Second Attempt to Break 10 kWh/kg Energy Consumption Barrier Using a Wide Cell Design

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Abstract

In this year's ALUMINIUM article [1], the author selected a wide cell design for breaking the 10 kWh/kg cell specific energy consumption barrier. In the study presented in that article, the lowest value of 10.2 kWh/kg Al was obtained. Yet, in that study, the reduction of the metal pad thickness left plenty of spare cell cavity. This provides space to increase the thickness of the cell lining below the cathode block. There is also the opportunity to use new semi-insulating lining materials that resist sodium penetration into the cell lining. This combination represents an opportunity to design a more insulating cathode lining and hence to reduce the cathode heat loss and the total cell heat loss. That same study also assumed that the lowest anode-to-cathode distance (ACD) was 2.8 cm, the lowest metal pad thickness was 10 cm, and the lowest cell superheat was 5 °C. Since then, operation below 2.5 cm of ACD has been reported so the current study will use 2.5 cm as lowest ACD, keeping the other two lowest limits unchanged. This design strategy can break the 10 kWh/kg Al energy consumption.

Keywords: Low energy consumption in aluminium electrolysis cells, wide cell design, cell heat balance, mathematical modeling of aluminium electrolysis cells.

1. Introduction

The work presented in this paper is part of a continuing effort to design a cell operating at the lowest possible energy consumption. The current goal is to break the 10 kWh/kg barrier starting with a design operating at 10.2 kWh/kg Al. In order to get to this already extremely low level of energy consumption, several important design changes or design innovations have already been implemented. Before proceeding with the presentation of the new work, the design change steps that led to the starting point of the current work are recapitulated here first.

1.1. Wide Cell Design

The first and very significant design change, compared to most recent high amperage cell designs, is the decision to go for a wide cell design that permits to place four anode carbon blocks through the width of the cell cavity. This in turn introduces two new longitudinal channels in addition to the usual center channel. As discussed in [2], the aim of adding those 2 extra longitudinal channels is to increase the bath volume and to decrease inhomogeneities present in the bath chemistry.

That cell design change innovation was promoted to the author by Barry Welch and was first presented in [2]. As already described in that ALUMINIUM article, using a wider cell permits the reduction of the ratio of external surfaces losing heat to the environment to the electrolysis surfaces. Another way to express this is to directly quote [2]: the usage of a wider cell is "*reducing the heat loss per unit production*", which is desirable if not required to minimize the cell energy consumption. Figure 1 is presenting the sketch of the very first wide cell design as presented in [2], and a more recent version presented in [3] produced by HHCellVolt, a software created by Peter Entner available in the Microsoft store [4].

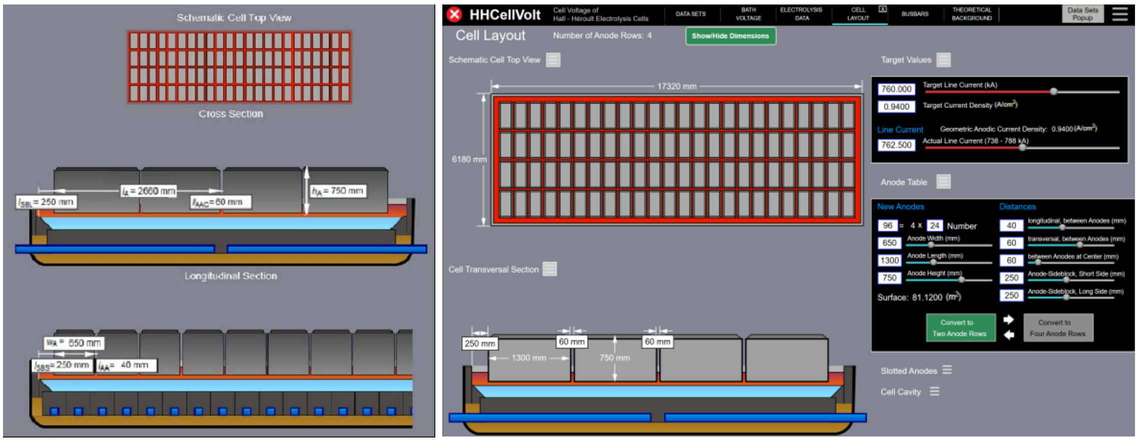

Figure 1. Sketch of the first wide cell design as presented in [2] on the left and a more recent version produced by HHCellVolt [4] as presented in [3] on the right.

1.2. Usage of Copper or Mostly Copper Collector Bars

As already described in [2], it would not have been possible to design a cell wide enough to place four regular size anode blocks through its width without the use of copper or mostly copper collector bars. Without it, it would not be possible to avoid the generation of very harmful horizontal current in the metal pad. Such a mostly copper collector bar design was first presented in [5] as a mean to mostly eliminate horizontal current in the metal pad and significantly reduce the cathode lining voltage drop. Figure 2 shows the mostly copper collector bar design used in [5]. It is essentially a copper conductor inserted in a thin steel tube that is cast iron rodded as usually done for steel collector bar. For a standard width cell design, using such a mostly copper collector bar design virtually eliminated the presence of horizontal current in the metal pad as illustrated in the calculated current density also presented in Figure 2.

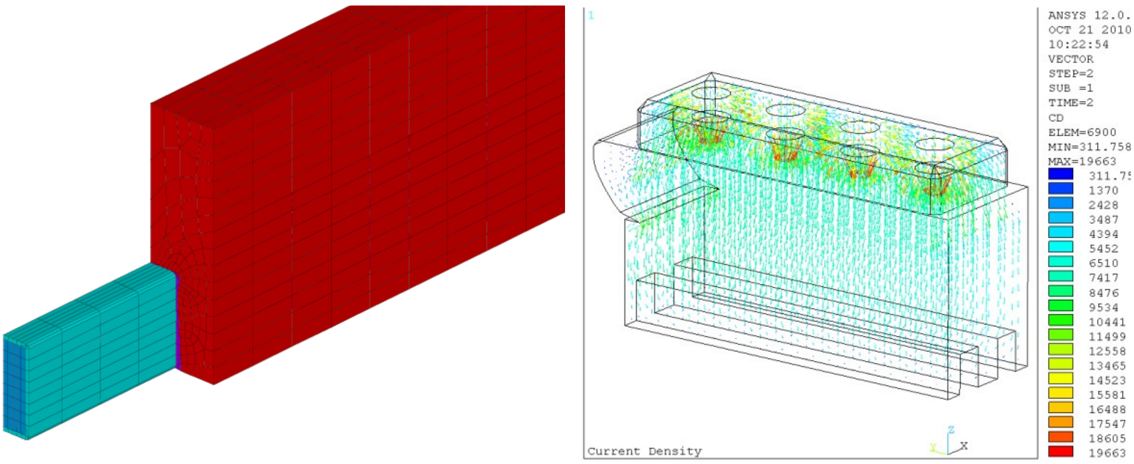

Figure 2. Mostly copper collector bar design on the left and resulting current density field on the right as presented in [5].

1.3. Design Feature that Reduces the Stubs and Collector Bar Heat Loss

As discussed in [6], it would not have been possible to use a mostly copper collector bar design without doing something to prevent those bars to dissipate an excessive amount of heat out of the cell. To avoid such a problem, a special design feature has been used in the design presented in [5]

3. Conclusions

The 10 kWh/kg Al barrier has been successfully reached at least on paper! Getting there required the implementation of several important design changes. The required operating conditions are also extremely challenging. Clearly a much more impressive achievement will be the successful prototyping of such a cell design operating at 10 kWh/kg Al.

4. References

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