Evaluation of anode cover heat loss

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Abstract

Thermal balance is a key parameter in any cell technology and has a major impact on cell operation and the resulting KPIs. The cell loses heat mainly through the potshell and anodes. The anode is typically covered with a layer of ore material to protect it from oxidation and is also utilised to maintain the required heat balance inside the cell. The desired heat loss is achieved by adjusting the height of the cover, which is one of the cell operating parameters. The impact of anode cover height on the cell thermal balance was studied using ANSYS thermoelectric models. These models predict heat loss through the anode cover, the resultant bath temperature and freeze profile. To evaluate the modeling results, the anode cover was equipped with thermocouples, allowing continuous temperature measurements throughout the anode life cycle. These thermocouples were installed at different heights to understand the variation in thermal conductivity as the cover changes from a hard layer at the bottom to a softer one at the top. In this paper, the result of these trials is presented, together with the model prediction and findings of this study.

Keywords: Anode cover; thermal conductivity; anode heat loss; modeling; cell thermal balance.

1. Introduction

Achieving good thermal balance is one of the key fundamentals for excellent KPIs in any cell technology. Understanding the pot's thermal state and the desired thermal balance of the pot enables better pot control and operation. Approximately half of the energy in a pot is lost as heat. The two major contributors are heat loss through the potshell sidewalls and heat loss from the top of the anode [1]. Understanding the heat loss through the potshell is essential for pot lining design. The lining material should provide enough thermal insulation to maintain the bath temperature on target, while providing adequate freeze on the side to protect the side lining. Another major contributor to heat loss is the top of the anode, accounting for approximately 40 % of the total pot heat loss [1]. In addition to the design of the anode and the thermal conductivity of its different components, the anode cover plays a major role in controlling the heat loss through the top. Anode cover material consists commonly of crushed bath and alumina. The anode cover serves two main purposes in the pot: to prevent anode oxidation, and to insulate the top of the pot to reduce heat loss through the top of the anode panel.

The heat loss through the anode cover depends on the composition of the cover material as well as the height of the cover. While increasing the percentage of alumina in the cover can help reduce the thermal conductivity of the cover, higher alumina content in the cover makes it more difficult for the cover to stay on top of the anode. The anode cover height is flexible and can be adjusted, if required, for heat balance when pot amperage or pot voltage changes (or any other parameter that affects the pot heat balance).

Anode cover heat loss depends on the thickness of the anode cover and its thermal conductivity. The thickness of the anode cover can be kept constant by anode redressing. The thermal conductivity depends on the composition of the cover. In this study, the cover comprised approximately 65 % crushed bath and 35 % alumina.

During the life of the anode, the cover changes continuously due to the penetration of bath vapours into the cover, which induces physical and chemical transformation of the cover, particularly in the bottom part, which becomes hard. Altough the top layer remains loose, the properties may also change because of the compaction and some penetration of bath vapours. Consequently, the thermal conductivity of the anode cover changes continuously during the anode life. This has been demonstrated by previous studies, specifically for free crust above the channels [2 - 4]. Our study involved the anode cover on the top of anodes, which covers a much larger area than the channels.

2. Modelling approach

To evaluate the heat loss from the cell, two major modelling approaches were used: quarter cell ANSYS 3D thermoelectric model, shown in Figure 1, representing the full cell by symmetry as well as separate anode and cathode models. The full model includes lining, potshell, anodes with the cover, liquid metal and bath. The model results include pot temperature distribution, freeze profile and heat loss from different parts of the pot, as well as the voltage drop in each component.

The anode slice model, Figure 2, was used for more detailed analysis of the anode cover heat loss. The results of the slice model are generalised to the whole anode panel, to obtain heat loss from the top of the pot.

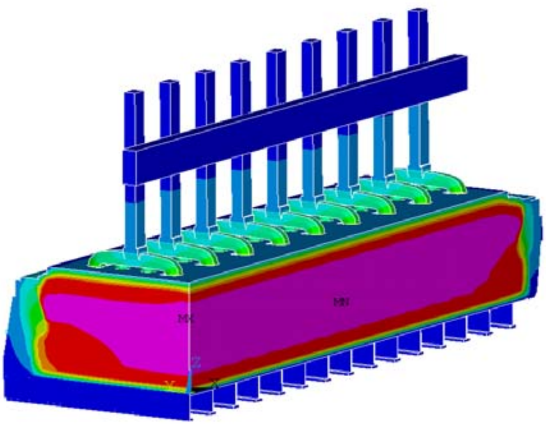

Figure 1. Full cell model.

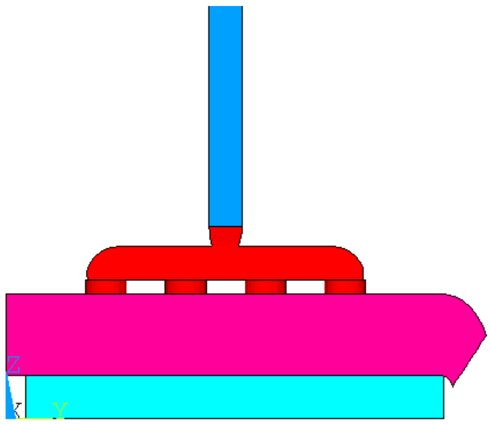

Figure 2. Anode slice model.

3. Measurement setup

To validate the anode model results, the temperature distribution through the thickness of the cover material was measured. This was done by installing a vertical stack of five equidistant thermocouples at different levels from the top of the carbon and fixing them on the anode yoke to secure them in the same position for the whole anode life cycle. The thermocouples were connected to a data logger, which recorded the temperature every 15 minutes. Figure 3 shows an anode with the thermocouples installed before anode setting. One of the thermocouples was fixed onto the top surface of the carbon and the rest were placed at 3 cm, 6 cm, 9 cm and 12 cm above the top of carbon surface. The thickness of the anode cover was 13 cm. For this study, five anodes were measured. The anodes in this study were DX+ anodes with four stubs and the location chosen for thermocouple installation was between the first and second stub from the

It is important to note that these results are specific to the cover material used at the time of trial, as composition and granulometry of the cover material can impact the results. Further studies and investigations are required to establish a more comprehensive understanding of the anode cover heat loss. The impact of changing cover height on heat loss should be determined experimentally by conducting more trials using different cover heights and comparing the results to the model.

6. References

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