Main Factors Affecting the Stability of Liquor Causticization Indexes in Aluminium Production

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Abstract

As the core process for alumina production, the Bayer process accounts for over 90 % of global alumina output. Its fundamental principle involves dissolving Al_2O_3 in bauxite using a so-called Bayer liquor (a NaOH solution, weak in sodium aluminate), possibly under high temperature and pressure conditions to form sodium aluminate solution. Subsequent dilution, cooling, and seeded precipitation processes yield $Al(OH)_3$, which is subsequently calcined into alumina (Al_2O_3). However, the accumulation of Na_2CO_3 in circulating process liquor reduces the caustic ratio (molar ratio of NaOH to (NaOH + Na_2CO_3) in solution), directly impacting bauxite digestion efficiency and the system caustic soda balance. To reduce caustic soda consumption and enhance alumina production efficiency, industrial trials of liquor causticisation were conducted to convert sodium carbonate into usable caustic for process make up. Notable fluctuations in key technical indicators of causticized liquor during these trials disrupted alumina production stability. To prevent such instability in large-scale operations, this study integrates theoretical foundations of liquor causticisation with industrial trial data to analyse critical factors influencing indicator stability. The research aims to optimize control strategies for carbonated spent liquor causticisation indicators and maximize operational efficiency.

Keywords: Bayer process, Alumina production, Liquor causticisation, Caustic ratio, Indicator stability

1. Introduction

The Bayer method is the core process of alumina production, and over 90 % of the alumina worldwide is produced by this method. The core principle is to dissolve the aluminous compounds in bauxite with Bayer liquor (a NaOH solution weak in sodium aluminate) possibly at high temperature and high pressure to generate sodium aluminate solution and then precipitate $Al(OH)_3$ through dilution, cooling and seeded decomposition, and finally calcined into alumina. However, in the circulating spent liquor, the accumulation of Na_2CO_3 leads to a decreased caustic ratio (molar ratio of NaOH to (NaOH + Na_2CO_3) in solution), which directly affects the dissolution efficiency and system caustic balance. In order to reduce the system caustic consumption and improve the alumina production yield, the industrial test of spent liquor was started to convert sodium carbonate into caustic. However, in the industrial test of spent liquor, the main technical indices of caustic liquor fluctuate greatly after extraction, which has an influence on the production of alumina. In order to avoid the fluctuation of the caustic technical indicators in future large-scale production, the main factors of the caustic index of spent liquor were analysed, so as to better control the caustic index of carbonated liquor, to maximize the efficiency of carbonated liquor.

2. The Theory of Process Liquor Causticization

Causticisation of spent liquor is the process of mixing the spent liquor with a certain amount of lime slurry to complete the causticisation reaction under certain conditions, so that the sodium carbonate in the spent liquor is converted into caustic which is favourable for the production of alumina. The advantage of the process is that the caustic is added into the Bayer process, to improve the critical ratio of the circulating spent liquor of the Bayer process to a certain extent and then increase the dissolution rate of soluble alumina and promote the production by the Bayer process. At the same time, the caustic production can consume a certain amount of carbonate liquid, which is conducive to do more carbonate content, alleviate the burden of carbonate evaporator, reduces carbonate evaporation steam consumption, and reduces the total amount of sintering mixing red mud, which is more conducive to the production capacity of sintering method.

2.1 Chemical Reaction Mechanism of Caustic Reaction

The causticisation is the reaction of the hydrated lime with the carbonate ions as per Bi Shiwen 1:

$$\mathrm{Ca(OH)_2(s) + CO_3^{2-} \rightarrow CaCO_3(s) + 2OH^-} \quad (1)$$

Equilibrium constant of this chemical reaction:

$$\mathrm{K} = \frac{2[\mathrm{OH^-}]}{\mathrm{CO_3^{2-}}} = \frac{\mathrm{K_{Ca(OH)_2}}}{\mathrm{K_{CaCO_3}}} \quad (2)$$

In the caustic formula, $K_{Ca(OH)_2}$ and K_{CaCO_3} are the dissolution product constants of $Ca(OH)_2$ and $CaCO_3$ in water, respectively. They are 4×10^{-6} and 4×10^{-8}, respectively, namely, the equilibrium constant is about 100, which means that the equilibrium conversion rate will eventually reach about 90 %.

2.2 The Equation for Causticisation of Spent Liquor

Spent liquor causticisation is the process of converting the carbonate in the spent liquor into an effective base – i.e. caustic that is favourable for production of alumina. According to the analysis of various components in the spent liquor, the main reaction is the reaction of carbonate and lime in the spent liquor, so the chemical equation is:

$$\mathrm{Na_2O_c + CaO_f \rightarrow CaO_c + Na_2O_K} \quad (3)$$

(Na_2O_k — caustic soda as Na_2O equivalent; Na_2O_C — Na_2CO_3 as Na_2O equivalent; CaO_C — calcium carbonate as CaO equivalent)

Therefore, the ingredient formula of spent liquor is:

$$\mathrm{v_1} = \frac{56 \times \mathrm{N_c}}{62 \times CaO_f} \times \mathrm{V_2} \times 90\ \% \quad (4)$$

where:

V_1	lime slurry volume
V_2	carbonate containing liquid volume
Nc	carbonate concentration in carbonate containing solution
CaO_f	lime slurry effective calcium oxide concentration
56	sodium oxide (Na_2O) molecular weight, g/mol

5. The Way to Stabilize and Improve the Caustic Index

5.1 Improving the Accuracy of the Caustic Ingredients

From the extraction theory, we can see that the correct degree of causticisation is the premise of stabilizing and improving the caustic production index. It is important to establish accurately the correct lime slurry addition level. Both more or less lime slurry will affect the production level. Therefore, in the caustic ingredients, improving the accuracy of the addition levels will result in greater stability and improve the caustic production technical indicators.

5.2 Improve the Critical Rate

Under the case of the correct caustic compound ratio, it is an important condition to ensure the stability of the caustic index and improve the caustic production technical index. However, according to the relevant extraction theory, the end point of extraction is 90 %, so the final extraction efficiency is controlled at 90 %, that is, the total alkali ratio of extraction liquid is controlled at about 10 %, which is an important guarantee for the maximum extraction efficiency.

5.3 Raise the Lime Slurry Level into the Caustic Alkali (N_K) within a Certain Range

According to the previous calculation, increasing the caustic concentration of the caustic ingredient lime slurry within a certain range can increase the caustic soda concentration of the caustic liquid within a certain range. According to the industrial test of spent liquor, when the concentration of caustic soda in lime slurry is 30–40 g/L, the concentration of caustic soda can be increased by about 15 g/L which will not greatly impact the causticisation.

5.4 Improve the effective calcium — CaO_f content of caustic slurry slurry

In the causticisation reaction, stabilizing the concentration of lime slurry is the first condition for the stability of the temperature and time of the causticisation reaction. At the same time, the concentration of effective calcium CaO_f of added lime slurry can reduce the dilution ratio of the spent liquor and increase the concentration of caustic soda to a certain extent, which is beneficial to the production of alumina. After the test, the effective calcium oxide concentration of lime slurry increased by 10 g/L, which can increase the concentration of caustic soda by about 5 g/L.

6. Conclusion

In order to reduce caustic soda consumption and enhance alumina production, industrial trials of liquor causticisation were conducted to convert sodium carbonate into usable caustic. The application of the aforementioned theoretical analysis in these trials demonstrated that: post-causticisation, the causticisation liquor consistently maintains a carbonate-to-total alkali ratio around 10 %, with a caustic alkali concentration typically above 90 g/L. Currently, the key production technical indicators of liquor causticisation remain stable, yielding significant economic benefits.

7. References

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