MHD Stability of End Cells

Louis Bugnion[1] and René von Kaenel[2]
1. Vice president modelling
2. CEO
KAN-NAK, Sierre, Switzerland
Corresponding author: louis.bugnion@kannak.ch
https://doi.org/10.71659/icsoba2025-al084

DOWNLOAD FULL PAPER

Abstract

Despite the periodic arrangement of cells, aluminium smelters include several cells with different magnetic configuration due to their particular position in the potline. It might be cells at the entrance or exit of potrooms as well as cells before and after passageways or before and after stopped cells. Cells most affected are generally last cells at the exit of potrooms before the cross-over busbars. Their collector bars current distribution can be disturbed by the cross-over busbars, and the absence of neighbouring cell at the downstream side combined with the vicinity of the cross-over busbars results in a less uniform magnetic field in the metal pad. Such cells experience larger magnetic forces resulting in higher metal velocity and more frequent and higher amplitude waves at the metal surface. At equal cell voltage, it translates into higher instability, lower current efficiency (CE) and often shorter cell life. The present paper investigates the magnetohydrodynamic (MHD) stability of last and penultimate cells with respect to standard cells as a function of amperage. It also evaluates the effectiveness of curative measures such as larger metal height and anode-to-cathode distance (ACD), hollow cell and compensation loop. A stability analysis software computes the evolution of perturbations to the 3D stationary variables (electric potential, magnetic field, velocity and pressure) accounting for ledge shape and ferromagnetic materials. Quantitative results are obtained that characterize the level of MHD stability for each scenario. The importance of busbars design, and also of operating parameters on the performance of end cells can be highlighted.

Keywords: Aluminium electrolysis cell, Metal oscillation mode and cell stability diagram, Potroom ends and cross-over busbars, Magnetic compensation loop.

1. Introduction

The magnetic field in the metal pad is responsible for magnetic forces and consequently for metal velocity, metal upheaval and waves at the metal surface. The magnetic field results from external current (busbars, anodic assemblies, cathodic assemblies, neighbouring cells) as well as from internal currents including induced currents (which depend on the magnetic field). The magnetic field is particularly strong close to busbars which carry high currents. Technologies with higher amperage cells have enlarged cell dimensions and added risers and external conductors to keep current density inside the cell and maximum magnetic field values below a certain level. Modern smelters arrange cells side-by-side into long potlines with the objective of minimizing land use and external voltage but also of reducing the number of end cells. The influence of adjacent potroom and potlines can be mitigated by asymmetries in the busbars design around the cell and by compensation loops. Only a small number of cells have a significantly different magnetic configuration, and these are cells at the entrance or exit of potrooms as well as cells before and after passageways or before and after stopped cells. In this paper, we focus on last cells at the exit of potrooms since their performance suffers the most.

As mentioned earlier, last cells are not only negatively affected by their magnetic configuration but also by their current distribution on the cathodic side. The busbars resistance network until an equipotential point before the cross-over busbars must be such that the collector bars current distribution is similar to the one of standard cells. In such case, the presence or not of a "hollow cell" – defined here as the area at the end of the potroom, with no cell, where the arrangement of the busbars mimics the spatial distribution of the current paths of a neighbouring cell – and the distance to the cross-over busbars will further determine how different the magnetic configuration of the last cell is in comparison to a standard cell.

To quantify the MHD stability of different cells across a potroom with various operating parameters, a specialized software analyses the evolution of perturbations to the stationary field variables that are: electric potential, magnetic field, velocity and pressure [1]. The frequency and growth factor of each oscillation mode are computed (see Figure 1), and the maximum growth factor defines the stability level. Oscillation modes (waves) with positive growth factors are more likely to grow over time whereas oscillation modes with negative growth factors will be damped over time.

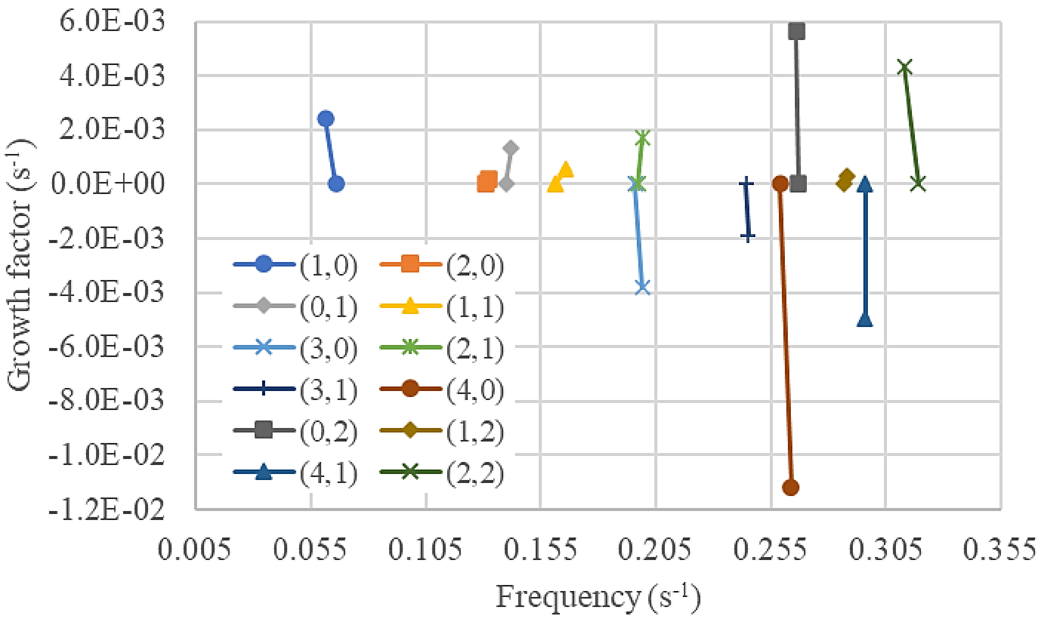
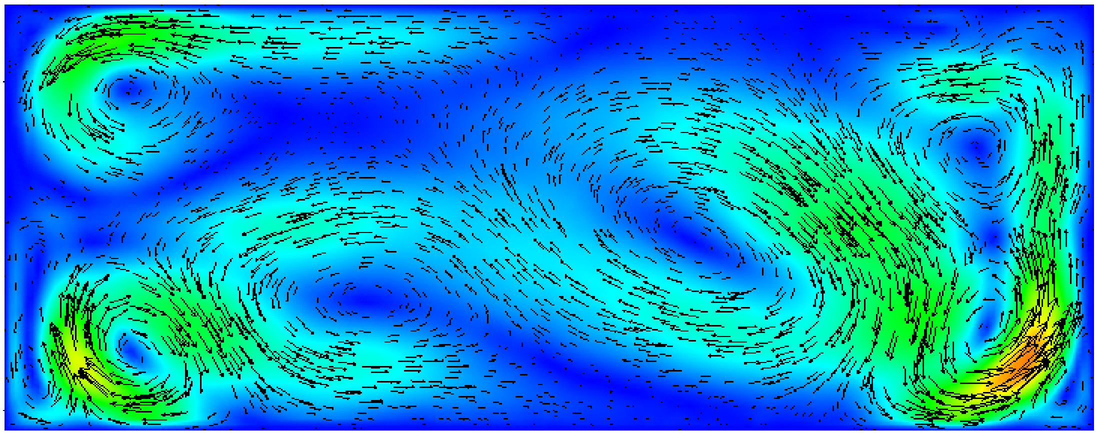


Figure 1. Stability diagram for a standard cell.
Legend for each curve where the oscillation mode is noted (Nx,Ny):
Nx =number of waves in the x-direction, Ny = number of waves in the y-direction.
For each 2-point curve, the point on the 0-growing factor line is the oscillating mode resulting from the gravity force only; the other point is the same mode with the MHD forces in addition.

Alternative models based on the shallow layer approximation were used to characterize the MHD stability of irregular and disturbed cells. In [2], the time evolution of cell voltage and metal height is computed for different scenarios.

2. Model and Scenarios

The study is performed on one potline with side-by-side cells. Electrically conducting materials of the studied cell (accounting for the ledge shape), as well as ferromagnetic materials are modelled in full 3D whereas busbars, neighbouring cells and adjacent potroom are modelled in filiform 3D (see Figure 2).



Last cell

Figure 5. Metal velocity field 10 cm above the cathode surface for standard and last cells.

4. Conclusions

End cells experiencing higher instability, lower CE, higher cell voltage and shorter cell life can be a thorn in the side of smelters, jeopardizing potential amperage increase. Their particular magnetic configuration as well as possibly different busbars current distribution explain their higher metal velocity, metal upheaval and amplitude and frequency of waves at the metal surface.

A specialized software is used to quantify the MHD stability of different cells across the potroom and the impact of operating parameters such as amperage, ACD and metal height. The last cell in potroom is the least stable cell. Even with higher metal height (+4 cm) and ACD, it is less stable than a standard cell at higher amperage (+10 kA) and lower ACD. Busbars design features such as hollow cell and compensation loop are effective means of improving the MHD stability of end cells.

5. References

1. Jacques Antille, René von Kaenel, Using a magnetohydrodynamic model to analyze pot stability in order to identify an abnormal operating condition, *Light Metals* 2002, 367-372.
2. Valdis Bojarevics, S. Sira, MHD stability for irregular and disturbed aluminium reduction cells, *Light Metals* 2014, 685-690.
3. Louis Bugnion, René von Kaenel, Impact of TE-MHD coupling on cell performance, *Light Metals* 2023, 1741-1747.