Design of Smelter Magnetic Solutions Using MHD Code

Robert Chahine[1], Benoit Bardet[2], Bertrand Allano[3] and Olivier Martin[4]
1. Modelling Engineer
2. Senior Design Engineer
3. Principal Advisor Reduction
4. Reduction Domain Director
Rio Tinto – LRF, Saint-Jean de Maurienne, France
Corresponding author: robert.chahine@riotinto.com

Abstract

Rio Tinto has developed an in-house MHD code to study the stability of aluminium electrolysis pots. The model is calibrated with experimental measurements of magnetic fields and pots stability. This tool plays a major role in using boosters in smelters in order to develop and test new AP Technology™ pot improvements. Furthermore, it is used to calculate the MHD stability limit for amperage increase in smelters and for designing new solutions in case of unstable pots. A recent example applied at Alma smelter is the design of a special compensation loop that increases the stability of end-line pots [1] which are known to be unstable relatively to middle-line pots, thus allowing the smelter to reach 450 kA.

Keywords: Aluminium electrolysis cells, MHD modelling, instability, magnetic solutions.

1. Introduction

Aluminium electrolysis is the industrial process used in smelters to produce primary aluminium. This process consists in dissolving alumina in an electrolytic bath at high temperature of the order of 970 °C, through which flows an electrical current, thereby launching an electrochemical reaction that transforms the dissolved alumina into liquid aluminium and CO_2 bubbles,

$$2Al_2O_3 + 3C = 4Al + 3CO_2 \tag{1}$$

The electrical current flowing through electrolysis pots is large enough (hundreds of kiloamperes) to generate a strong magnetic field that impacts its surroundings, e.g., metal transport vehicles, metallic structures, etc. Furthermore, this magnetic field modifies the metal heave and the fluid dynamics in the pot, thus impacting the alumina dissolution and pot stability. When the vertical component of the magnetic field is large, the pot becomes unstable due to generation of a horizontal MHD force that amplifies the metal-bath interface perturbations [2]. Hence, the design of busbars transporting electrical current between the different pots and providing the distribution of magnetic field in the pot, plays a major role in the conception of a stable pot-line. However, optimal conception of pot busbars is not enough in the case of important amperage increase where the potline operation point, i.e., anode-cathode distance (ACD), metal height and pot-line current, drastically change in order to conserve pot thermal and chemical equilibria. One of the solutions consists of additional electrical conductors parallel to the pot-line to compensate the neighboring potlines magnetic field and to optimize the one in the pots [1]. These additional electrical conductors are called magnetic compensation loop. Their advantage is their adjustability with respect to the pot-line current, enabling higher amperage increase without changing the pot busbars design. Such magnetic solution is designed using an in-house MHD code developed by Rio Tinto. This code will be presented in Section 2, then multiple applications will be shown in Section 3, and concluding remarks will be given in Section 4.

2. MHD Code Description

The MHD stability code was developed using shallow water model which is suitable for geometries with a horizontal length scale much greater than the vertical length scale. The model inputs are: the position of pot-line conductors and current they carry, ACD, metal height and pot geometry (anode and cathode dimensions, steel shell geometry). The model outputs are the resulting magnetic field and a pot stability criterion. Figure 1 shows pot-line conductors as in the code interface.

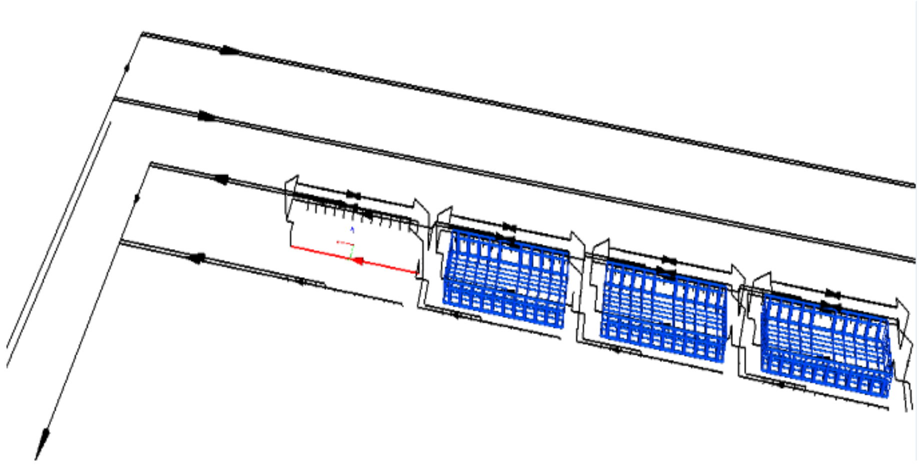

Figure 41. Interface of the MHD code showing potline conductors.

Several magnetic field measurements in the pot are done regularly and compared to the numerical results to validate the model. This is shown in Figure 2, where the red curve corresponds to pot magnetic field measurements along the pot long-side at Alma smelter, and the blue curve corresponds to the numerical model. The close superposition of the two curves shows a good consistency between the numerical model and the pot measurements.

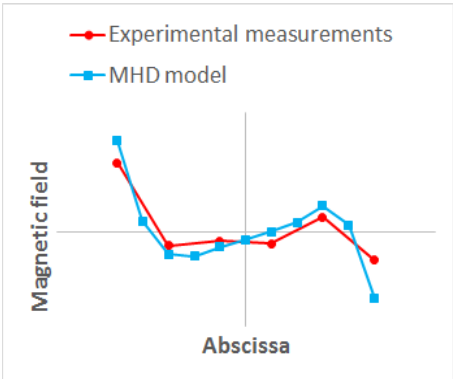

Figure 2. Comparison of magnetic field distribution resulting from experimental measurements and from MHD model.

In order to validate the pot stability prediction model, the stability criterion requires calibration. This is done via a squeezing test that consists in reducing the ACD until the pot becomes unstable, thus identifying the value of stability criterion corresponding to this threshold ACD. An example of a squeezing test is shown in Figure 3 where the green curve is the ACD and the blue curve is the measured pot voltage perturbation. During this test, the ACD was gradually decreased until the pot voltage perturbation became instantly greater than the predefined threshold, represented by

It should be noted that new technology development is not only done using this code. To check more precisely the stability and the fluid dynamics in a pot, ALUCELL software suite is coupled with this code [4] and used for example to calculate the velocity field (see Figure 10) and optimize alumina dissolution as shown in Figure 11.

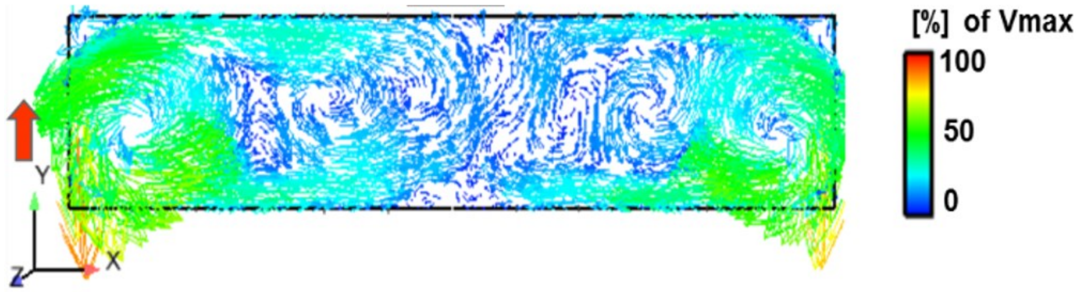

Figure 10. Velocity field in a pot calculated with Alucell.

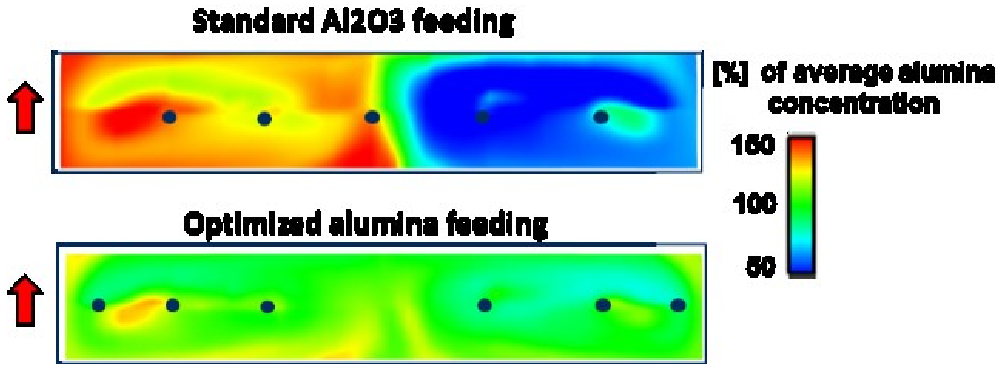

Figure 11. Alumina concentration field in the bath calculated with ALUCELL.

4. Conclusions

The MHD code presented in this article has been developed by Rio Tinto to calculate magnetic fields in the pot-line and predict pot stability. This code was validated with pot measurements and proved to be a main contributor in pot-line development and in the design of multiple magnetic solutions, e.g., magnetic compensation loops, boosters, new pot technology.

Furthermore, these solutions are designed by taking into consideration the optimization of financial aspects (CAPEX/OPEX). Moreover, the code works on different technologies and was used to provide solutions for AP Technology™, P-69/P-155, Alusuisse, Sumitomo and CD200.

5. References

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