of produced sinter is excellent and good economic benefit is realised.
Using the bauxite in Shanxi province with \(\text{Al}_2\text{O}_3\) content 62.5% and A/S=5 as an example, Bayer process, mixed combination process and series combination processes are respectively used for alumina production, the technical and economic indexes such as raw materials, fuel and energy consumption are as the following table:

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Unit</th>
<th>Bayer process</th>
<th>Mixed combination process</th>
<th>Series combination process (innovated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bauxite (A/S=5)</td>
<td>t/t-(\text{Al}_2\text{O}_3)</td>
<td>2.181</td>
<td>1.712</td>
<td>1.678</td>
</tr>
<tr>
<td>2</td>
<td>Lime stone</td>
<td>t/t-(\text{Al}_2\text{O}_3)</td>
<td>0.417</td>
<td>1.074</td>
<td>0.858</td>
</tr>
<tr>
<td>3</td>
<td>Soda ash</td>
<td>kg/t-(\text{Al}_2\text{O}_3)</td>
<td></td>
<td>105.5</td>
<td>73.1</td>
</tr>
<tr>
<td>4</td>
<td>100% NaOH</td>
<td>kg/t-(\text{Al}_2\text{O}_3)</td>
<td>204.3</td>
<td>(78.0)</td>
<td>(54.1)</td>
</tr>
<tr>
<td>5</td>
<td>Soft coal for sintering</td>
<td>t/t-(\text{Al}_2\text{O}_3)</td>
<td></td>
<td>403</td>
<td>248</td>
</tr>
<tr>
<td>6</td>
<td>Hard coal for sintering</td>
<td>t/t-(\text{Al}_2\text{O}_3)</td>
<td></td>
<td></td>
<td>242</td>
</tr>
<tr>
<td>7</td>
<td>Coal for lime production</td>
<td>kg/t-(\text{Al}_2\text{O}_3)</td>
<td>33.4</td>
<td>52.8</td>
<td>18.5</td>
</tr>
<tr>
<td>8</td>
<td>Steam</td>
<td>t/t-(\text{Al}_2\text{O}_3)</td>
<td>2.848</td>
<td>2.995</td>
<td>2.410</td>
</tr>
<tr>
<td>9</td>
<td>Producer gas</td>
<td>Nm(^3)/t-(\text{Al}_2\text{O}_3)</td>
<td>590</td>
<td>590</td>
<td>590</td>
</tr>
<tr>
<td>10</td>
<td>Dynamic power</td>
<td>kWh/t-(\text{Al}_2\text{O}_3)</td>
<td>260</td>
<td>400</td>
<td>350</td>
</tr>
<tr>
<td>11</td>
<td>Fresh water</td>
<td>t/t-(\text{Al}_2\text{O}_3)</td>
<td>4.377</td>
<td>7.791</td>
<td>4.962</td>
</tr>
<tr>
<td>12</td>
<td>Yield of red mud</td>
<td>t/t-(\text{Al}_2\text{O}_3)</td>
<td>1.393</td>
<td>1.270</td>
<td>1.039</td>
</tr>
<tr>
<td>13</td>
<td>Capacity rate of Bayer and sintering process</td>
<td>Rate</td>
<td>-</td>
<td>44.5:55.5</td>
<td>71.4:28.6</td>
</tr>
<tr>
<td>14</td>
<td>Yield of alumina</td>
<td>%</td>
<td>72.50</td>
<td>92.37</td>
<td>94.21</td>
</tr>
<tr>
<td>15</td>
<td>Energy consumption of process</td>
<td>kg standard coal/t-(\text{Al}_2\text{O}_3)</td>
<td>442.5</td>
<td>1094.5</td>
<td>767.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GJ/t-(\text{Al}_2\text{O}_3)</td>
<td>12.97</td>
<td>32.08</td>
<td>22.50</td>
</tr>
</tbody>
</table>

It is shown from the above table that when converting soda loss into 100%NaOH, the number of series combination process is lower than that of Bayer process and mixed combination process by 150.2kg and 23.9kg. The alumina yield rate of series combination process is higher than that of Bayer process and mixed combination process by 21.7% and 1.9%. The process energy consumption of this series combination process is lower than that of mixed combination process by 9.58GJ but higher than that of Bayer process by 9.53GJ. The significant feature of series combination process (innovated) is that it is suitable for the processing of the middle/low grade bauxite. It is also better in production cost. Using the prices of raw material and fuel based on the market price in 2010, the production cost of series combination process (innovated) is lower than that of Bayer process and mixed combination process by RMB122 and RMB175 [3].

Innovation of traditional series combination process for alumina production

In order to exert the good qualities of series combination process for treating low grade bauxite and reduce its negative effects, the traditional series combination process shall be innovative. The sintering procedure in traditional series combination process includes: raw slurry grinding, raw slurry adjusting, sintering, sinter leaching, red mud separation and washing of sinter process, desilication of pregnant liquor. Soda ash is added during sinter
leaching to adjust the concentration of sodium carbonate in pregnant liquor to be 20-25g/L. The traditional series combination process has the following shortcomings:

1) Long flow of sinter process part;
2) High energy consumption for sintering of raw slurry fed into the kiln in wet;
3) Spend liquor is added before desilication of sinter-process pregnant liquor to promote the stability of solution, and energy consumption for desilication is high (only the steam consumption can be 899.2kg/t-Al₂O₃ when indirect heating is adopted for desilication);
4) The concentration of sodium carbonate in the solution after the desilication of sinter-process pregnant liquor is relatively high, and bad effects shall show after joining into Bayer process: viscosity is increased and the precipitation rate is lowered, desalting amount by evaporation is a lot and evaporating difficulty is enlarged, causticization amount is increased, and the live steam amount for evaporation and causticization is increased.
5) The Al₂O₃ concentration is low in sinter-process pregnant liquor, normally is about 90g/L, and after joining into Bayer process, the material flow and conveying power are increased, and the steam amount is large and live steam usage is increase;

The followings are implemented for the new series combination process:
1) The sinter-process raw material is fed into the kiln for sintering in dry;
2) The sinter leaching with low carbon and sodium is adopted, i.e. soda ash is not added during sinter leaching to adjust the concentration of sodium carbonate in pregnant liquor;
3) The desilication of pregnant liquor is removed, and the pregnant liquor from red mud separation is directly brought to the ex-digesting slurry of Bayer process. By the waste heat of Bayer process digestion, the joint slurry is desilicated;
4) The Al₂O₃ concentration in pregnant liquor is lifted to above 130g/L.
5) The quick separation and washing of sinter leaching slurry with high solid content (>230g/L) is done by filter, and it solves the problem that the settle can not perform the liquid/solid separation of high solid-content slurry, and it also reduce the secondary reaction.

These have simplified the process flow, reduce the energy consumption for sintering, lower the material flow and power consumption, decrease the live steam consumption, increase the net yield rate of Al₂O₃ and Na₂O in sinter by 2%, lower the difficulty of evaporation, and the mixed green liquor with high supersaturated degree (low caustic ratio) is in favor of production of sandy alumina and promotion of precipitation rate. Comparing with the traditional series combination process, the process energy consumption per ton alumina can be lowered by about 100kg standard coal (2.93GJ).

Conclusion
As for the middle/low grade bauxite with silicon existing in the form of kaolinite and A/S =5, the new series combination process have resulted in the higher yield rate of aluminacompared to Bayer process (by about 22%) and in the increase in the resource availability. The innovation for the series combination process include: feed the sinter-process raw material into the kiln for sintering in dry, adoption of sinter leaching with low carbon and sodium, removal of desilication of pregnant liquor and the desilication of joint slurry. In this case, the Al₂O₃ concentration in the pregnant liquor is increased, the sinter leaching slurry with high solid content is quickly separated and washed via the filter. Not only the process flow is simplified, but also the energy consumption per ton alumina is lowered, the competition ability in market is enhanced, energy is saved and emission is minimized, and the
significant economic and social benefits are produced. Before the emergence of the new mature process, this series combination process provides a solution for alumina production with middle/low grade bauxite in which silicon exists in the form of kaolinite [3].

Reference:

(1) Liao Xinqin, Feasibility Discussion of Mud Charge Sintering with Low A/S, Light Metal, 1997 July.
(2) H.C. New Development of Series Combination Process for Alumina Production, China Science and Technology Press, 1991;
(3) Liao Xinqin, Li Laishi, Optimal Process for High-Efficient and Economic Production of Alumina with Middle/Low Grade Bauxite, ICSOBA-2010 International Academic Annual Meeting Symposium, 2010 October;

Biography of Presenter

Mr. Liao Xinqin

Principal Engineer, CHINALCO
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Mr. Liao Xinqin, born in Jiangxi Province, has been working in CHALIECO Shenyang branch, which is also known as Shenyang Aluminum & Magnesium Engineering & Research Institute Company Limited (SAMI), after graduated from university in August 1982. Being engaged in alumina process design and research, Liao Xinqin is now the Principal Engineer of CHINALCO, Design Master of China Nonferrous Metal Industry, and Deputy Chief Engineer of SAMI. Liao Xinqin has taken charge of and participated in engineering design of about 20 domestic and overseas alumina plants. In alumina process area he has accomplished a number of research achievements, including 10 national patents, most of which are widely used.

CHINALCO, Aluminum Corporation of China, an investment management and holding company authorized by the state, is a backbone state-owned enterprise. CHALIECO is the world’s second largest alumina producer and the third largest primary aluminum producer.

Shenyang branch of CHALIECO, Shenyang Aluminum & Magnesium Engineering & Research Institute Company Limited, bearing a history over 60 years is one of the earliest national large and comprehensive engineering and research institutes in China. Now SAMI is leading advanced technologies in aluminum industry in China.