Electrical Resistivity and Baking Level Improvement through Anode Manufacturing Process Optimization

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Abstract

Aluminium reduction cells in the Mahan Aluminium operate with the prebaked anodes. In its journey towards becoming the smelter operating at highest amperage, in India, Mahan has faced various challenges. With increased amperage, carbon dust quantity and number of spikes per month was increased. Historical carbon plant process data for six months was analyzed to identify significant causes leading to deterioration in anode performance. High grain to sand (G/S) ratio, low pitch demand and low baking level (represented by crystallite size 'L_c') were identified as key culprits. G/S ratio, coarse material (+4.75 mm) and ultrafine mass fraction were optimized to improve pitch demand without affecting dry aggregate density. This helped in reducing electrical resistivity of anodes, from ~63 µΩm to ~58 µΩm. The average L_c value measured out of core samples was observed to be sub-par (~31.5 Å); even after increasing the fire peak temperature to 1180 °C and the soaking time to 50 hours. To assess the baking temperature variation inside the pit, a thermal mapping campaign was conducted. Anodes located at some locations were observed to reach relatively low baking levels. The baking process parameters were optimized to make the baking profile more homogenous. There is number of small improvements done to reduce the heat loss, such as peep hole design cover modification, draft optimization, packing coke granulometry optimization. As a result, the average baking level was improved from ~31.5 Å to ~32.8 Å.

Keywords: Prebaked Anode, Anode Baking Furnace, Baking Level, Dry Aggregate Recipe, Electrical Resistivity.

1. Introduction

Carbon anode quality plays a critical role in achieving the desired current efficiency in aluminum reduction cells. Anode performance in pots becomes even more critical in amperage creep scenarios. An anode with substandard baking levels can exhibit higher reactivity in pots, leading to an increase in carbon dust [4]. Pots with a higher level of carbon dust may show symptoms such as an increased number of high bath temperature excursions (>970 °C), red spots on the steel shell, unusual variation in bath and metal height and anode spikes/mushrooms, etc. [3]. One of the major issues associated with carbon dust is the increase in the electrical resistivity of the cryolite bath. Based on lab experiments, Bugnion et al. [2] reported that the electrical resistivity of the bath can increase by 70 % if the carbon concentration in the bath increases from 0.06 % to 1.01 %. As the bath resistivity increases, ACD gets squeezed to keep the voltage in the set operating band. High electrical resistivity of anode blocks increases the voltage drop across anode assemblies, which can lead to further squeezing in ACD, thereby enhancing the severity of the problem. The presence of carbon dust in the bath also increases the emissivity of the bath by 23 %, as reported by Bernd Rolofs [5]. The increased radiative heat loss due to carbon dust will lead to a localized drop in the superheat of the bath. A decrease in superheat can lead to the freezing of electrolyte on the anode bottom surface, causing uneven carbon consumption and eventually forming mushrooms or spikes [5]. Computational studies by Thorat et al. have shed light on the possible adverse effects of anode spike formation and excess carbon dust on the pot performance parameters [6].

Mahan Aluminium have AP 36 potline, designed for 360 kA. In recent past it had been raising the amperage up to 374 kA to cater the rise in demand for aluminium, such increase in amperage leads to rise in anode current density from 0.9 A/cm² to 0.92 Amp/cm². The anode consumption rate in the pot also increased from 1135 to 1175 kg/pot/day, which had adverse impact on anode butt height as well as operation time i.e., number of shifts. Consequently, the anode height was increased from 650 mm to 685 mm, which helped the pot-room operate with the same shift schedule. With increase in potline amperage, an increase in the frequency of anode spikes and anode slabbing incidents was observed. Figure 1 illustrates the correlation between pot line amperage, anode height and anode spike frequency.

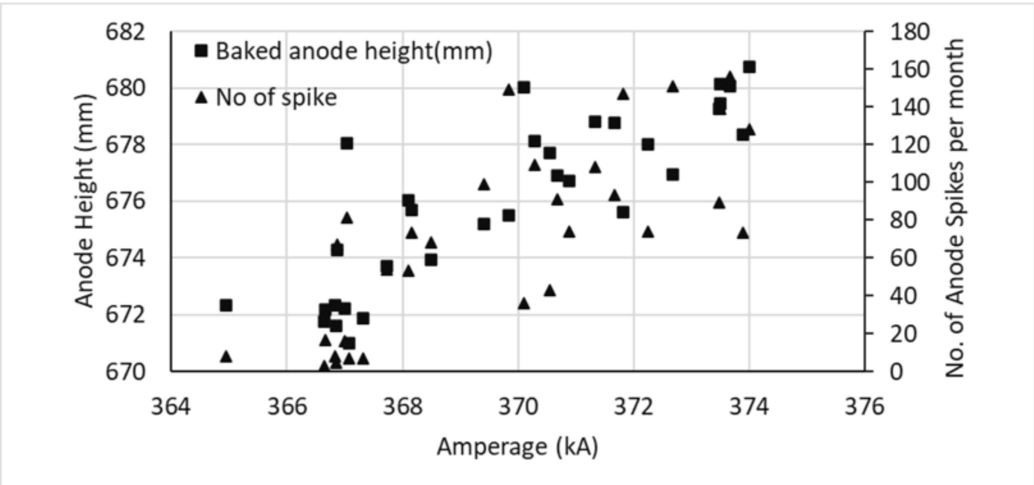

Figure 1. Variation in anode height and spike frequency with potline amperage.

A root cause analysis was conducted to identify the key contributing factors behind the issues related to anode performance. Data on anode manufacturing process parameters and anode quality over a span of 6 months was analyzed. It was observed that the electrical resistivity (ER) and baking level also represented by crystalline length / crystallite size (L_c) were deteriorating over time. Literature survey and brainstorming was performed to identify key variables impacting ER and L_c [9,10]. Fishbone diagram created after this discussion is shown in figure 2. Data analysis was performed to identify correlations between the cause-and-effect variables.

However, the subpar baking level or L_c remained a mystery as no correlation was observed between the anode baking process parameters and the resulting L_c. To investigate this further, a measurement campaign was planned and executed. Thermal mapping was conducted to evaluate the variation in baking temperature across the length and height of the pit. These measurements provided valuable information regarding the non-uniformity of the baking profile inside the pit.

Further optimization efforts, such as adjusting the soaking time and fuel injection ratio, helped in reducing the baking temperature gradient between downstream (D/S) and upstream (U/S) anodes. This optimization resulted in an improvement in the Lc values of the anodes. Overall, the study highlights the importance of recipe control, process improvements, and optimization techniques in achieving desired anode quality parameters.

5. References

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