A Strategy to Adjust Anode Vertical Position After Setting Using Anode Current Profile

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Abstract

Anode change events introduce significant mass and thermal disturbances to the aluminium reduction process. Smelters aim to mitigate these impacts by setting new anodes at a higher vertical position to accommodate reduced carbon consumption, ensuring that once the new anodes recover their normal current load, their bottom surface aligns with other anodes. However, this increment may not be optimally implemented due to varying local cell conditions and work practice tolerance. Continuous measurements from an Individual Anode Current Monitoring system facilitates the prediction of anode consumption rates and variations in anode-cathode distance following anode changes. This paper proposes re-adjusting the vertical position of new anodes based on the anode current recovery profile, aiming to minimise unnecessary crane usage. Prompt restoration of anode current distribution aids in mitigating process perturbations from subsequent anode change events, thereby enhancing cell stability and energy and operational efficiency.

Keywords: Anode setting, Individual anode current measurement, Mass and energy balances.

1. Introduction

In the Hall-Héroult process, aluminium is produced by the reduction of alumina and the oxidation of carbon anodes. The anodes are consumed continuously and must be replaced manually at the end of their service life, typically around 3–4 weeks. At this point, the anodes having diminished to no less than a quarter of their original size to prevent the iron stubs from being chemically attacked by the corrosive electrolytic bath, which would lead to product contamination [1]. Anode changes or "settings" are staggered (see Figure 1) for practicality and to maintain process continuity, as these changes significantly disrupts the cell mass and thermal balances.

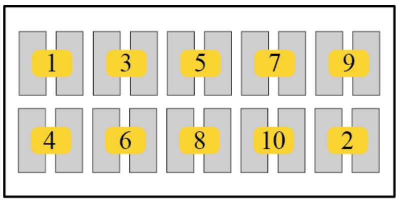

Figure 1. Example sequence of anode pair replacements in a cell.

Consequently, each cell in the pot room undergoes an anode change every few days, making this the most common manual operation. Given the regularity of the operation and the disturbance caused, an optimal anode change strategy and its proper execution are critical for maintaining high cell efficiency. This includes re-adjustment of the anode vertical position, and consequently local ACD, post-change where necessary.

A common strategy to determine if re-adjustment is necessary involves measuring the instantaneous current flowing through the anode rod using a hand-held tool to ensure it falls within acceptable bands. However, this method assumes a well-operating, homogeneous cell with the newly changed anodes being the sole irregularity. In actuality, the re-distribution of anode current is not limited to local anode condition, as it could be caused by elsewhere in the cell. This assumption is increasingly challenged in modern cells, where the growing global aluminium demand has led to capacity increase in existing smelters and the construction of larger cells with more anodes, higher line currents, squeezing anode-cathode distance (ACD), and a larger anode-to-electrolyte volume ratio [2-4]. These factors exacerbate the non-uniformity in alumina concentrations and ACDs, among other spatial cell conditions. Consequently, as modern cells operate closer to process constraints, non-uniformity in anode current distribution, heat generation, and consumption of alumina and anodes are not uncommon. Thus, spot anode current measurements provide insufficient information to accurately determine the need for re-adjusting the vertical position of anodes previously set.

Continuous measurement and analysis of anode currents have garnered significant interest due to their potential in revealing spatial information on cell conditions. Continuous individual anode currents can optimise alumina feeding strategies [5-13], detect early signs of process abnormalities [14-19], and improve cell operation strategies [20-22]. Aligning with the Industry 4.0 vision of using advanced sensors for digital automation, control, analytics, and flexible manufacturing, our team has developed sophisticated measurement systems that provide real-time data on individual anode currents. These data enable strategies that ensure the energy-intensive smelting process remains adaptable and efficient, such as power modulation strategies to adjust electrical power usage in smelters in response to a variable power landscape driven by decarbonisation efforts and increased integration of intermittent solar energy [23-26]. This paper explores another application of continuous anode current measurement: using anode current profile of new anodes to determine if their vertical positions can be improved post-change.

2. Anode Change and Vertical Position Increment

The operation begins with crust breaking to release the anodes, during which the crust and anode cover material fall into the bath, introducing a thermal energy deficit and an excess of alumina. Next, the spent anode butt is removed, taking with it at least 50 kWh of stored energy. The replacement anode, typically at pot room temperature (far below the bath liquidus temperature), causes the surrounding bath to rapidly solidify. This solid phase, having a different composition from the liquid bath, alters the bath composition. Additionally, the solid phase impedes bath flow, slows mass transport, and introduces spatial variations. Furthermore, this freeze acts as an electrical insulator, blocking and redistributing anode current to other anodes. At least 160 kWh are needed to restore optimal cell conditions, including the dissolution of the freeze and heating the bath and new anodes to operating temperatures. Although preheating anodes can reduce these impacts, it is not commonly practiced due to higher energy costs [27].

Initially, the freeze completely covers the anode in contact with the bath, preventing current flow. Anode current gradually increases to its operating capacity as the freeze dissolves over hours or days, during which local heat generation and material consumption are relatively less than that of other anodes. Consequently, informed by positive experimental results [28, 29], smelters typically set the new anode at a greater vertical position than the old butt it replaces, ensuring the ACD of the new anode matches that of other anodes when it eventually draws the normal current load.

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8. References

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