Numerical Modeling of the Alumina Distribution in Aluar Cells

Dagoberto S. Severo[1], Vanderlei Gusberti[2], Pablo Navarro[3] and Marcos Domínguez[4]
1. Director
2. PhD Engineer
CAETE Engenharia Ltda, Porto Alegre, RS, Brazil
3. Head of Electrochemical Process R&D
4. Process Analyst
Aluar Aluminio Argentino SAIC, Puerto Madryn, Argentina
Corresponding author: dagoberto@caetebr.com

Abstract

This article presents the use of numerical modelling of the alumina transport and distribution in Aluar's end-to-end end-risers cells. The numerical models were built based on the MHD behavior of the cell, which includes the metal heave and the bubble flow evolving from the anodes. The anode slots were modelled at different times over the anode rota, producing a 3D bath flow solution for each timeframe situation. The influence of different aspects of alumina transport mechanism in the bath was studied separately in the models, such as metal drag at the interface, internal bath MHD forces and bubble induced forces. The model was validated with bath temperature measurements over time and showed a good agreement with the experimental findings.

The models were useful to analyze the alumina distribution pattern with the current configuration of point feeding locations enabling the virtual test of improvements by modifying the feeder location and feeding strategies. It was also possible to identify areas of bath stagnation in the bath volume, which can be associated with practical observations regarding carbon dust and
undissolved alumina.
The model predicted the anode position that systematically shows a tendency to operate with lower alumina concentration and which is prone to start an anode effect. Configurations that show a better alumina distribution and which should result in better process efficiency than the existing feeding procedure were obtained.

Keywords: alumina distribution, feeder location, anode effect, current efficiency, alumina transport.

1. Introduction

In aluminium electrolysis smelters, there is always pressure on better energy efficiency associated with production increase. In this context, some actions are frequently adopted such as: anode area increasing, ACD lowering and line current increasing. Those modifications reduce the bath volume of the cell and further increase the alumina dissolution capacity demand. The ability of the bath to dissolve alumina is therefore a critical aspect in cell design development. In addition to the sufficient bath volume, other conditions are important to promote good alumina dissolution such as superheat, alumina dump size and frequency, bath flow and turbulence.

Another relevant aspect is the alumina transport from the feeding locations to the ACD regions below each anode, where the electrolysis reactions occur. It is desirable that the convective transport ensures concentration homogeneity among all anodes. If one of the anodes is not adequately served with alumina rich bath, it will become prone to produce successive anode effects during cell operation, reducing cell electrolysis efficiency.

The objective of this work is to develop numerical models capable of studying the alumina transport behavior inside the bath. Using the models, it is possible to study alternative feeding strategies in order to find a configuration that optimizes alumina distribution inside the bath, which is beneficial to increase electrolysis efficiency. Experimental work was carried out at ALUAR and it helped to develop and calibrate the numerical models.

Back in 2007, CAETE Engenharia developed bath flow models [1] where the bubble induced forces and MHD forces were included in the model formulation. The efficiency of the use of anode slots was the focus of the referred work. It was then concluded that the gas bubbles are the major contributor for the bath flow. However, the inclusion of MHD forces and metal drag is important to represent the asymmetry present in the bath flow of the cell. In [5] and [6], the bath flow results and alumina concentration are symmetric because no MHD effect is included in the simulation.

The same conclusions were made by another work about the importance of the bubble induced flow on the alumina transport by the bath [2], in opposition to some alumina distribution models also present in the literature [3, 4]. Alumina distribution in the bath space was measured by Tessier et al. [7]. Important variation on the concentration of alumina over the space and time was found and the bath flow pattern is responsible for the alumina dissolution and distribution in the electrolyte. They reported that “sick pots” presented stronger alumina concentration variation.

One possible experimental way to track alumina transport is measuring the bath temperature over time at selected channel positions. Usually, after the feeding shot, a transient drop in the bath temperature is observed along the alumina transport path in the bath, because fresh alumina is entering the bath at ambient temperature and energy is consumed to heat up and to dissolve the alumina. The sensor must be located at the downstream of the feeding position regarding the bath flow pattern. The temperature drop means that alumina rich bath is passing at the sensor area at the moment. After a certain time, the bulk hot bath comes back to the sensor region ending the temperature perturbation. As alumina heats up and dissolves, this effect fades and the particular bath temperature disturbance is not detectable anymore, this occurs far from the feeding positions or upstream to the feeders. In this work, as described above, the temperature measurement of the bath at selected positions will be used to infer the alumina concentration variation in time and space during the electrolysis process. Other processes can cause bath temperature variation such as non-uniformities in bath energy generation and consumption, heat losses through the holes, anode spike, etc. However, the type of temporal temperature variation of alumina feeding is very distinguishable because it matches with feeder frequency. Also, the magnitude and rate of the variation is usually higher compared to the other cited phenomena.

2. Bath Flow - Model Description and Assumptions

The fluid flow models were developed using the Finite Volume Method. The space occupied by the bath is the discretized geometry. The model physics is described as Euler-Euler multiphase flow with one continuous phase (liquid bath) and one dispersed phase (bubbles). Turbulence models are included in both fluid phases: k-epsilon model for bath and Zero-equation model for the bubbles.

The dominant electrolysis reaction of the process produces metallic Al and CO_2:

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

eddies that communicate the distinct cell regions. Alumina distribution is then strongly influenced by MHD forces.

9. Conclusions

The model for alumina transport inside the bath was successful developed. It presents very good agreement with the bath temperature measurements performed by ALUAR, at least in the cases where the temperature variation was detected at the measurements. It is important to include the bubble induced forces as well as the MHD forces and metal drag in the simulations. The same model can be modified in order to predict the regions of higher bath temperature and superheat. The place and number of feeders can be optimized using the models.

In the particular cell technology presented in this article, if the tapping channel at sidewall is used displacing one anode towards the center channel, the bath flow will be affected, because the center channel must be narrowed. The channel strangulation will improve the alumina mixing, mainly in the A3 tapping channel position. As a consequence, fresh alumina is more homogeneously spread in the bath volume. Usually the central channel is simply focused on sufficient width to distribute alumina, but more complex geometries may improve bath flow pattern helping the alumina distribution.

Analyzing the dispersion found in alumina concentration under the anodes regarding each feeding setup case, we observe that the best alumina distribution was found in Case 6, which uses the A3 tapping channel in combination with 3 feeders. If, for other technical reasons, there is the need to keep using 4 feeders, a good option is case 2 where the tapping position requires displacement of anode A4.

It has been shown in the model that energy generated in the ACD tends to concentrate in the middle of the cell bath layer. In the model, the bath temperature is lower at the feeders near the cell ends. Less flames are observed at these feeder holes in real cells, which may be correlated with the energy transport. The models help to optimize the position of the feeder regarding bath temperature and alumina transport pattern.

10. References

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