3D Flow of Deposits on the Surface of Cathode Blocks in an Aluminium Electrolysis Cell

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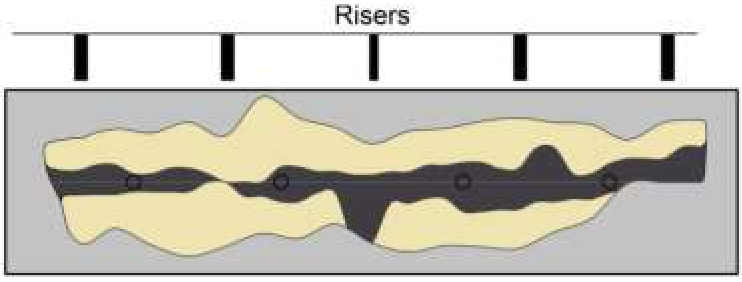
Abstract

Lab-scale experiments and observations from industrial aluminum electrolysis cells have shown that a layer of deposits can be formed at the surface of the cathode blocks. Studies have shown that the thickness, composition and state (liquid, mushy, solid) of the deposits can vary along the cathode surface, depending on the operational conditions. The deposits are highly resistive and at the origin of local horizontal currents generated in the cell, a situation that is not favorable to cell stability. Moreover, these deposits increase the cathode voltage drop (CVD) which also reduces the energy efficiency of the cells. When they are in the liquid state, these deposits have been suggested to be the source for the back feeding and for ledge formation at the metal level. Some authors have postulated that at the metal level, the formation of the ledge is only possible if there exist a bath film between the metal and the ledge. In order to understand more clearly the behavior of the deposits at the surface of the cathode, a transient multiphase finite-volume model is developed to couple the mass and momentum conservation equations to a hybrid method combining the volume of fluid and level-set function. The numerical model enables to predict the time-varying velocity field and volume fraction of the deposits. From these predictions, the mass flow of deposits moving along the cathode surface is calculated and compared to values reported in the open literature. The proposed model is finally used to verify the impact of the initial deposit thickness on the movement of deposits and the corresponding mass flow. For a cathodic panel periphery of 30 m long, results show that the mass flow of the deposits vary over time, with a rapid initial peak and then an exponential decrease ending up to a value two orders of magnitude smaller than the peak. For an initial thickness of 0.5 mm and 1.5 mm, the calculated final thicknesses are respectively 0.25 mm and 0.4 mm, while the mass flow peak values are 0.17 - 0.19 kg/s and 0.55 - 0.76 kg/s.

Keywords: Aluminum electrolysis cell, bottom deposits, mathematical modeling, CFD, multiphase flow.

1. Introduction

Lab-scale experiments and observations from industrial aluminum electrolysis cells have shown that a layer of deposits can be formed at the surface of the cathode blocks [1 - 6]. As reported in these studies, the deposits consist of a mixture of electrolytic bath and alumina. Results have shown that the thickness, composition and state (liquid, mushy, solid) of the deposits can vary along the cathode surface, depending on the operational conditions (Figure 1). The deposits are highly resistive and can lead to local horizontal currents, a situation that is not favorable to cell stability. Moreover, these deposits increase the cathode voltage drop (CVD) which also reduces the energy efficiency of the cells.



a) Schematic top view of the deposits formation [3]: Grey zone- ledge toe, Yellow zone- thin film, Dark zone – thick deposits

b) Surface of industrial cathode block [4]
Figure 1. Deposits on the surface of cathode blocks.

In addition, when the deposits are in the liquid state, they have been suggested to be one of the mechanisms for the back feeding and ledge formation at the metal level. The ledge at this location behaves differently than at the bath level as reported in various studies [7 - 9]. Some authors have postulated that at the metal level, the formation of the ledge is only possible if there exist a bath film between the metal and the ledge.

For years, numerical modeling of aluminum electrolysis cells has been performed and enabled to achieve more energy efficient aluminum production [10]. In the current work, a transient finite-volume numerical model is first developed in order to understand more clearly the behavior of the deposits at the surface of the cathode. The model enables to predict the time-varying velocity field and volume fraction of the deposits. From this information, the objective is to gain knowledge on the deposits mass transfer process in the optics of later adjusting the operational parameters of the electrolysis cell or to modify the design of cathode blocks so to minimize the impact of resistive deposits on its surface.

From the time-varying velocity field and volume fraction of the deposits, the current work aims secondly to predict the mass flow of deposits moving along inclined geometry of cathode blocks and to compare it with values reported in the open literature. Finally, the proposed model is used to verify the impact of the initial deposits thickness on its movement and the corresponding mass flow.

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6. References

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