Influence of Calcination Parameters on Alumina Quality in Gas Suspension Calciner

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Abstract

Improving the alumina calcination process with the objectives to reduce specific fuel energy consumption and enhance product quality has been the driver of recent technological advancements. Alumina quality in terms of parameters such as LOI, surface area and phase composition impact the efficiency of downstream smelting process. Gamma alumina is often considered the most desirable phase from a pure dissolution perspective; the operating parameters of the calciner has profound impact on the phase transformation reactions and final phase composition. In this work, calciner operation is optimized using computational fluid dynamics (CFD). The optimum thermal profile is obtained by simulating cases with various air-to-fuel ratios. Fairly good agreement has been obtained with the available temperature measurements that were recorded for model validation. The physical and phase analysis reveals that the final alumina is over-calcined with the current operational strategy. In addition, a non-uniform solid and gas flow is observed in furnace at a wide range of operating parameters. The CFD simulations indicate that for the particular calciner examined; more uniform air/solid distribution and mixing are achieved by maintaining an air to fuel ratio of approximately ~23. Onsite trials have been conducted to reduce the calciner temperature from 1140 °C to 1075 °C. The result indicated an increase of LOI and specific surface area from 0.4 to 0.7, and from 58 m^2/g to 74 m^2/g, respectively, thereby meeting the quality requirements of smelting grade alumina.

Keywords: Alumina calcination, Gas suspension calciner, Specific surface area, Combustion, CFD modeling.

1. Introduction

The metallurgical grade alumina required for smelting is predominantly produced through the Bayer process. During the process, selective dissolution and precipitation of aluminium hydroxide takes place. The precipitated aluminium hydroxide is then calcined to form polycrystalline grains of aluminium oxide. The fundamentals of the Bayer process have remained largely unchanged since its invention and will likely continue to be the primary method used to produce smelting grade of alumina in the future [1]. However, the calcination conditions dictate the many of the parameters that determine the quality of the alumina for smelting requirements.

During calcination, the aluminium hydroxide ($Al(OH)_3$) gets converted to a series of transition alumina based on the temperature and residence time. The thermal treatment leads to conversion of hydroxide to water, however certain structural hydroxyls get retained which is quantified as "Loss on Ignition (LOI)". The commonly found phases in smelting grade alumina are gamma, delta, theta and alpha [2]. From an economic perspective, many technological advancements have been made, however, the quality of alumina has received less attention. In refineries, higher attention is given on the percentage of alpha content in comparison to the rest of the transition phases as alpha is easier to quantify and monitor. In addition, it also causes adverse effects in aluminium smelting, which is explained in detail below.

The alpha phase of alumina is the final stable form of alumina with loss on ignition (LOI) content close to negligible. However, typical smelter grade alumina has an LOI near to ~1 wt %. During aluminium smelting, transition alumina is favoured for alumina dissolution in the electrolyte bath due to better dispersion. The electrolyte bath is usually maintained at temperature close to 950 ºC. When the transition alumina comes in contact with the bath, the hydroxide content (OH) reacts to form HF and immediately releases as gas causing local agitation. This helps in the rapid dispersion of the alumina which promotes dissolution. When the LOI content in alumina increase above permissible limit, the excess HF formation results in the loss of bath [3].

The low temperature calcined material such as gamma alumina possess lower funnel time (for flowability) and higher surface area in comparison with high temperature calcined alpha alumina [4]. The phases after gamma alumina, are prone to formation of lumps in the bath, hampering the dissolution rate with formation of sludge. Sludge formation is one of the major reasons for the decrease in the current efficiency and increase of the energy demand in smelting. It also affects the metal recovery and hampers the productivity of smelter [5].

Unfortunately, in refineries, there is a rare practice of measurement for intermediate phases and only alpha content is quantified. Also, the impact of various phases on smelting is less understood. Due to these reasons, the operation of calciner may get deviated from the optimal range. Maintaining and prioritizing the alumina characteristics are essential for efficient functioning of smelter. It is most important to produce desired grades of alumina, which immediately dissolve in the electrolyte bath. This has been discussed thoroughly and listed as one of the important objectives for 21st century in the Alumina Roadmap [6]. There is an ongoing debate about the ideal quality of alumina for smelting purposes. Different smelting technologies may require specific qualities of alumina. At many situations, a single smelting unit might be purchasing alumina from different refineries to support the needs of production demand. If the quality of alumina is dissimilar, then it may cause decrease in the performance and productivity of smelter.

For producing smelting grade alumina, many refineries use so called static calciners such as gas suspension, fluid flash or circulating fluidised bed calciners in favour of less energy efficient rotary kilns. These static calciners operate on the principle of fluidization. The impacts of high heating rates and residence time can be observed on the structural properties of alumina in terms of morphology and pore structure. Since these are operated with high air flowrates with high velocities, depending on the strength of gibbsite particle, the percentage of fines may increase considerably after calcination. Due to both internal recirculation as well as heat and mass transfer effects, these fine particles tend to get more calcined increasing the alpha phase [7]. Slight variation in the hydrodynamic parameters can induce uneven flow pattern inside the furnace, impacting the quality of alumina. Hence, it is crucial to study the internal flow pattern i.e. hydrodynamics along with fuel combustion. Moreover, it is important to take a holistic approach, considering both the alumina properties and how these impact the performance of the alumina when used as a feedstock in downstream smelting and dry-scrubbing applications. Therefore, in this paper, an attempt has been made to bridge the gap between the Bayer and Hall-Héroult process in terms of quality of final calcined alumina.

smelter. Onsite trials supported the findings and resulted in reduction of specific fuel consumption by 0.66 kg/t.

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6. Reference

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