Comparison of CVD, Horizontal Currents and MHD Stability of Different Cathode Designs

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Abstract

MHD stability is known to limit aluminium reduction cell power efficiency. Normally, cell stability is achieved by designing the cell with an optimized magnetic field and electric current distribution in the liquid metal. Modelling of electric current distribution requires a detailed 3D representation of the cell cathode assembly 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 is described which 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. Cathode voltage drop (CVD) and horizontal current density obtained by MHD-VALDIS software are compared with those obtained using a 3D ANSYS electric software. The impact of reducing both JX and JY on the MHD stability is then analyzed using MHD-VALDIS software.

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

1. Introduction

The present work is a follow up of the work presented at ICSOBA 2023 [1], so it is addressing some of the limitations of the previous work. In this work as in the previous work, CVD and the metal pad horizontal current density in the longitudinal direction (JX) and the transversal direction (JY) are calculated using both a 3D ANSYS finite element based electric model and MHD-VALDIS cell stability software. As its name indicates the main purpose of the MHD-VALDIS software is to analyze the bath-metal interface stability once a perturbation is offsetting it from its steady-state position.

In order to be able to do that, MHD-VALDIS software must first compute that steady-state interface position and in order to do so it must solve for the two liquid phases flow solution under the influence of both the gravity and the Lorentz forces. In order to calculate the Lorentz force field (**F**), the MHD-VALDIS software must calculate first its two components: the current density vector field (**J**) and the magnetic flux density vector field (**B**), both are equally important as the Lorentz force vector field is the vector product of the current density vector field by the magnetic flux density field:

$$\mathbf{F} = \mathbf{J} \times \mathbf{B} \tag{1}$$

Over the years, a lot of work has been done in MHD-VALDIS to improve **B** calculation accuracy that is computed using the very efficient and convenient integral formulation that eliminates the need to mesh the air around the cell to solve for **B** in the bath and metal in the cell considering all the source currents of the full smelter and the shielding effect of the ferro-magnetic steel of the potshell and superstructure of that cell [2].

Until recently, less work had been performed in MHD-VALDIS to improve **J** calculation accuracy. The steady state **J** must be calculated initially in order to provide the source terms required to calculate the steady state **B** and then the steady state **F**, but it must also be recalculated at each time step during the transient cell stability analysis in order to recalculate **F**, as it is the change of **F** due to the change of **J** that drives the interface displacement, in turn responsible for the change of **J**.

So, it is important to be able to quickly recalculate **J** at each time step, to do so MHD-VALDIS solves a network of discretized conductors using the Kirchhoff's law. Givry was the first to solve for **J** vector field in the metal pad using this method [3]. Figure 1 presents how the end block was discretized and the impact of the end ledge toe on the network current boundary condition. The combination of the offset between the anode shadow and the edge of the end block and the end ledge toe position is having a great influence on the intensity of the longitudinal horizontal current density JX.

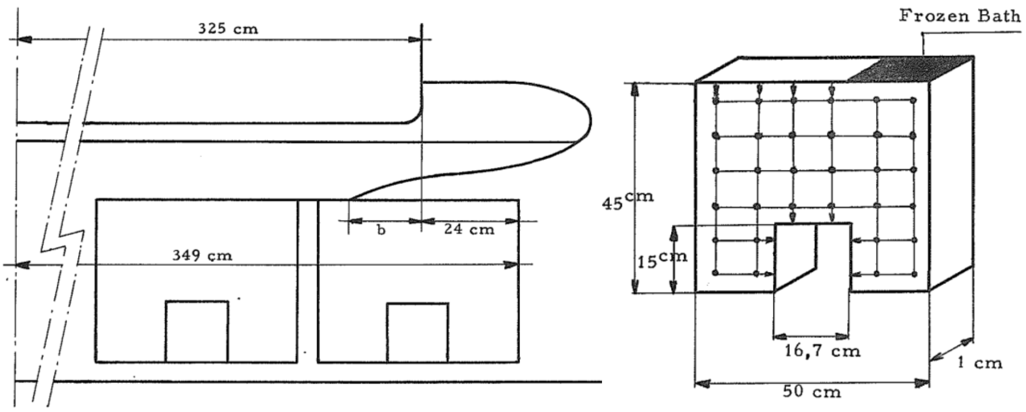

Figure 1. Representation of the end wall cathode assembly and the discretization of the end block by a network of 1D conductors, reproduced from Figure 18 and 20 in [3].

Another way to discretize the cell and to solve for the metal pad current density **J** is to use the finite element method, this has been done for the full cell in 3D using the finite element code ANSYS in [4]. Figure 2 presents the mesh of such a 3D finite element model for the case of the TRIMET cell geometry that will be used again in the present work, as it was used for the first time in [5]. As we can see in Figure 2, the geometry of the TRIMET cell is similar to the geometry presented in Figure 1, the end block exceeds significantly the anode shadow of the end anode.

As already explained in [1], contrary to **B** that can be measured, it is not practically possible to measure **J** in the metal pad. It is well known that horizontal current densities JX and JY are detrimental to cell stability, and great effort have been made to reduce JY principally by the introduction of copper inserts in collector bars, but JX that is as important has not been studied much. One of the reasons is that in order to calculate JX accurately in the metal pad, you need to build a full cell model, calculate the collector bar current pickup, and this requires to model and solve for the current in the busbar network between cells.

Since the TRIMET 3D ANSYS electric model is not representing the busbar network, the current pickup is a boundary condition in the model. The usual boundary condition is to impose a uniform current pickup which is a good boundary condition if the busbar network is well balanced, but it is not actually the case for the TRIMET cell case. So, for the purpose of the comparison of **J** in

The subsequent cell stability analysis has demonstrated that it is as important to reduce the JX as it is important to reduce the JY in order to increase cell stability. By combining with the results presented in [1], we can conclude that when intense JX are present, continuous reduction of the JY intensity may not result in continuous increase of the cell stability. Hence it is important to reduce both JY and JX intensity to maximize cell stability.

Finally, the reduction of the horizontal current densities also affects the steady state Lorentz force field which in turn affects the steady state bath and metal flow pattern. Since the bath flow pattern affects the path of dissolving alumina particles added into the bath, a change of bath flow pattern will also affect the pseudo steady state alumina concentration gradient present in the bath responsible for continuous PFC emissions in region(s) of very low alumina concentration. For the series of the four analyzed design changes, the modifications aiming at reducing the horizontal current in the metal pad also resulted to the reduction of the alumina concentration gradient in the bath.

15. References

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