# Simulation and Analysis of the Impact of Current Variations on Electrothermal Balance in Aluminum Electrolysis Cell

**Ao Hongmin[1], He Song[2], Yan Feiya[3] and Liu Zheng[4]**
1. Design engineer
2. Group leader
3. Department head
4. Department head
Guiyang Aluminum Magnesium Design and Research Institute Co., Ltd., Guiyang, China.
Corresponding author: ahm1989@126.com

## Abstract

With the worsening of energy shortage, aluminum electrolysis plants in some areas will face the problem of power shortage, which will lead to variations in the current of electrolytic cells. At the same time, some aluminum smelters are increasing their metal production by strengthening cell design. This will affect the electrical distribution of the aluminum electrolytic cell, but the electrical balance of the aluminum cell is crucial to the electrolytic production. In this paper, the changes of voltage distribution, energy consumption and temperature distribution of 500 kA aluminum electrolysis cells are analyzed in detail when the current fluctuates within ± 10% by using ANSYS software.

**Keywords:** Aluminum electrolytic cell, Electrothermal balance, ANSYS simulation calculation, Current variations.

## 1. Introduction

Aluminum production is an energy-intensive process, and aluminum electrolytic cells are an important part of the production line. Maintaining the electrothermal balance of the aluminum electrolytic cell is essential to ensure efficiency of aluminum production and minimize energy consumption. Due to power constraints and cell upgrades, electrolytic plants may face the problem of variations in the cell current. Understanding the effect of current variations on thermal balance is critical to optimizing the operation and production efficiency of aluminum electrolysis processes.

In this paper, the influence of current variations on thermal balance in 500 kA aluminum electrolytic cell is analyzed by using ANSYS simulation software.

## 2. Mathematical Model and Simulation Condition of Cell Electrothermal Field

### 2.1 Electric Model

The cell voltage of aluminum electrolysis cell is mainly composed of the following parts, as shown in Equation (1):

$$V_{\text{Cell}} = V_{\text{ACD}} + V_{\text{Anode}} + V_{\text{Cathode}} + V_{\text{Busbar}} + BEMF \tag{1}$$

where:

| | |
|---|---|
| $V_{\text{Cell}}$ | Average cell voltage, including voltage adders and anode effects, V |
| $V_{ACD}$ | Voltage drop between anode and cathode, comprising bath and bubble voltage drops, V |

| | |
|---|---|
| $V_{\text{Anode}}$ | Anode voltage drop, V |
| $V_{\text{Cathode}}$ | Cathode voltage drop, V |
| $V_{\text{Busbar}}$ | Busbar voltage drop from end of collector bars in one cell to anode rods below the anode beam on the downstream adjacent cell, V |

The potline busbar linkage voltage drop, comprising passageways and crossovers is not included in Equation (1) because it does not belong to any cell, and does not participate in cell heat balance. However, it has to be included in the overall energy consumption of the cell.

## 2.2 Energy Balance Model

The cell generates a large amount of energy from the current, which is necessary to maintain the electrochemical reaction. In addition, energy balance also includes the overall heat loss from the cell and the heat required for electrochemical reactions. The heat loss of the cell is generally divided into three parts: heat loss from the top of the cell, heat loss from the side of the cell and heat loss from the bottom of the cell [1].

## 2.3 Governing Equation

### (1) Differential Equation of Electric Potential

Under normal production conditions, the current does not fluctuate. The transmission speed of the current is very fast without lag. As a result, the conductive process can be represented with a 3D Laplace Equation (2) [2]:

$$\frac{\partial}{\partial x}\left[\frac{1}{\rho_x}\frac{\partial V}{\partial x}\right]+\frac{\partial}{\partial y}\left[\frac{1}{\rho_y}\frac{\partial V}{\partial y}\right]+\frac{\partial}{\partial z}\left[\frac{1}{\rho_z}\frac{\partial V}{\partial z}\right]=0 \tag{2}$$

where:

| | |
|---|---|
| $\rho_x$, $\rho_y$, $\rho_z$ | Resistivities of the material in x, y and z, respectively, $\Omega \cdot \text{mm}^2/\text{m}$ |
| V | Electrical potential, V |

### (2) Differential Equation of Heat Conduction

Heat transfer in the cell follows the Poisson heat conduction equation with electric internal heat source, Equation (3) [3, 4]:

$$\frac{\partial}{\partial x}\left[k_x\frac{\partial T}{\partial x}\right]+\frac{\partial}{\partial y}\left[k_y\frac{\partial T}{\partial y}\right]+\frac{\partial}{\partial z}\left[k_z\frac{\partial T}{\partial z}\right]+q=0 \tag{3}$$

where:

| | |
|---|---|
| $k_x$, $k_y$, $k_z$ | Thermal conductivities in the 3 directions, respectively, which vary with temperature, W/(m·K) |
| q | Volumetric heat generation rate of internal heat source per second, $\text{W/m}^3$ |
| T | Temperature, K. |

q in Equation (3) refers to the joule heat generated by the current passing through per second, so it is relevant to the potential in Equation (2) and the two equations need to be coupled for solution.

The calculation of the cell electrothermal field involves solution of both equations (2) and (3). In this paper, the cell model is established for the electrothermal field of 500 kA cell by using the finite element software ANSYS.

## 4. Conclusions

The influence of current variations on electrothermal balance of 500 kA cell was analyzed by ANSYS simulation. The results show that when the current decreases, the voltage of the cell decreases, the energy consumption distribution decreases, the maximum temperature of the side potshell decreases, and the temperature of the bottom and the lower side potshell changes little. When the current increases, the voltage of the electrolytic cell increases, the energy consumption increases correspondingly, the maximum temperature of the side potshell increases, and the temperature of the bottom and lower side potshell changes little. This calculation is based on a single factor change calculation, by varying cell current, to understand the distribution of heat generated by the electric current. This is different from an actual production situation but understanding these effects is critical to optimizing aluminum production and ensuring stable operation during current variations. Further research will focus on developing control strategies to mitigate the adverse effects of current variations, thereby improving the overall efficiency of cell operation.

## 5. References

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