Thermoelectrical Modelling of the Effect of Metal Height and Cathode Erosion on Cell Heat Balance

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Abstract

The adaptation of the control strategy to be used during the life of the aluminium reduction cell is a critical issue. The evolution of the dynamic behaviour of the cell leads to significant changes in the thermal balance and current efficiency, which require such adaptation to maintain an efficient process. To do so, a good understanding of the parameters affecting the cell behaviour is required. One of those parameters is the metal mass in the cell which affects, among others, the thermal balance and hence the protective ledge. During its life, the erosion of the cathode leads to an additional mass of metal in the cell, which may also change this equilibrium. To guide the control strategy, a calibrated thermoelectrical quarter-cell model (ANSYS™) is used to investigate the effect of the metal mass via the variation of the metal pad height and/or the eroded cathode profile. The results obtained from the simulations allow to estimate the energy input correction for a given metal mass in order to assure proper protective ledge/thermal balance. This estimation is based on the minimisation of the change in the ledge profile between a specific scenario and the reference one as obtained with the calibrated conditions. Such procedure and results give critical information for further optimisation of the operational procedure.

Keywords: Aluminium reduction cell, Metal height, Thermal balance, Cell thermoelectrical modelling.

1. Introduction

The dynamic behavior of the cell results in continuous changes of the cell state due to the nature of the process and the required interventions such as: metal tapping, cathode erosion, anode change, evolution of material properties, bath chemistry evolution, anode effects and many others. Some of those elements such as the metal tapping and the cathode erosion phenomena can lead to operating the reduction cell with a higher mass of metal mainly because of three reasons:

- Unforeseen events in the plant cause the delay of the planification which includes the tapping procedure of the metal leading to higher metal pad height for some reduction cells
- Unavoidable and continuous erosion of the cathodes/lining leading to an additional mass of metal for a same metal pad height
- Change in the target value of the metal pad height in order to adjust the ledge thickness toward the optimal

In the aluminum industry, it is well known that operating at a higher metal pad height change the thermal balance leading, for instance, to an increase of the heat loss by the sides of the cell and then a thicker protective ledge. Therefore, when operating with an additional mass of metal, it is necessary to take the right action to remain with an optimal thermal balance. Amongst others, one of the available actions is to change the internal heat of the cell via the cell voltage/ACD. In order to determine the amplitude of this correction, this paper will focus on the effect of the mass of metal on the thermal behaviour of the reduction cell.

2. Problem Statement and Objective

Operating with a different mass of metal causes a variation in the thermal balance of the cell, more specifically to the:

- Protective ledge thickness
- Location of the critical isotherm in the lining
    - 955 °C, bath liquidus
    - 820 °C, harmful for insulating lining
    - 660 °C, metal liquidus
- Heat loss distribution around the cell

However, since the behavior of the cell is highly transient and complex, it is difficult to properly quantify the correction to be made to the cell voltage to maintain an adequate thermal balance for a given additional metal mass. Also, there is no guarantee that a correction in the cell voltage leading to an adequate protective ledge (for instance) will also lead to critical isotherm in the lining that are harmful for the operation and cell life. Which brings us to the objectives:

- Determine the effect of an increase of the metal pad height on the thermal behavior
- Determine the effect of an increase of the cathode erosion on the thermal behavior
- For a given additional mass of metal, determine the cell voltage correction in order to:
    - return to the optimal ledge thickness
    - ensure that the critical isotherms (955 °C, 820 °C, 660 °C) are not harmful to the operation and the cell life

3. Proposed Approach

The proposed approach consists on the utilization of a transient ¼ reduction cell model using 3D finite element method in order to evaluate the thermal and electrical behavior of a reduction cell for the following scenarios:

1. Normal metal pad height (15 cm) without cathode erosion (reference scenario)
2. Additional metal pad height (22 cm) without cathode erosion
3. Normal metal pad height (15 cm) with an estimated 5-year cathode erosion

To represent the cell thermal and electrical behavior properly, the model must include the proper geometry, material properties and boundary conditions. All those elements were determined and calibrated previously, as explained in detail in [1].

Regarding the ledge profile, it is required that the ledge hot surface (corresponding to the 955 °C isotherm) be positioned according to the TE behavior of the reduction cell. To do so, the strategy is to create a fictive material for the volume that include the liquids (metal/bath) and the solid ledge. The properties of this selected volume are those of the liquid metal/bath above 955 °C and those of the solid ledge below 955 °C. This element will be discussed further in the model description.

The model is then used to predict a resulting ledge profile for each one of the scenarios (1 to 3). An external calculation procedure is then used to quantitatively compare the changes in the ledge profile between the scenario under investigation and the reference scenario. Finally, simulations of the scenarios with additional metal (2–3) will be carried out in order to estimate the additional

9. References

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