AL05 - A 700 kA Alumina Reduction Cell with Downstream Cathode

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Abstract

The aluminium electrolysis industry is continuously aiming to increase cell amperage with the final goal of reducing the cell energy and financial costs. In this direction, some innovations have been proposed during the last decade. One of them is the "Downstream Cathode" [1] arrangement, which consists in cathode blocks and collector bars built and placed in a way that the collector bar ends exit only at downstream side of the cell lining and therefore, the entire cell current is pulled out from that side. The proposed arrangement produces an important busbar voltage drop reduction because the busbar path becomes shorter and the collector bars are made of copper. The Downstream Collector Bar Exit design is potentially viable because it takes advantage of high electrical conductivity of the copper collector bar, producing lower horizontal currents in the metal pad than the conventional steel collector bars.

This article presents the study of a 700 kA cell using the Downstream Collector Bar Exit concept. Magnetohydrodynamic model results are presented, considering a proposed busbar arrangement, potshell and magnetic compensation loops, necessary for controlling the vertical magnetic field generated in such high line current. In this work, the design of the collector bar is discussed, considering electrical and structural aspects. A full copper bar would present insufficient structural strength, and a combined material bar is proposed. Other aspect is the tendency of higher cathode wear at downstream. A special cathode design is presented to compensate the expected erosion difference between the two sides of the cell.

Keywords: Aluminium electrolysis cell, magnetohydrodynamics (MHD), numerical simulation, cell design, cathode design with downstream collector bar exit.

1. Introduction

In aluminium electrolysis cells, there is a trend of reducing the production costs and electrical energy consumption through the increase of the cell size and current, modifications in busbar arrangement among other initiatives such as using copper instead of steel in the collector bars. The copper collector bar became commonly employed in smelters in the last decade. Because the copper electrical resistivity is much lower than the steel, the cathode cathodic voltage drop (CVD) reduces 80–150 mV when compared to the traditional steel bars. The metal pad current density is also greatly affected reducing the transversal current density "y" (see coordinate system of Figure 1) [2, 3] and as a consequence, the MHD forces are also reduced.

The impact of the copper bar utilization opens a window for further improvements in cell design, considered not viable earlier when using traditional steel bars. The "Downstream Cathode" suggested by Dupuis [1] is one of such promising ideas. The busbar can then be greatly simplified, as shown in Figure 1, because the cathodic current path becomes shorter. It potentially decreases the cost of busbar construction, and as well as the busbar voltage drop. In this work, the downstream cathode arrangement [1] is adopted in a 700 kA cell design study. The cell geometry is presented in Figure 1 where the busbar, shell and cathode arrangement are shown. The cell is built using 32 cathode blocks of 3 620 mm (L), 670 mm (W) and 450 mm (H). Each cathode block has two collector bars. There are 32 double anode assemblies where each anode presents 685 mm (W) and 1 700 mm (L). The steel shell is 4 340 mm wide and 23 560 mm long considering internal dimensions. The cell to cell distance is 6.1 m while the returning line is placed at 150 m distance.

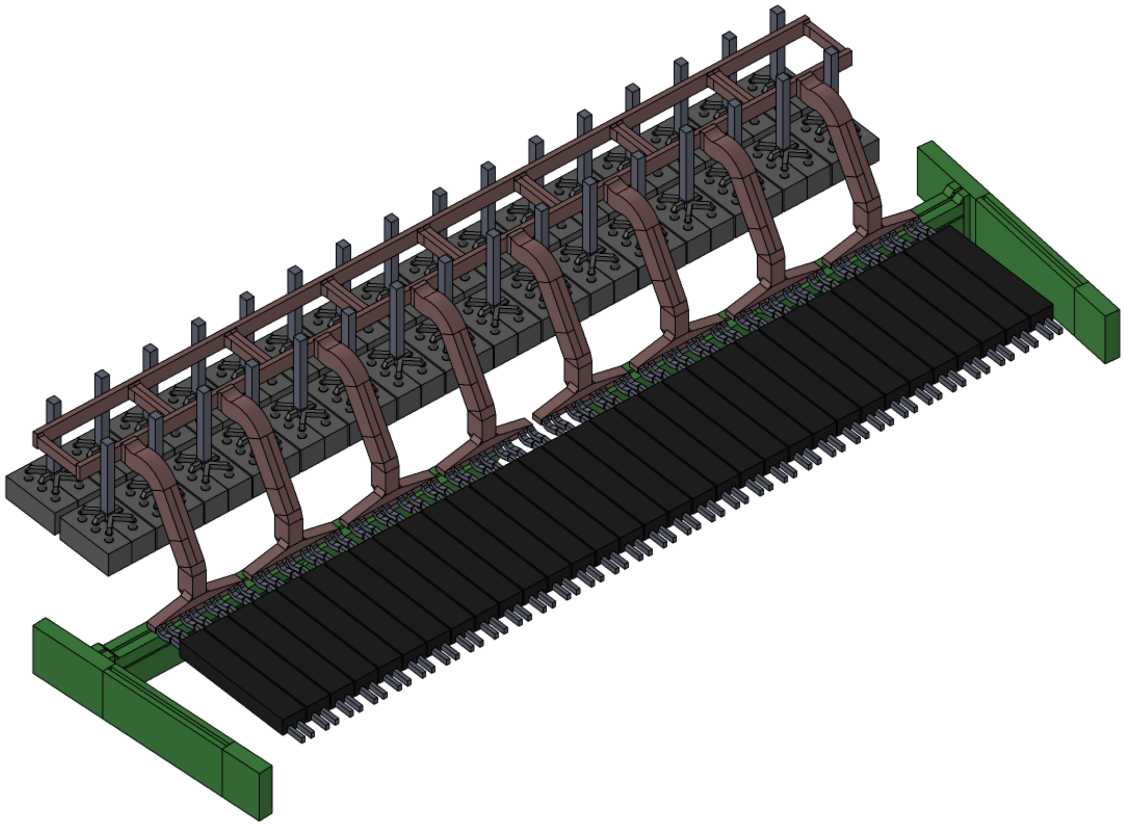

Figure 1. 700kA downstream cathode cell busbar and cathode blocks. Bypass busbar is included.

According to the proposed design, the resulting nominal anode current density (at 700 kA) is 0.94 A/cm^2 while the cathode nominal current density is 0.90 A/cm^2. The cathode block grade used in all the studies is 100 % graphitic. In order to keep the metal horizontal current under a reasonable value (10 000 A/m^2), the cell presents a large length/width ratio because the downstream cathode concept tends to promote more horizontal currents towards the downstream side when compared with the traditional cathode design. Another important design aspect that deserves to be mentioned is the 8 riser's busbar, including a workable bypass. The busbar weighs 60 t of aluminium per cell, which results in around 86 kg Al/kA (at 700 kA). In this aspect, there is also a gain when comparing the typical 100–150 kg Al/kA of US/DS high amperage cells. The gain could be made bigger if another solution can be found for the need of 25 t of busbar only for the cell electrical current bypass.

In cell designs of these current magnitudes there is a need for a magnetic compensation busbar to reduce the vertical magnetic field generated by the neighbor line and by the cell internal current. Considering these characteristics, the ECC concept presented by a Pechiney 1987 patent [4] as in Figure 2 is chosen. It consists of two busbars running at both sides of the cell, at the same current flow direction of the cell line and it is the most effective for very long cells. In this case, loops running with around 90 % of the total cell current are necessary to compensate the magnetic fields. The compensation loop needs 16 tons of aluminium in its construction and it is expected to cost around 10 mV (for a 700 kA equivalent) for each cell during operation.

6. References

1. Marc Dupuis, New Busbar Network Concepts Taking Advantage of Copper Collector Bars to Reduce Busbar Weight and Increase Cell Power Efficiency, *Proceedings of 34th International ICSOBA Conference*, Quebec City, Canada, 3–6 October 2016, Paper AL39, *TRAVAUX*48, 883-890.
2. Amit Gupta et al., Impact of copper insert on low amperage aluminium reduction cell, Proceedings *of 33rd International ICSOBA Conference*, *Travaux* No. 44, Dubai, UAE, 29 November – 1 December 2015, Paper AL22, 709-716.
3. Marc Dupuis et al., Low Energy Consumption Cell Designs involving copper inserts and innovative busbar network layout, *Light Metal*s 2017, 693-703.
4. Joseph Chaffy; Bernard Langon and Michel Leroy "Device for connection between very high intensity electrolysis cells for the production of aluminium comprising a supply circuit and an independent circuit for correcting the magnetic field", *US patent no 4,713,161 (1987)* filed June 5, 1986, granted December 15, 1987.
5. Vinko Potočnik, Principles of MHD Design of Aluminum Electrolysis Cells, *Light Metals 1991*, 99-105.
6. Vanderlei Gusberti and Dagoberto S. Severo, Electromagnetic Modeling of Aluminium Electrolysis Cells using Magnetic Vector Potential, *Proceedings of 37thInternational ICSOBA Conference*, Krasnoyarsk, Russia, 16–20 September 2019, Paper AL25, *TRAVAUX* 48, 967-980.