New Busbar Network Concepts Taking Advantage of Copper Collector Bars to Reduce Busbar Weight and Increase Cell Power Efficiency

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Abstract

At the 2015 ICSOBA conference a reversed compensation current (RCC) busbar network concept was presented. There is no return potline as the full return current passes under the cells back to the rectifiers. The concept preferably uses upstream and downstream anode risers to produce a symmetric upstream/downstream steady-state bath-metal interface deformation. This busbar arrangement gives a very stable cell operation but requires more busbar weight.

In order to reduce the busbar weight, the concept has been improved by the use of copper collector bars, which allows extracting 100 % of the cell current on the downstream side of the cell and then feeding 50 % of the current to the standard upstream risers and 50 % to busbars passing under the next cell to the downstream risers. The improved concept has alternated upstream and downstream risers. It decreases busbar voltage drop and increases cell power efficiency.

This concept can also be used for the external compensation current (ECC) busbar design, which does not require downstream anode risers and reduces the busbar weight and cell voltage further. This paper presents detailed results for B_x, B_z, metal pad flow, cell voltage and power efficiency, for improved RCC and ECC concepts.

Keywords: MHD cell stability; busbar design; mathematical modeling; power efficiency; copper collector bars.

1. Usage of Copper Collector Bars

In its 2011 ALUMINIUM article [1], the author presented a 500 kA cell design using massive collector bar inserts, covering 76 % of steel collector bar cross-section (see Figure 1). At the time, it was speculative whether such a collector bar design could actually be built, but it is no longer the case today after Storvik AS publication at the ISCOBA 2015 conference, presenting technology for casting copper inserts into steel [2]. Furthermore, at the TMS 2016 conference KAN-NAK advocated that copper collector bars do not even need to be protected by steel shell and rodded to the block with cast iron [3]. The results presented in Figure 8 of [1] demonstrated that the usage of copper bars having similar sizes as standard steel collector bars completely eliminate horizontal current in the metal pad while Figure 6 of [1] (reproduced in Figure 1 below) presents model prediction of a 63 mV cathode drop operation for that 500 kA cell.

1.1. Extracting 100 % of the cell current on the downstream side

What the author did not realized in 2011 is that with the usage of copper collector bars, 100 % of the cell current can be extracted on the downstream size without generating excessive horizontal current in the metal pad or generating excessive cathode voltage drop. In order to test this idea, the 3D thermo-electric model previously used in [1] was adapted keeping exactly the same lining design and collector bar size.

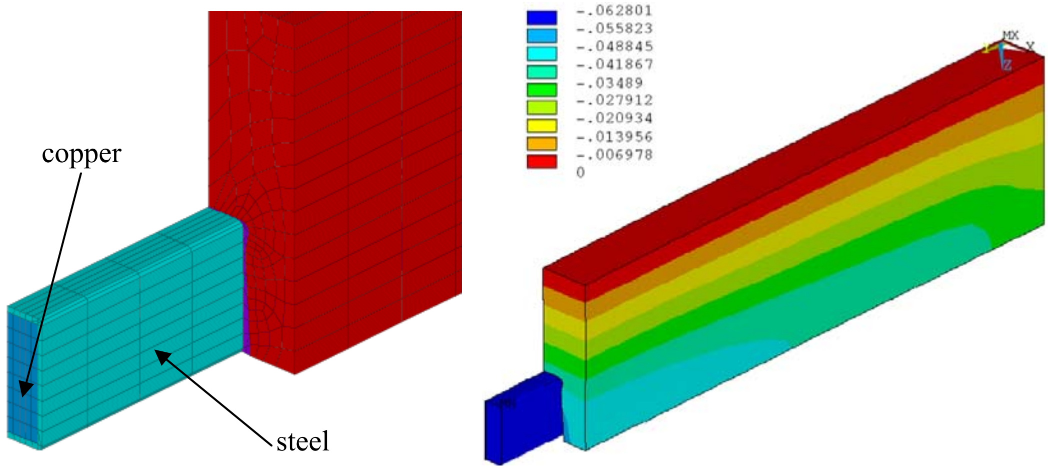

Figure 1. Thermo-electro-mechanical model with copper cross-section shown (left) and predicted cathode voltage drop (right from [1]).

The cell has now a single collector bar across the whole width of the pot. In the model, the carbon-cast iron contact resistances of 4 $\mu\Omega m^2$ for the vertical interface and 8 $\mu\Omega m^2$ for the horizontal interface were used. The resulting calculated current density when all the current is extracted from the downstream side is presented in Figure 2.

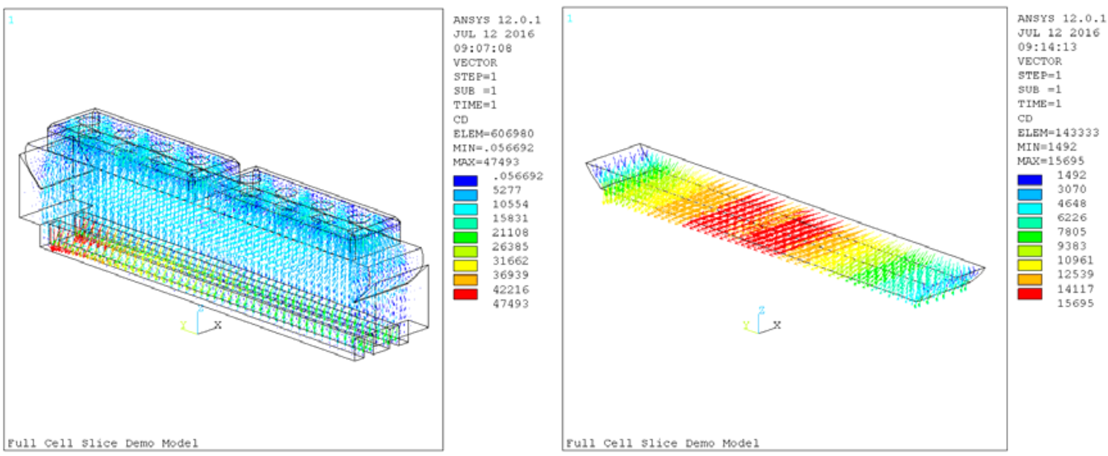

Figure 2. Thermo-electric model with current density in the whole domain (left) and in the metal pad only (right).

With that size of collector bars, the resulting horizontal current density in the metal pad has the same order of magnitude that the one obtained when using a standard steel collector bar designs. Figure 3 presents the predicted corresponding cathode voltage drop and temperature.

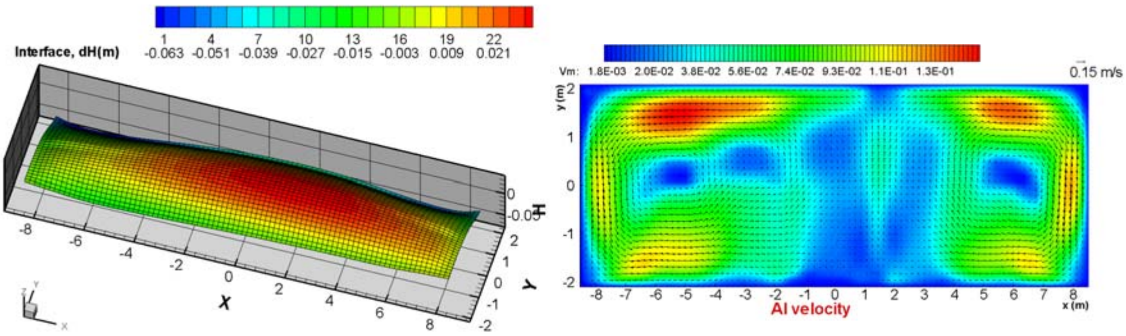

Figure 11. Steady-state bath-metal interface deformation and steady-state metal pad flow velocity field for ECC.

As compared to the previous RCC busbar network case, the change of the predicted cell energy consumption depends only on the change of the external busbar voltage drop as the cell design remained exactly the same. Assuming a reduction of 130 mV of the external busbar drop, the corresponding reduction of the cell energy consumption is 0.4 kWh/kg so that 500 kA cell with copper collector bars extracting 100 % of its current on the downstream side and using ECC busbar configuration is predicted to operate at 12 kWh/kg while operating at the same 3.5 cm ACD reported in [1].

A revised calculation was done using 3.2 cm of ACD instead of 3.5 cm as since 2011, indications are that ACD has been reduced further in low energy consumption cell prototypes. At an ACD of 3.2 cm, the predicted cell energy consumption is calculated to decrease to 11.7 kWh/kg Al.

3. Conclusions

The results presented demonstrated that the usage of copper collector bars with similar sizes as standard steel collector bars can be used to extract 100 % of the cell current on the cell downstream size without generating excessive horizontal current in the metal pad or generating excessive cathode voltage drop.

A 500 kA cell with copper collector bars extracting 100 % of its current on the downstream side and using a revised alternating anode risers RCC busbar configuration is predicted to be MHD stable and to run at 12.4 kWh/kg while operating at 3.5 cm ACD and 0.8 A/cm^2 of anode current density.

From [4] it can be extrapolated that a 740 kA or a 1500 kA cell with copper collector bars extracting 100 % of its current on the downstream side and using the same type of revised alternating anode risers RCC busbar configuration would work equally well at the same level of power efficiency.

A 500 kA cell with copper collector bars extracting 100 % of its current on the downstream side and using a revised ECC busbar configuration is predicted to be MHD stable and to run at 12 kWh/kg while operating at 3.5 cm ACD or 11.7 kWh/kg while operating at 3.2 cm ACD and 0.8 A/cm^2 of anode current density.

4. References

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