Impacts of Cathode Current Density on Cathode Wear

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Abstract

Cathode wear in aluminum electrolysis cells significantly impacts their efficiency and lifespan. Key drivers of cathode wear rate include cathode current density and metal velocity. Controlling current density and ensuring uniform current distribution across the cathode surface may potentially minimize localized wear. A study was conducted on two Sumitomo S-170 cells at Rio Tinto Aluminium's Boyne Smelters Limited (BSL) to assess whether changing cathode current density distribution can lead to any changes in the pattern of cathode wear. The study involved the trial of hybrid cathode collector bar designs to reduce cathode current density variations. Cell design development and plant trial performances from planned measurement campaigns including physical measurements of cathode wear, have been compared with those of the normal control cells. Detailed results of this proof-of-concept study are presented in this paper.

Keywords: Reduction cell life, Cathode wear, Cathode current density.

1. Introduction

Cathode wear in aluminium electrolysis cells is a critical issue impacting the efficiency and longevity of the cells. The wear mechanisms are complex and influenced by various factors, including the cell design, composition of the cathode material, the electrochemical environment, and operational parameters. One of the causes of cathode wear is the electrochemical reaction between the carbon cathode and the molten aluminium. This reaction leads to the formation of aluminum carbide (Al_4C_3), which can be transported around the cathode surface under the influence of magnetohydrodynamic-driven metal pad flow, causing cathode erosion. Localised high cathode current density may contribute to high wear rate over these cathode areas and lead to uneven wear patterns and shorten cell life. Controlling current density and ensuring uniform current distribution across the cathode surface may potentially minimize localized wear [1].

2. BSL SAS Cell Life Challenges

2.1 BSL Lines1&2 Cell Technology

The original potroom technology at BSL lines 1&2 is the Sumitomo S-170 cell, a side-by-side, end-riser prebaked cell that was originally designed for operation at 170–175 kA. Since commissioning in 1982, BSL has made substantial improvements to increase amperage by more than 40 % above nameplate capacity while improving specific power consumption as illustrated in Figure 1. To achieve this:

- The anode length has been increased by 250 mm, culminating in the need for a new rod assembly in 2005, which corrected the asymmetry of the anode on the rod and increased stub diameter.

- The alumina feeding system has been improved by replacing the centre feed “bar breaker” technology with point feeders in 1989 and installing an automatic alumina distribution system (AADS) to individual cells in 2011.
- Rio Tinto has also developed and implemented many generations of cell lining designs to improve productivity, efficiency and cell life. The existing low energy 4A cell design was validated in early 2015 and fully implemented in 2018.
- A compensation loop was installed on Line 2 in 2013 to further increase Line 2 amperage and reduce specific-energy consumption.
- A magnetically compensated bus bar upgrade (consisting of Under Cell Busbars (UCB) and side risers) was carried out for 53 SAS cells since 2017 [2]. The implementation of UCB cells on Line 2 is planned to continue in 2026.

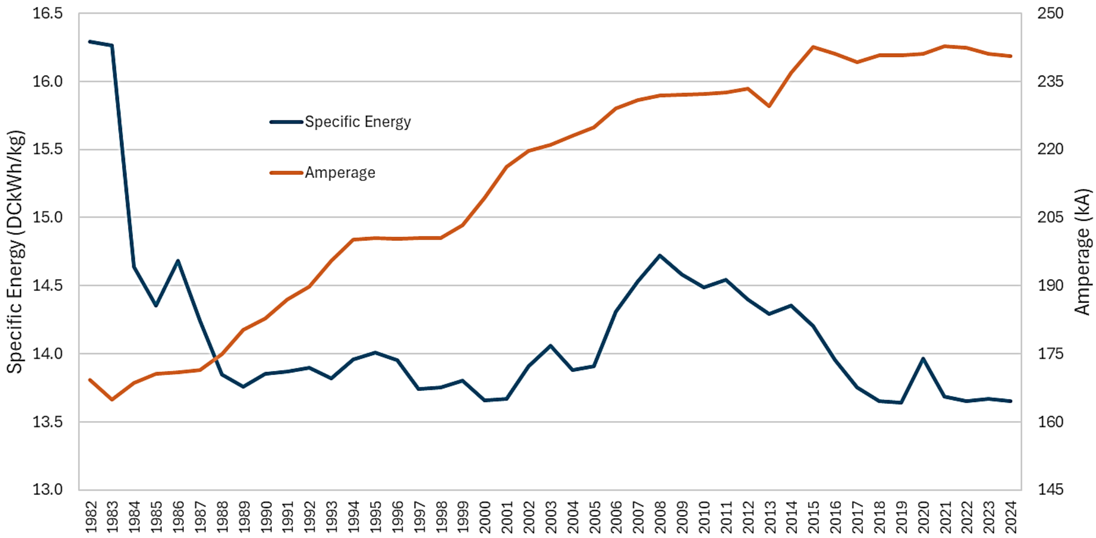

Figure 1. BSL Line 2 amperage and specific energy consumption since commissioning.

2.2 Technical Developments to Improve Cell Life by Reducing Cathode Erosion

Back in 2009, an increasing number of cells at BSL SAS Lines 1&2 were failing 300–500 days earlier than expected. Many of these cells were showing high cathode erosion rates of up to 80 mm/y in the cell corners, with some resulting in the attack of the steel collector bar and “tap-out”. Figure 2 shows that the highest cathode erosion occurred in upstream cathode number 2 among the high erosion area between upstream cathodes 1 and 4 during a cell autopsy. Figure 3 shows a typical cathode surface topography for cells that fail through the cathode.

A series of measurement campaigns were carried out to understand the root causes of cathode erosions in order to better understand wear mechanisms and identify potential options to improve cell life. Cathode ‘Erosion Map’ measurements were carried out using the metal heave/cathode erosion tool (Figure 4). The cathode surface was “mapped” both across its length and width around the area of highest erosion.

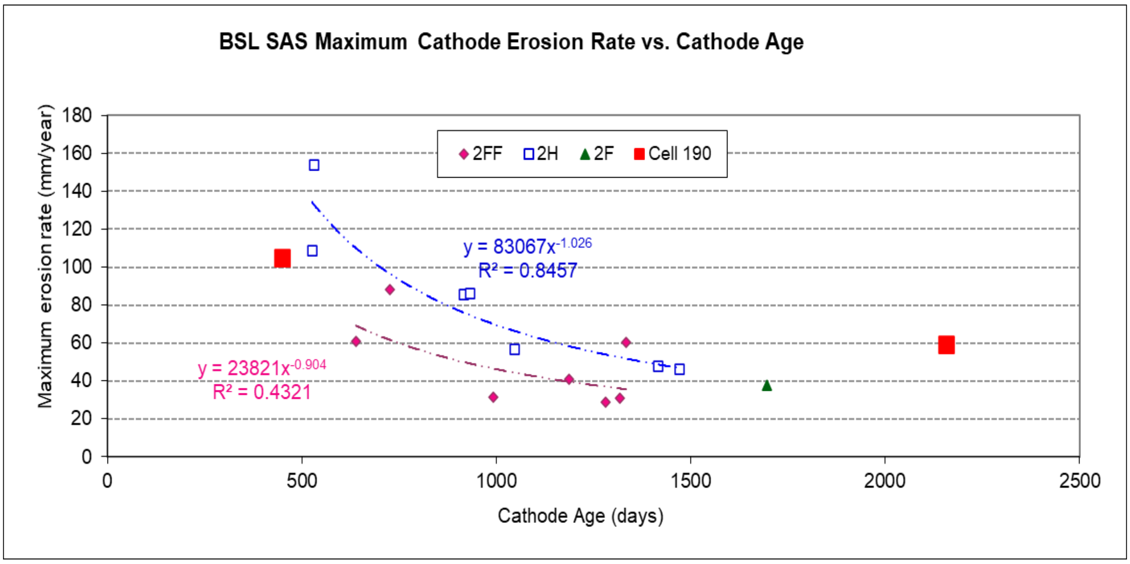

Figure 23. A comparison of cathode wear rate of cell 190 with other designs.

5. Discussion and Conclusions

A "proof of concept" technical trial has been conducted to assess if the cathode wear pattern can be influenced by using a hybrid cathode design to even out cathode current density in the end riser S-170 cell with no magnetic compensation. The use of copper in the middle cathodes was found to be successful in redirecting more than 20 % current from the end cathodes towards the centre cathodes. However, it did not result in any significant change in cathode wear patterns as well as the maximum cathode wear rate. This implies that the cathode wear mechanism for S-170 technology is very complex and unlikely to be caused by any single mechanism [4]. Varying cathode current density itself was not sufficient for altering either the cathode wear pattern or the magnitude of cathode wear. MHD related wear mechanism is believed to play a major role in the wear pattern of S-170 cells because no significant improvements in metal velocity and metal pad stability were achieved in the trial cells.

Despite the fact that one out of the two trial cells achieved a record cell life with a 40 % cell life increase compared to the average cell life of standard cells during the same period, its cathode wear pattern and maximum wear rate remained high. Eventually, the project team chose to pursue alternative designs to improve energy efficiency and cell life, including busbar modifications to address the root cause of the significant cathode wear [3]. These cell design changes have proven to be highly successful, with the average cell life now at BSL L12 close to 2000 days as opposed to 1500 days back in 2015.

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