Cathode Design Effects on MHD Stability of Aluminium Reduction Cells

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Abstract

Magnetohyrodynamic (MHD) stability is known to limit aluminium reduction cell efficiency. Normally cell stability is achieved by designing the cell with an optimized magnetic field, while the electric current distribution in the liquid metal is an equally important requirement. Modelling of electric current distribution requires a detailed 3D representation of the cell cathode coupled to the liquid metal zone.

The modelling software known as MHD-VALDIS is an established tool for MHD stability investigation and cell design. The recent update described herein permits to account for current distribution in liquid metal and coupled cathode features including variable contact resistance along collector bar and carbon, temperature-dependent collector bar conductivity variation, carbon block length limitation, ledge profile along cell wall, etc.

In the present article, we demonstrate MHD stability improvement when these features are optimized along with the total cathode voltage drop (CVD) control. The software permits to recompute the full electric current distribution change in time with the continuous magnetic field update resulting in the velocities and metal/electrolyte wave development leading to damping in a stable state or growth in an unstable cell. Examples of commercial cell applications are presented.

Keywords: Aluminium reduction cells, MHD stability, Electric current distribution, Cell modelling.

1. Introduction

To be able to compute the Lorentz force field responsible for the bath-metal interface instability, it is first required to compute the current density field in the liquid zone. It is particularly important to compute accurately the horizontal current in the metal pad as this significantly contributes to the interface instability. Givry was the first to present mathematical models that could perform current distribution calculations [1].

Givry's models are based in the discretization of 3D conductors by a network of 1D conductors, as illustrated in Figure 1. MHD-VALDIS (Magnetohydrodynamic versatile aluminium pad instability solver) software uses that type of representation for the solid parts of the electrical network as it leads to extremely fast computing time which is required to solve the full non-linear dynamic evolution of the current redistribution initiated by the interface wave motion in the cell stability analysis. The complete cell electric current is obtained at each development time step combining the extensive 1D element network representing the 3D cell busbars and the high order Fourier representation in the liquid zone, see details in [2].

When the only purpose is to solve for the steady-state current density distribution in the metal pad, using a more detailed 3D Finite Element (FE) representation of the system leads to a more accurate solution. One of the earliest 3D FE-based full cell model was presented at the 1994 ANSYS conference [3], see Figure 2.

The solution of the metal pad current density is very sensitive to the model setup as the liquid metal electrical resistivity is very low. Any discrepancy between two given models will affect their respective solution of the metal pad current density.

A comparison between MHD-VALDIS and ANSYS-based 3D model was first published in 2003 [4] for a 500 kA demonstration cell. This paper revisits this comparison in more detail using the 180 kA TRIMET cell with the most recent version of the code MHD-VALDIS. The new version of MHD-VALDIS is used to study impact of some design changes of the cathode assembly on the horizontal current in the metal and consequently on the cell stability.

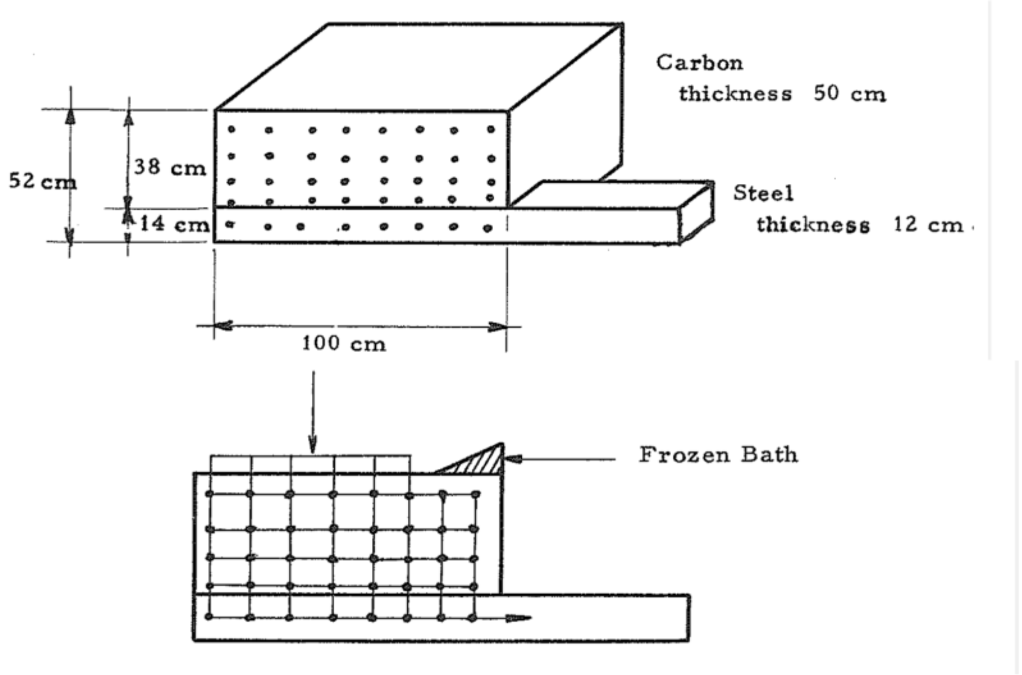

Figure 1. Representation of a cathode assembly by a network of 1D conductors, reproduced from Figure 14 in [1].

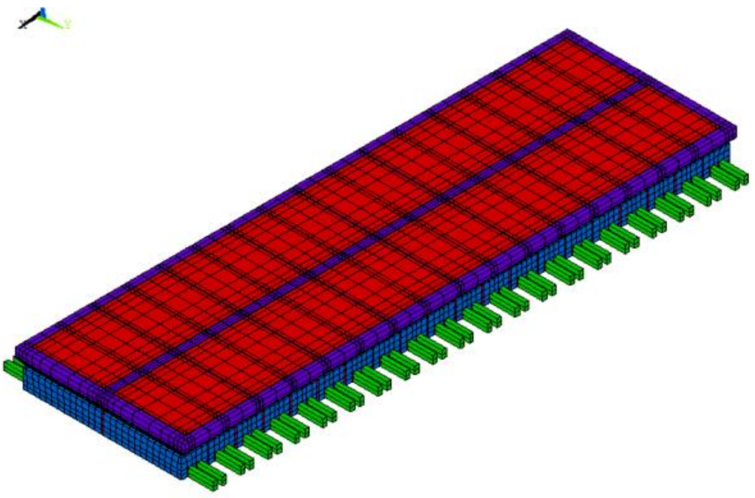

Figure 2. Representation of cathode assemblies, liquid phases and anode blocks by 3D finite elements, reproduced from Figure 4 in [3].

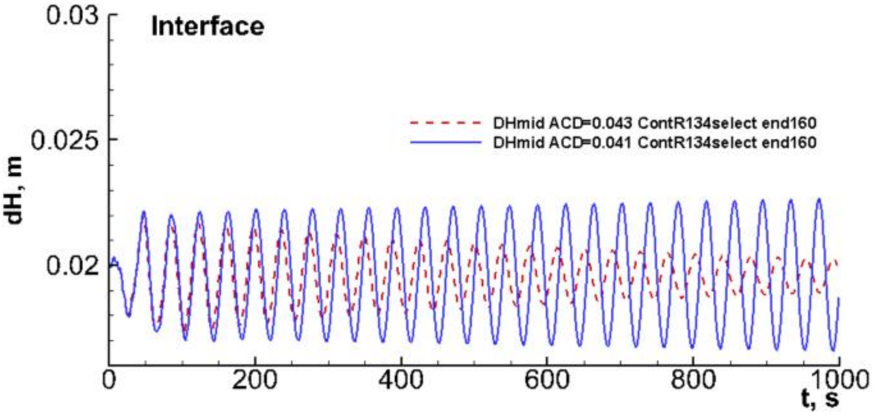

Figure 19. Comparison of the cell stability for the selective rodding case at 43 (dashed line) and 41 mm (solid line) ACD.

6. Conclusions

A more accurate method of computing the current density in the metal pad has been implemented in a new release of the code MHD-VALDIS using a new, more flexible way to define the contact resistance value(s) between the bar and the cathode block.

1. It was demonstrated that using the old contact resistance definition method with the new code version produced wrong results, so it is highly recommended to use the new code version with updated model setup for the contact resistance definition method based on the `CBARCONTR.txt` file;
2. The metal pad horizontal current obtained using the new MHD-VALDIS code version and the `CBARCONTR.txt` input file are very comparable with the solution produced by a 3D ANSYS model for the same TRIMET 180 kA cell case;
3. The gained input flexibility provided by the `CBARCONTR.txt` input file was used to test the impact of both stopping collector bar rodding short of both edges of the cathode block and selective rodding. The assessment was performed both in terms of metal pad horizontal current density and cell stability;
4. It was confirmed that both methods reduce the metal pad horizontal current and increase cell stability.

7. References

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