Analytics-Driven Control for Anode Effect Reduction in 85 kA Pots

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Abstract

The Hall-Héroult process is used to produce aluminum from alumina using the electrolysis process in an aluminum reduction pot. Alumina is usually fed into the pot at regular intervals, using a point-feed mechanism. At very low alumina concentration (< 2 %) cryolite decomposition occurs and perfluorocarbon (PFC) gases evolve in the process. These gases form a highly electrical resistive layer underneath the anode, that suddenly increases the pot voltage resulting in an anode effect (AE). High anode effect frequency (AEF) and anode effect duration (AED) may lead to reduced anode life, high heat generation, crust collapse, ledge melting, low current efficiency, high fluoride emission, and the possibility of pot leakage. Therefore, high AEF and AED have a major contribution to the PFCs emission and global warming. Apart from the environmental challenges, AEs significantly increase the specific energy consumption and affects pot life. Aluminum smelter industries are belligerently examining ways to reduce the number of AEs as well as their duration. This paper discusses in detail the work related to reducing the AEF and AED in 85 kA retrofit pots. For improving the alumina concentration control in the electrolyte, feed logic has been optimized as well as also assessed reduced feed size/quantity. Moreover, real-time data analytics was used to predict alumina deficiency and the feeder hole choke, for early prediction and prevention of AEs. Various algorithms, based on anode lowering and ultra-fast feeding, have been developed and evaluated for AE termination. This AE termination logic has been deployed using PLC-based controllers to ensure the early termination of AEs, thus reducing the need for manual intervention. The trial was conducted in a section of pilot pots, wherein a reduction of more than 50 % in AEF was observed.

Keywords: Aluminum smelting, Anode effect prediction, Anode effect frequency, Specific energy, Anode effect termination.

1. Introduction

The Hall–Héroult process is the only industrial process for aluminum production. In this process aluminum oxide (alumina) is dissolved in molten cryolite (Na_3AlF_6), and electrolysed to produce aluminum and CO_2. This process operates in the range between 940–980 °C and produces 99.5–99.8 % pure aluminum. A few additives such as AlF_3, MgF_2, CaF_2, and LiF, etc. are added in the molten cryolite (Na_3AlF_6) to lower the liquidus temperature for more efficient electrolysis of dissolved alumina (Al_2O_3) [1]. The cross-section of a contemporary point-feed aluminum electrolysis cell (Hall–Héroult cell) is shown in Figure 1 (a). It is an energy-intensive process with electricity comprising 30–40 % of the cost of production. During the process, the dissolved alumina gets electrolyzed in the reaction zone, where liquid aluminum is formed and settles down on the cathode surface and CO_2 gas escapes from the top. Modern smelters run at current efficiencies close to 94 % with the benchmark of 96 % [2]. In the anode to metal pad zone, underneath the anode, a highly resistive layer of gas bubble forms at the low alumina concentration. The bubble formation and its growth are shown in Figure 1 (b). The gas bubble under the anode constrains the path of the electric current, the electric resistance increases resulting in increased specific energy consumption. When the gas bubbles become denser and cover the anode bottom surface completely it leads to an anode effect (AE) [3]. During AEs the rate of perfluorocarbon gases emission is high.

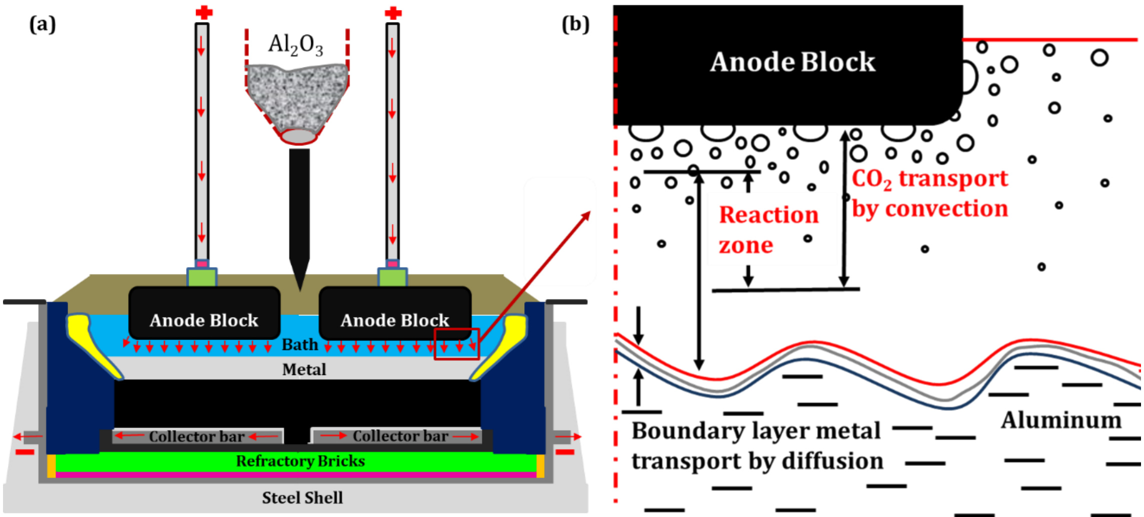

Figure 1. a) Schematic cross-sectional view of Hall–Héroult cell; b) Anode to metal pad reason presenting gas bubbles.

Earlier, automatic feed control systems were not present in the aluminum smelters. Therefore, Al_2O_3 had to be fed manually at regular intervals, if there is no anode effect (AE) during this interval, then feed quantity was kept constant. If AEs come frequently then the amount of alumina was increased and vice versa. The termination of the AE was done manually with iron rakes or green wood poles. However, nowadays there is consent that AEs are detrimental and must be avoided [4, 6]. Because the high voltage in the range of 10 to 80 V AEs increases the DC energy consumption and reduces the current efficiency. AEs caused the emission of harmful perfluorocarbon (PFC) greenhouse gases such as CF_4 and C_2F_6 which have extremely high global warming potentials [5]. Due to the availability of automatic feeders and computer-controlled feeding, but also automatic AE termination routines, the aluminum industry can eminently reduce the frequency and duration of AEs [4]. The rate of PFC emission during anode effects in aluminum cells is variable depending on the type of aluminum cell technology and the computer control anode effect termination (AET) algorithm [7]. Aluminum smelters are one of the largest anthropogenic sources of PFC emissions worldwide [8]. An AE occurs when the alumina (Al_2O_3) concentration in the electrolytic bath drops below approximately 1.5 %, the overall cell voltage rises, and the bath and carbon anodes begin to react and form PFC gases [2]. AEs typically start in a localized area of pre-bake electrolysis cells (on one or two anodes). As the AE reaction propagates to additional anodes in the cell, the overall cell voltage rise. When the cell voltage rises above a specific threshold (typically 8 V), an anode effect duration (AED) counter is initiated in the plant control system to allow tracking of AE minutes per cell per day. Most aluminum companies have initiated voluntary programs for actively reducing PFC emissions [9]. All modern pre-bake smelters have implemented automated methods for terminating anode effects. These

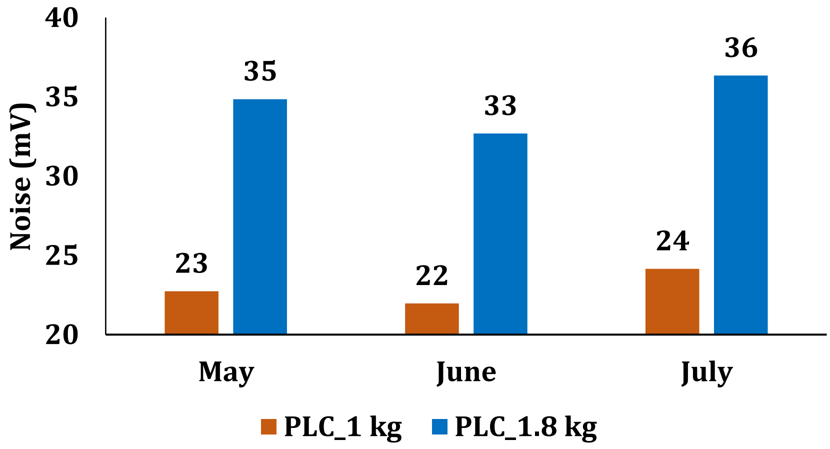

Figure 9. Noise for reduced feed size 1 kg/feeder and existing 1.8 kg/feeder.

4. Conclusion

Alumina feed strategy, anode effect prediction (AEP) and anode effect termination (AET) logic have been developed and incorporated in the control system (PLC-based). AEP logic was developed for predicting the AEs at the early stage, resulting in a reduction in anode effect frequency (AEF). The performance of AET logic was monitored and based on its performance, it was improved to further reduce the anode effect duration (AED). Logic-based auto AE quenching procedure is relying on pot resistance to activate and kill the anode effect. With the help of modified AET, AED was reduced by 1.17 min w.r.t no AET logic and 0.71 min w.r.t existing AET logic. The trial was also carried out in one pot with a feed strategy for 1 kg/feeder (earlier 1.8 kg/feeder), and over the last three months average AEF was observed to be 0.26 /pot-day. Hence, the drastic reduction in AEF and AED was observed after incorporating feed strategies, AEP and AET techniques in the new control (PLC-based) system.

5. References

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