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 provinnces 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 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-Al$_2$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-Al$_2$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-Al$_2$O$_3$</td>
<td>105.5</td>
<td></td>
<td>73.1</td>
</tr>
<tr>
<td>4</td>
<td>100% NaOH</td>
<td>kg/t-Al$_2$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-Al$_2$O$_3$</td>
<td>403</td>
<td></td>
<td>248</td>
</tr>
<tr>
<td>6</td>
<td>Hard coal for sintering</td>
<td>t/t-Al$_2$O$_3$</td>
<td>242</td>
<td></td>
<td>147</td>
</tr>
<tr>
<td>7</td>
<td>Coal for lime production</td>
<td>kg/t-Al$_2$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-Al$_2$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-Al$_2$O$_3$</td>
<td>590</td>
<td>590</td>
<td>590</td>
</tr>
<tr>
<td>10</td>
<td>Dynamic power</td>
<td>kWh/t-Al$_2$O$_3$</td>
<td>260</td>
<td>400</td>
<td>350</td>
</tr>
<tr>
<td>11</td>
<td>Fresh water</td>
<td>t/t-Al$_2$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-Al$_2$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-Al$_2$O$_3$</td>
<td>442.5</td>
<td>1094.5</td>
<td>767.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GJ/t-Al$_2$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 sintering.
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-\text{Al}_2\text{O}_3 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 \text{Al}_2\text{O}_3 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 \text{Al}_2\text{O}_3 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 \text{Al}_2\text{O}_3 and Na_2O 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 alumina compared 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 \text{Al}_2\text{O}_3 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:

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(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

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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.