Enhancing Operational Efficiency Through Advanced Thermal Management Tools

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Abstract

Maintaining optimal thermal conditions within potlines is critical to the operational efficiency of aluminium reduction cells. To address this, we have developed an advanced suite of tools and models specifically designed for monitoring and managing cell thermal performance. Our updated operating window model now integrates the impact of current efficiency and introduces adaptive limits that automatically adjust for changes in essential variables, including anode dimensions, cell age, metal height, forced convection network (FCN) flowrate, and cover materials. We present the "core power" concept and define new criteria to identify cells deviating from their thermal limits over time. Our interactive tools now allow for instant simulations of thermal windows and operational monitoring via a comprehensive dashboard. Efforts are currently underway to develop a "cell at risk" indicator, leveraging these developments to proactively mitigate side erosion risks. These tools represent a leap in operational efficiency via improved thermal management, and have paved the way to the creation and ongoing testing of our complete "numerical thermal twin".

Keywords: Aluminium electrolysis potlines, Thermal balance management, Cell operating window, Cell core power

1. Introduction

Maintaining optimal thermal conditions in reduction cells is essential, as these conditions impact current efficiency (CE), specific energy consumption, and cell life. Over the past decades, Rio Tinto has developed high productivity strategies to operate cells at high current density and low Anode-Cathode Distance (ACD), using very conductive sidewalls and forced convection networks (FCNs). These strategies have resulted in high heat fluxes and minimal side ledge formation. Together, these factors favour higher superheat, increasing the risk of thermal excursions and creating a significant obstacle to maintaining good CE as well as cell life.

To address these challenges, we have developed tools specifically designed for monitoring and managing cell thermal performance in our smelters. This paper provides an overview of our efforts, highlighting key advancements, starting with our thermoelectrical model and the core power concept as a more accurate metric for a steady thermal state. We then discuss the integration of temperature effects on current efficiency and its interaction with ACD within the context of an operating window. We also demonstrate how our adaptive operating window model dynamically adjusts for variables such as cell age, anode length, metal height, FCN flowrate, and cover material thickness. Finally, we introduce new criteria to identify cells deviating from their thermal limits over time.

Our thermal dashboard, which is built upon all these developments, will be presented in the final section. It enables technical staff to visualize thermal indicators and make data-driven decisions to optimize cell operation and mitigate risks associated with thermal excursions. This paves the way for improved operational efficiency and cell longevity.

2. The Foundation: Rio Tinto's Thermoelectrical Slice Model

The thermoelectrical slice model is the workhorse of Rio Tinto's cell design. It is part of a number of models used by Rio Tinto [1, 2]. The slice model represents a half cathode block and its corresponding anode, as exemplified in Figure 1. Bath overvoltage contributions are calculated using a proprietary voltage decomposition module.

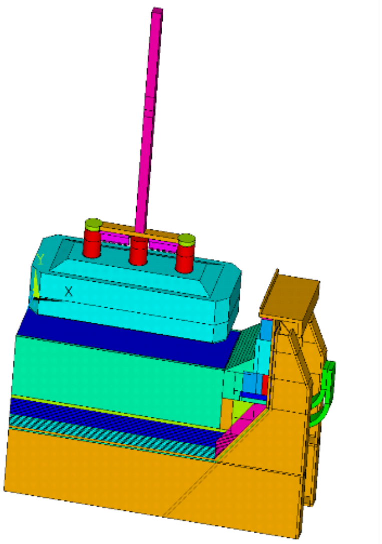

Figure 1. Thermo-electrical slice model representation.

The model is fully parameterized and can be run across a wide range of technologies operated by Rio Tinto and its technology customers, from the Kaiser P57 and AP18 to the AP60, by simply modifying a parameter file. This allows for easy transposition of developments across various designs.

The thermoelectrical model performs a heat balance and iteratively solves for ledge position. However, it cannot be applied industrially on a purely predictive basis due to several factors:

- Many complex phenomena are not solved within that relatively simple model, among which: reoxidation, fluid flow associated with MHD and bubbles, electrical contact resistances, bubble resistance, transformation/degradation of lining materials.
- There is variability over time in a given cell and between cells.
- The transposition of temperatures and ledge profile to impacts on cell life and acceptable ranges cannot be quantitatively predicted.

Therefore, the real value of the TE model in defining acceptable limits can only be achieved through comparisons with detailed industrial measurements and extensive process statistics in various situations.

3. Building Block 1: Core Power (Rethinking the Internal Energy)

During amperage changes (amperage increase, power modulation), the objective is generally to maintain bath thermal balance (ledge profile and superheat); this is especially important when operating near critical thermal limits.

8. References

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