Studies on background PFC and current distribution using individual anode signals in aluminium reduction cells

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Abstract

The growing world demand on aluminium has encouraged modern smelters to increase their production output through increasing operating amperage together with proportional increase in anode size to maintain acceptable anode current density. Though, the increase in anode size was outweighed with a reduction in molten electrolyte volume which added a stress on process of alumina mixing and dissolution in bath. Under such condition, convectional cell control signal which is cell volt cannot detect variation in cell spatial and temporal condition which causes non-uniform current density whilst at high anode potential; the anode reaction product could change to include the co-evolution of PFC species. In this paper, individual anode current signals were used to study the impact of anode stall location on its current pick up curve whilst a complimentary time and frequency domain analysis is conducted. A detailed analysis for the impact of changes in cell spatial condition which result in the increase co-evolution of carbon monoxide (CO) and fluorocarbon species namely tetrafluoride CF_4 emissions is studied.

1. Introduction

The continuous increase in modern Hall-Héroult electrolysis cell amperage rating has been combined with a reduction in cell inter-electrode distance aiming for lower energy consumption whilst operating with an increase anode size to maintain acceptable current density. Accordingly, a reduction in total available molten electrolyte volume in the cell has occurred where at higher rates of daily alumina dumps, the process of steady alumina dissolution process has become a challenge. Under conditions of low energy input, there is an increased tendency to form local spatial abnormalities that lead to the co-evolution of fluorocarbon species where anodes are partially passivated but cannot be monitored by convectional cell control algorithms which rely on the measured cell voltage signal. Previous studies [1] have shown that the rate of current pick-up for newly set anodes decreases as anode size increase resulting in a prolonging of the period of operating under non-uniform current distribution and high magnetohydrodynamic (MHD) instability. Management in modern smelters aims to maintain the same number of feeders while increasing cell amperage and dimension to maintain lower costs. This however adds an extra challenge for the homogeneous alumina dispersion and mixing in the electrolyte. The work in this paper is divided into two parts, the first of which describes a detailed study to understand the impact of anode stall location on characterising the current pick-up curves for newly set anodes where the different chemical kinetics, local MHD and heat transfer process between molten electrolyte and anode interface play a dominant role in controlling anode current evolution. The second part of the work studies changes in individual anode current signals while introducing a spatial variation in cell condition such as blocking a feeder or creating an imbalance in anode current distribution which results in the co-evolution of fluorocarbon species. Sequentially, the work illustrates the broad potential of using individual anode currents as an aid for early fault diagnostics for operating cells.

2. Part 1: Anode setting analysis

The aluminium electrowinning process given in reaction (1) is responsible for 75 % of carbon consumption in the Hall-Heroult process [2]:

$$2Al_2O_{3\,(diss)} + 3C = 4Al_{(l)} + 3CO_{2(g)} \quad (1)$$

Discharged oxygen atoms from the active surface of alumina react with the anode carbon electrode producing carbon dioxide at the anode and liquid aluminium at the cathode.

Mechanisms that account for the remaining 25 % of carbon consumption are associated with the air burn reaction, the boudouard reaction and carbon dusting where selective wearing of anode components occurs resulting in detachment of unreacted particles from the anode surface. Accordingly, the combined effect of various anode consumption mechanisms result in reducing anode height to a minimum operating level typically after 25 - 30 days of setting after which the carbon anodes are replaced to avoid contamination of produced liquid aluminium by impurities from the anode yoke. A new anode is replaced every 1 - 3 days causing MHD instability and losses in process efficiency [3] as a result of subsequent disturbance in cell thermal and electric balance, with the new anode requiring 6-8 days to achieve steady anode current draw and hence current distribution [4]. Modern cells are designed to operate with a balanced anode current distribution while under low energy operating conditions, current pick-up curves become more individualistic based on anode stall location.

2.1. Methodology of analysing anode current evolution based on anode stall location

Massive disturbances in anode cell thermal balance occur due to local energy deficits during anode setting, resulting in formation of a frozen bath layer which hinders current flow and alumina dispersion in the vicinity of the replaced anodes. While temperature distribution simulations reported by Cheung et al showed a higher operating temperature toward the central anodes [5], characteristic changes in the rate of current pick-up based on anode stall location was rarely covered in literature.

In the present study, more than 207 anode current curves were analysed and central anodes showed a faster average rate of current pick-up compared to corner anodes as shown in Figure 1.

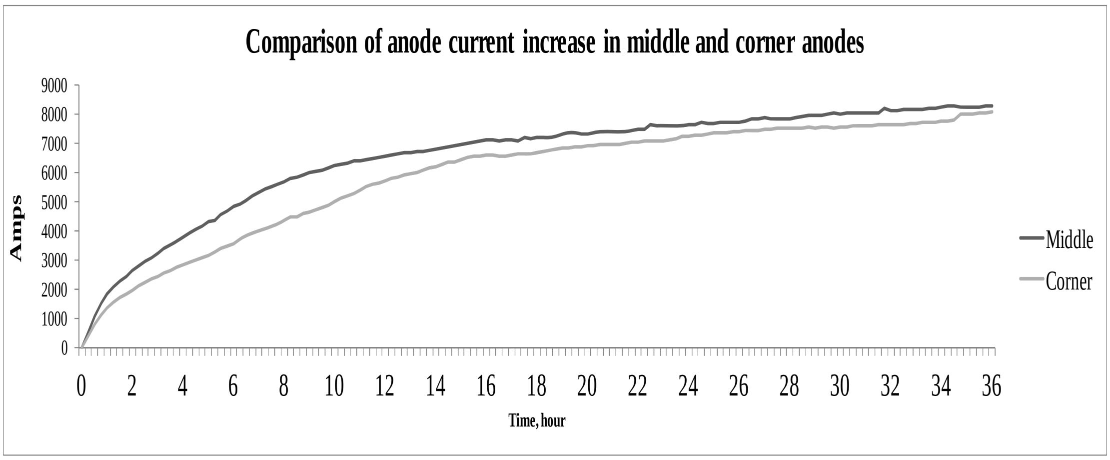

Figure 1. Actual average anode current profile for corner and central anodes.

anodes, illustrating the independent relation between generating PFC and location of anode stall imbalance. However, the impact of feeder blockage was different, with the study illustrating that the impact would be worse for a shortage in alumina supply from a corner feeders due to typical bath flow patterns which restrict alumina supply to corner anodes. The work should stimulate prospects for future development of controlling feeding algorithm in Hall-Héroult reduction cells based on feeder location and on-line monitored individual anode current signals.

5. References

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