Mitigating the Impact of Varying Alumina Sources on the Smelting Process

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Abstract

The quality of alumina, in particular the quality of Smelter Grade Alumina (SGA), is paramount in the Hall-Héroult process, the predominant process for aluminium production. Ensuring stable and productive cell operations, achieving high metal quality for the cast house and minimizing environmental impact are critical aspects that depend heavily on the consistency of SGA properties. Only with reliable and constant SGA can smelters adapt and optimize their equipment, operating practices, and control parameters to achieve the highest possible efficiency.

Given the global variations from raw materials and the Bayer process, refineries often produce SGA with differing physical and chemical characteristics. Consequently, aluminium smelters strive to procure alumina with consistent specifications to mitigate adverse effects on production efficiency, process stability, and environmental performance. Despite these efforts, variation in SGA is at times inevitable, requiring adjustments in the reduction process to accommodate these changes. Any significant change in SGA properties can potentially impair the effectiveness of alumina reduction due to non-optimized control parameters established around processing relatively consistent SGA.

The operational efficiency and economic viability of aluminium smelters are significantly influenced by factors that compromise the consistency of SGA properties. These factors include price fluctuations, refinery issues, fluctuating freight costs, supply chain disruptions, geopolitical issues, and natural resource depletion.

This paper aims to investigate the advancements in mitigation strategies employed by Alcoa and its smelters in recent years, focusing on pot process control practices related to SGA variability. Considering the frequency of variation in SGA sources and the mitigation exercised via flexibility in operational practices, the ability to adapt quickly could expand the range of SGA sources that can be utilized, which were otherwise not considered.

Keywords: Smelter Grade Alumina, Feed control strategy, Alumina dissolution, Flow funnel sensor, STARProbe™.

1. Introduction

Alcoa, as a vertically integrated aluminium corporation, engages in multiple stages of the aluminium production process, encompassing bauxite mining, alumina refining, aluminium production (including smelting and casting), and energy generation. Smelter Grade Alumina (SGA) produced in Alcoa's refineries is distributed to both internal and external aluminium smelters. However, for logistics considerations or when the internal demand for SGA occasionally surpasses the production capacity of Alcoa's refineries, procurement of SGA from external suppliers is sometimes needed to fulfil internal requirements.

Refineries produce SGA with differing physical and chemical characteristics, depending on the raw materials they use and on the Bayer process lead [1, 2]. The variability in SGA sources, or more specifically the transition between different SGA sources, presents more than occasional challenges, particularly for smelters situated at a distance from the refineries. Smelters located in proximity to refineries are evidently better positioned than those situated remotely. Nonetheless, reliance on a single refinery can also result in quality challenges in terms of dependence on SGA sourcing and specific problems within the refineries.

SGA plays, as stated before, a fundamental role in the aluminium production process. Particularly in the electrolysis stage where alumina is dissolved in molten cryolite to produce aluminium. The quality and characteristics of SGA significantly influence various aspects of the smelting operation. This paper only focuses on the process impact, although SGA variability has a broader impact outside of the smelting process.

Impact on the Process

- **SGA impurities**: The presence of impurities in SGA, such as phosphorus or sodium, can adversely affect the electrolysis process. These impurities can reduce current efficiency, increase energy consumption, and lead to the formation of unwanted by-products, thereby impacting overall productivity.
- **SGA dissolution rate**: The flowability of SGA inversely correlated to its dissolution rate in the electrolytic bath. High-quality alumina with optimal flowability dissolves more efficiently, ensuring a steady supply of aluminium oxide for the reduction process. Conversely, poor flowability can lead to the formation of alumina rafts, which hinder dissolution and disrupt the process.

Impact on Pot Performance

- **Current efficiency**: Optimal SGA quality ensures high current efficiency, which is crucial for maximizing aluminium production. Impurities and poor flowability can reduce current efficiency, leading to lower output and increased energy costs.
- **Pot stability**: Consistent SGA quality helps maintain pot stability by preventing the formation of alumina rafts and mucking. Stable pots operate more efficiently and require less frequent interventions, reducing downtime and maintenance costs.
- **Anode effects**: Poor-quality SGA can increase the frequency of anode effects, which are disruptive events that cause voltage spikes and reduce current efficiency. Managing anode effects requires additional energy and resources, impacting overall pot performance.
- **Environmental**: Hydrogen Fluoride (HF) emissions during the electrolysis process, coupled with inadequate scrubbing mechanisms, represent a substantial environmental challenge. The insufficient HF capture efficiency of smelter grade alumina (SGA) not only exacerbates environmental pollution but also disrupts the fluoride (F) balance within the reduction pots. This disruption can lead to inefficiencies and operational instability in the electrolysis process.

In conclusion, SGA properties are critical factors influencing the efficiency, stability, cost-effectiveness of the aluminium production process, and environment. By continuously optimizing the process for a given SGA, aluminium producers can optimize their pot performance, reduce operational challenges, and achieve greater productivity. To address these challenges, Alcoa has deployed several practices aimed at ensuring stability in the reduction cells and mitigating, or at least delaying, the adverse transitional effects associated with varying SGA sources.

If there is an increase in the number of anode effects, shorter track times, and more frequent alumina dumps, the base feed interval is reduced using a special modifier to ensure the pots receive more alumina. Conversely, if track times are increasing or the number of overfeeds is decreasing for a group of pots, the amount of alumina fed to the pots is decreased. To prevent compensatory control, the base feed interval adjustment is kept within a range of -3 % to +4 %.

In the event of dissolution problems, the final step to promote alumina dissolution involves modifying the shot frequency of the overfeed phase by 5–10 % of its duration and increasing the overfeed time to maintain an equivalent enrichment of the liquid bath. These steps have proven relatively successful in managing variations in alumina sourcing.

3.5 Other Considerations

When a shipment of SGA is anticipated to adversely affect process performance, and after mitigating or slowing down the deterioration, process conditions can quickly restore normal by introducing a more suitable quality shipment. Another strategy is to mix the bad alumina with some good alumina to even out the effects.

Fines and super fines can lead to scaling of the feeders and ultimately blocked feeders. This required extra personnel to deal with.

4. Conclusions

Significant variations in alumina sources can lead to process deterioration when electrolysis cells are unable to effectively process the alumina due to improper parameter settings. From an impurity perspective, maintaining an optimal ratio of calcium oxide (CaO) and sodium oxide (Na_2O) is essential. Adjusting the bath chemistry based on the Na_2O, CaO and fluoride (F) content in reacted alumina is crucial to maintaining fluoride balance. The physical properties of alumina and their impact on the electrolysis process are more complex, necessitating the development of effective tools to adapt to new conditions or mitigate the effects of deteriorating conditions.

In recent years, Alcoa has implemented proactive countermeasures to address the significant changes in alumina sources and reduce plant instabilities. By standardizing these measures, Alcoa has successfully minimized the frequency and severity of process excursions. The fundamental strategy involves establishing robust data collection and indicator systems that facilitate informed decision-making regarding the adjustment of control parameters.

Implementing a dashboard that monitors SGA properties in conjunction with key process health indicators helps in tracking the condition of the production lines. Any deviation in these properties and indicators should be considered systematic, warranting action on a group of pots rather than individual pot adjustments. Pot tuning should be reserved for outliers.

Certain aspects of variations in alumina sources remain challenging to manage, particularly when different sources are mixed within the same alumina silo. This complexity arises from the inherent differences in the physical and chemical properties of alumina from various sources, which can affect the consistency and predictability of the electrolysis process. To address these challenges, it is essential to develop advanced monitoring and control systems that can detect and compensate for these variations in real-time.

5. References

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