Modification of Flue Gas Semi-Dry Desulfurization Technology Applied in Primary Aluminium Smelting to Reduce the Consumption of Hydrated Lime Reagent

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Abstract

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With the implementation of increasingly strict emission standards, imposed energy-saving and emission reduction policies, the emission concentration limit of flue gas SO_2 in the production process of primary aluminum has been reduced from 200 mg/Nm^3 to 100 mg/Nm^3. To reduce the SO_2 in the flue gas produced by aluminium electrolysis, desulfurization technology has been added to the original flue gas purification system process to achieve the required desulfurization. This paper introduces a primary aluminium smelter using semi-dry desulphurization process. In this application the consumption of reagent to neutralize the captured SO_2 is far beyond the theoretical design value. In addition, the reagent reactions are insufficient resulting in frequent built-up of material inside the desulfurization tower. The material hardens and often falls off the wall causing irregularities in operation. In view of the above, problems are analyzed. It is found that in the flue gas in the desulphurization tower, there is a bias phenomenon. The concentration of SO_2 at inlet was reduced by modifying the defluorination and slag removal tank. The flue gas guide vane was modified to optimize the flue gas flow field and reduce the system resistance. A series of measures, such as optimizing the layout of two-fluid water gun and improving atomization effect, further improved the utilization of reagent, reduce the consumption of reagent, and improve the efficiency of desulfurization.

Keywords: Aluminium electrolysis, Flue gas, Semi-dry flue gas desulfurization, Desulfurization efficiency.

1. Introduction

In primary aluminium production, the flue gas exhausted from the electrolysis cells contains atmospheric pollutants, including fluoride, dust, SO_2 and other species. At present, primary aluminium smelters mainly use an alumina dry adsorption combined with bag dust collector purification process, which can recover most of the fluoride and dust in the flue gas, but the SO_2 cannot be effectively removed.

The SO_2 in the flue gas of electrolysis cells is mainly derived from calcined petroleum coke, the raw material used to make the anode, with a sulfur content of 2 % to 3 % or sometimes higher. Only about 20 % of the sulfur is removed in the calcination process, and 80 % of the sulfur will remain in the calcined petroleum coke. After being mixed in the recipe of the carbon anode, some sulfur is lost in the baking process. After baking, the sulfur in the anode is electrochemically oxidized into carbonyl sulfide (COS) gas and enters the flue gas during electrolysis. The COS gas is instable and reacts with the oxygen in the air to form SO_2. In the alumina dry scrubber the SO_2 is partially absorbed by Al_2O_3, but SO_2 will be re-released when the alumina containing SO_2 is returned to the electrolytic cell. With the sulfur content of 2 % in the anode and the net anode consumption of 420 kg C/t Al, a primary aluminium smelter with an annual output of 500 000 tonnes can emit up to 8400 tonnes of SO_2 per year, which is extremely harmful to the environment.

In recent years, with the rapid development of the domestic Chinese aluminium industry, the demand for carbon anodes has increased, and the low sulfur petroleum coke as a raw material is in short supply resulting is a high price. As a result, anode producing companies have increased the use of high sulfur coke leading to an increase in the sulfur content of carbon anode, and ultimately through aluminum electrolysis flue gas emissions, causing an increase in environmental pollution.

In 2013, on the basis of the "Aluminium Industry Pollutant Emission Standard" (GB25465-2010), the Chinese state issued a more stringent "Amendment to the" Aluminium Industry Pollutant Emission Standard ", which stipulates that the SO_2 emission concentration in key areas is reduced from 200 mg/Nm^3 to 100 mg/Nm^3. Before 2019, the highest measured value of SO_2 in a 500 kA potline was about 140 mg/Nm^3, which met the requirements of the "Aluminium Industry Pollutant Emission Standard" (GB25465-2010). However, there is still a certain gap between the revised "Aluminum industry Pollutant Emission Standards" (2013) with a limit of 100 mg/Nm^3, which means the smelters don't meet the increasingly stringent environmental requirements. Moreover, to further strengthen the prevention and control of air pollution and to meet the needs of the improvement of the atmospheric environment in the Beijing-Tianjin-Hebei region and its surrounding areas, in 2017, the state issued the Work Plan for the prevention and control of air pollution in the Beijing-Tianjin-Hebei Region and its surrounding areas in 2017, raising the requirements for the prevention and control of air pollution in some areas. Inner Mongolia Autonomous Region requires the implementation of the standard of key areas (SO_2 emission limit of 100 mg/Nm^3), Baotou City in the "Baotou Heavy Pollution Weather Emergency Plan (2020 revision)" requires that the SO_2 emission concentration are stabilized to 35 mg/Nm^3 from November 1 to January 31 of the following year. Therefore, a 500 kA potline began to conduct in-depth treatment of flue gases in 2019 by adding a desulphurization system after the existing gas treatment centre (GTC), and adopting calcium hydroxide ($Ca(OH)_2$) multi-point injection of new semi-dry flue gas desulfurization technology to conduct further treatment of the flue gas after the GTC, effectively removing sulfur dioxide from the electrolytic flue gas and further reducing the total emission of pollutants. With the additional scrubbing system the smelter now meets the existing and future national and local government requirements for environmental protection emission standards, and improve the competitiveness of the aluminium companies.

2. Application of Lime/Gypsum Semi-dry Desulfurization Technology in a Primary Aluminium Smelter

2.1 Process Principle

Lime/gypsum semi-dry desulfurization technology uses hydrated lime (dry calcium hydroxide ($Ca(OH)_2$)) as a desulfurization reagent. This reacts with SO_2 in the flue gas in the desulfurization reactor and the material after the reactions have taken place is separated from the flue gas in the dust collector followed by a discharge into the atmosphere through the chimney. A semi-dry desulfurization process is used because $Ca(OH)_2$ reacts slower with SO_2 under dry conditions. In a semi-dry process, the lime is initially present in slurry droplets for fast absorption. Once the water evaporates the solids turn into dry solids. However, the treatment of desulfurization products in the dry state after it has dried by the heat of the flue gas itself that evaporates the moisture of the absorption liquid while the acid-base reaction is carried out, so that the final product is presented as "dry state".

The researchers apply the understanding that $Ca(OH)_2$, process water and flue gas in the absorption tower mainly carry out the following reactions after the $Ca(OH)_2$ slurry is atomized into small droplets that mix with the flue gases:

9. Conclusions

In this paper is presented the addition of a flue gas desulfurization system to existing dry alumina scrubbers in a 500kA potline. The desulfurization system is based on a multi-point injection semi-dry desulfurization process, which effectively reduces the pollutants such as fluoride, SO_2 and dust emitted in the process of aluminum electrolysis production and meets the requirements of national pollutant discharge standards.

In the operation of the desulfurization system, it is found that the consumption of reagent is much higher than the theoretical value, the $Ca(OH)_2$ reaction in the reagent is insufficient, and problems such as built-up of desulfurization ash on walls, clogging and falling sheets are often found in the desulfurization tower wall during maintenance, which increases the workload of maintenance personnel and increases the risk during maintenance. After analysis, the main reasons are as follows:

- The increase of sulfur content in the anode causes the SO_2 concentrations at the inlet of the desulfurization system to exceed the design value, and the atomization effect of the atomizing nozzle in the process water system of the desulfurization tower cannot meet the reaction demand after the increase of SO_2 loads.
- The modification of the induced draft fans of the GTC increased of flue gas flow leading to the turbulence phenomenon after the flue gas enters the desulfurization tower. The uneven flue gas in the reaction area leads to the low reaction efficiency of the reagent.
- The content and particle size of reagent Ca(OH)2 did not meet the requirements of the desulfurization system, resulting in low desulfurization efficiency.

By optimizing the process water system in the desulfurization system, changing the flue gas guide vane, improving the quality of reagent and other measures, the problems were largely solved, and the desulfurization efficiency was improved. Compared with the pre-transformation, the amount of desulfurizer was reduced by 7.13 t/d, and the price of desulfurizer was calculated at 500 ￥/t, which saves the plant 106 900 ￥ per month, and the implementation effect was remarkable.

10. References

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