Impact of Cathode Ring Busbars on Potshell Temperature by Radiation Heat Transfer

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Abstract

Cell energy balance is typically treated independently from both magnetohydrodynamics (MHD) and pot-to-pot busbar design, even though all three aspects are intertwined in many ways. Of particular interest is the fact that the downstream (DS) sidewall of typical side-by-side, side riser reduction cells is usually hotter than in the upstream (US), suggesting that the MHD behavior impacts the distribution of heat losses around the shell. This has been investigated by different authors and it was found that the flow of the liquid metal and bath, the reduction of anode slot depth with anode block consumption and the metal pad heaving all contribute to the asymmetry of the potshell temperature distribution. Moreover, during the 41st International ICSOBA Conference in 2023, it was suggested that hotter DS cathode busbars would also contribute to the hotter DS sidewalls observed in actual practice; specifically, the DS busbars are hotter because they have smaller cross-section as the means of balancing the US-to-DS current split. To address this intriguing assertion, this work investigates the radiation heat transfer between cathode ring busbar and potshell, which has not been included in the past models. The radiation heat transfer between the potshell, pot-to-pot busbars and ambient was implemented in the modernized ANSYS-based cell energy balance model presented earlier [1–3]. Key conclusions are illustrated by means of numerical results obtained for a fictitious 375 kA reduction cell.

Keywords: Aluminum reduction cells, Energy balance, Busbars, Potshell temperature, Thermal radiation.

1. Introduction

As pointed out in a previous paper [3], the operational window of an aluminum reduction cell is largely determined by magnetohydrodynamics (MHD) and energy balance. While these two fundamental aspects of cell design are usually studied independently, they are in fact coupled. The ledge profile affects the internal electrical current distribution – and, ultimately, Lorentz forces – while MHD impacts both the metal pad heave and the flow pattern of the liquid phases. These interactions are commonly neglected in numerical modeling thus enabling the employment of pure, stand-alone thermoelectrical (TE) numerical analyses to study the energy balance of a Hall-Héroult cell. Such modeling approaches [1–2, 4–8] often ignore the local effects of metal pad velocity, alumina concentration, bubble-driven flow and metal pad heaving (amongst other phenomena) on the heat transfer between the liquid phases and the ledge.

However, actual practice shows that the downstream (DS) sidewall of typical side-by-side, side riser reduction cells is usually hotter than in the upstream (US), suggesting that the MHD behavior impacts the distribution of heat losses around the shell – see Figure 1.

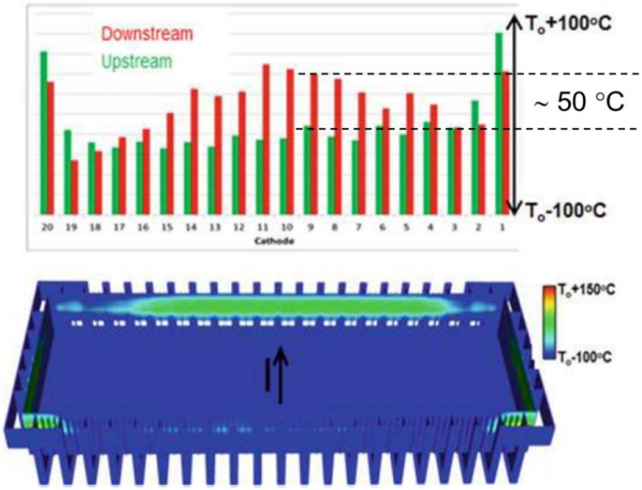

Figure 1. Sidewall temperature distribution above collector bars for an AP4X cell, where potline current flows from the bottom to the top of the page – adapted from [9]. Top: measurements. Bottom: numerical predictions.

Considerable efforts have been made by different authors [3, 9–13] to better account for the effects of the liquid phases flow on the energy balance of a reduction cell. For instance, Langlois *et al*. (2015) [10] introduced a coupled MHD-TE model that considers the MHD-induced flow while ignoring the bubble-driven effects on the bath, the thermal effects caused by alumina dissolution and the metal pad-bath interface deformation. Application [11] of this validated approach [9] to the AP44 reduction technology installed at the Rio Tinto Alma smelter indicates that metal pad flow regions with high velocity magnitudes correlate (to some extent) with hot potshell regions – compare, for instance, the hot headwalls and US corners found in Figure 1 against the high velocity vectors in the same locations in Figure 2. Notice, however, that the flow velocity magnitude on its own cannot explain the hot central region of the DS sidewall found in this same work.

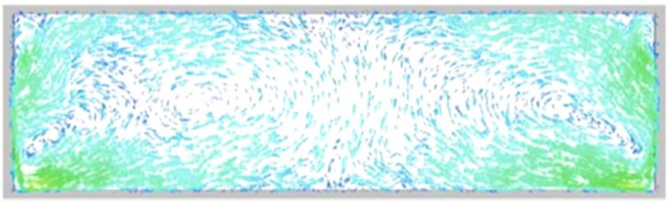

Figure 2. Predicted liquids velocity field for an AP44 cell (scale not shown), where potline current flows from the bottom to the top of the page – adapted from [10].

Bugnion and Kaenel (2023) [12] showed that directionality of the flow is also important as heat advection within the liquid phases – *i.e.*, the heating (or cooling) of a portion of bath or metal as it follows a given streamline – contributes to a non-uniform distribution of thermal power to be dissipated along the shell perimeter thus leading to uneven ledge profiles and, consequently, potshell temperature distributions. It is worth noticing that the relevance of heat advection was also pointed out by [9].

Modeling and experimental work by Chailly and coworkers (2023) [13] suggests that the evolution of the gas bubbles-induced recirculation of bath within the lateral channels as a function of anode service life may be responsible for local cyclic melting and forming of ledge and, therefore, temporal variations in measured sidewall temperature. The combined effect of the work estimated an impact of about 10 °C in $T_{hot\ sidewall,avg}$, suggesting that the influence of the hot sidewall-to-busbar view factor $F_{hotsidewall,bus}$ is more relevant than that of busbar temperature T_{busbar} itself.

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