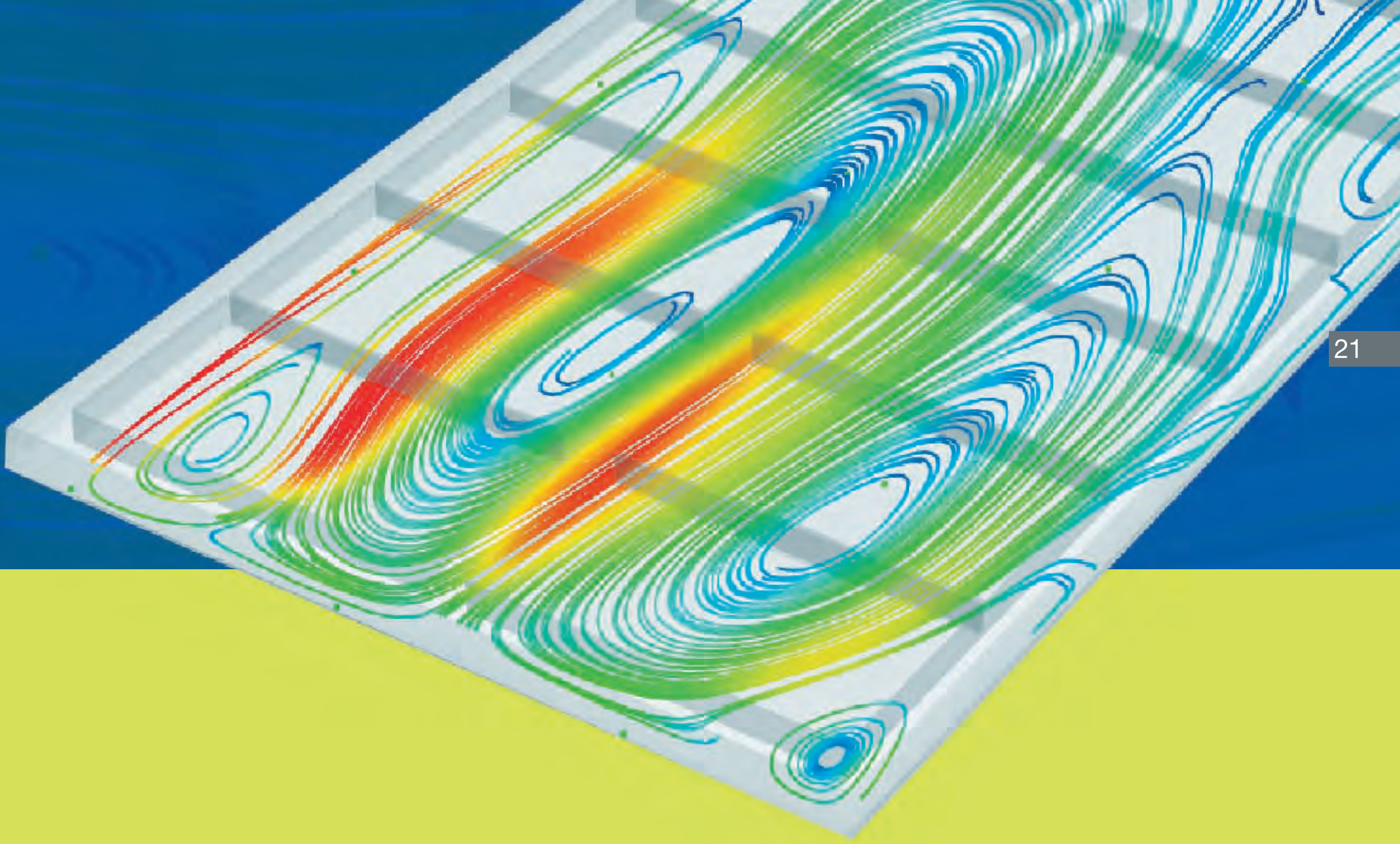


Increasing Efficiency in Aluminum Processing

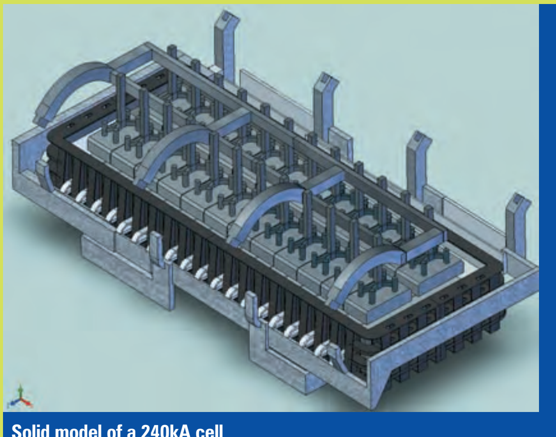
ANSYS Multiphysics with ANSYS CFX helps improve electrochemical reduction.

By Dagoberto S. Severo, André F. Schneider,
Elton C. V. Pinto and Vanderlei Gusberti
PCE Engenharia S/S Ltda, Brazil

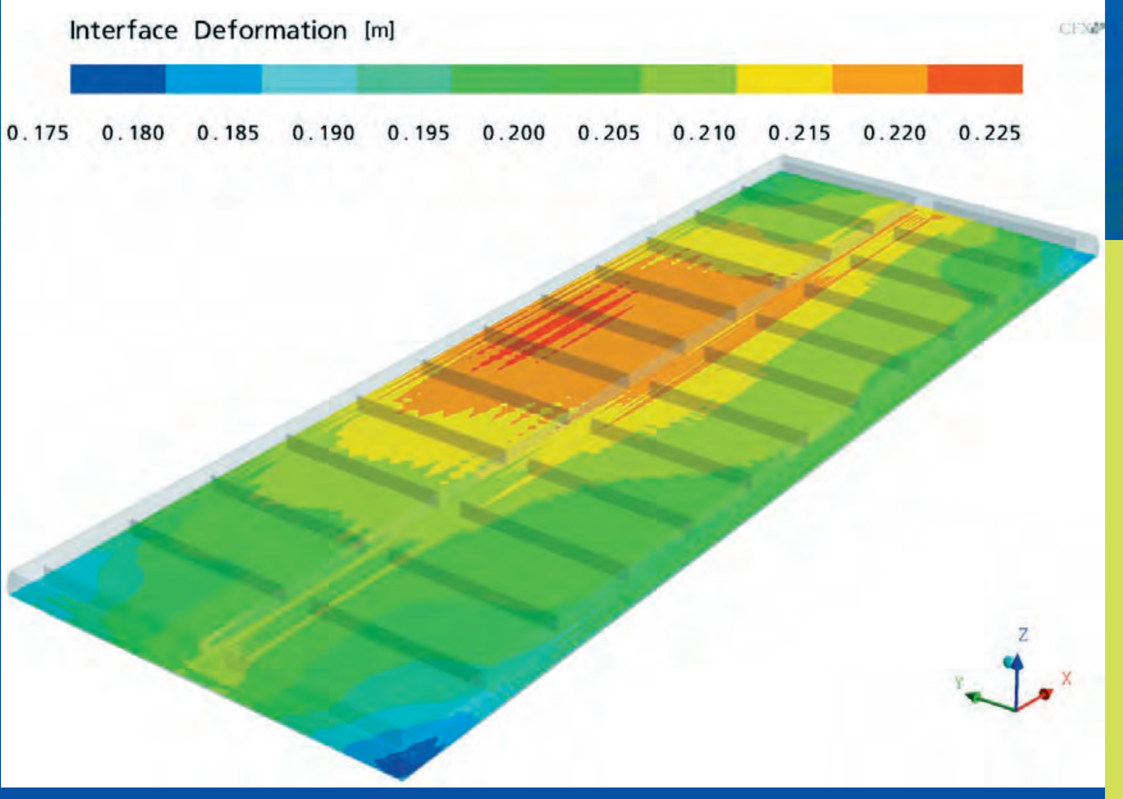
Today's aluminum industry is continually studying ways to increase the efficiency of reduction cells in smelters. Numerical simulation has become a highly effective tool for analyzing such complex processes. PCE Engenharia Ltda, S/S located in Porto Alegre, Brazil, has been using simulation for more than 10 years. The industry consulting firm simulates equipment in the aluminum production chain and, in partnership with customers, develops new technological solutions for primary aluminum production.

Primary aluminum is obtained by a complex process of electrochemical reduction of alumina in Hall-Héroult cells. DC current on the order of hundreds of thousands of amps flows from cell to cell in aluminum busbars. Inside each cell, current flows downward through the anodes, molten electrolytic bath, molten metal and cathode carbon block. The electrolytic bath floats on the top of the metal because of slightly different densities, and the two liquids do not mix. Undisturbed, the metal–bath interface would be flat and horizontal, but this is never the case in an operating cell. The combination of the electric current and the magnetic field generates volumetric forces known as Lorentz or electromagnetic forces. These set the metal and the bath in motion and deform the metal–bath interface.

Magnetohydrodynamics (MHD) is the science that studies the effect of electromagnetic forces on



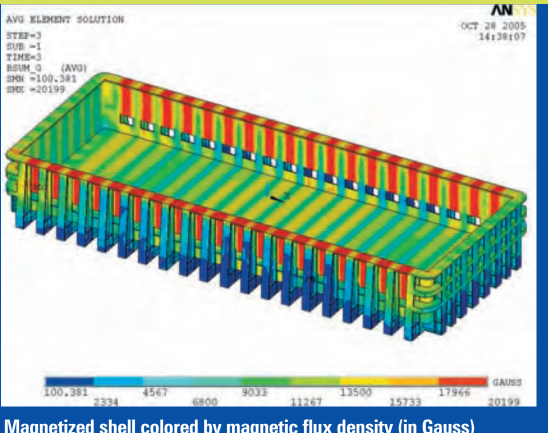
Solid model of a 240kA cell



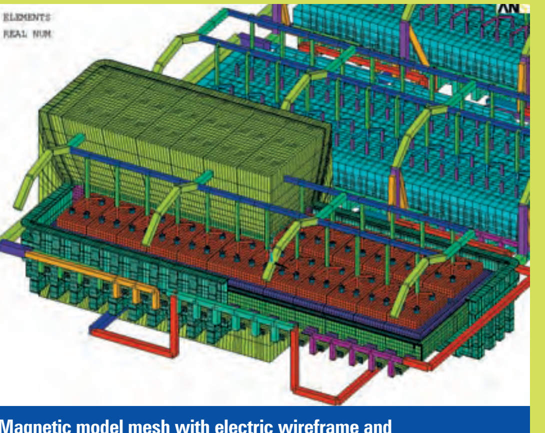
Deformation of the interface between the bath and liquid aluminum

fluid flow. The resistive generation of heat in the bath layer is proportional to the anode-to-cathode distance (ACD); therefore, this layer should be as thin as possible. However, the cell may become unstable at a small ACD due to interface waves, resulting in current efficiency loss. The minimum ACD at which the cell remains stable depends on cell design, busbar design and cell operation. Thorough understanding and control of cell MHD is the key to high current and energy efficiency.

The first step in MHD modeling is to obtain a detailed electromagnetic model. All relevant aspects of the cell are taken into account, such as external conductors (busbar arrangement), internal conductors (liquid layers, collector bars, anodes and cathodes) and the steel shell. ANSYS Multiphysics software was the natural choice for such a complex model due to its flexibility with element types and physics phenomena representation. For magnetostatic field problems, the ANSYS product has the magnetics scalar potential approach. Several options are available, but only general scalar potential is applicable to electrolysis cells to account properly for electrical current going out through the steel shell. The advantage of magnetic scalar potential is that the source conductors do not need to be part of the solid finite element mesh, so that it was not necessary to mesh the entire smelter. Solid mesh is needed only in the subject cell for a detailed electrical and magnetic solution [1]. At this point, the calculated magnetic field, the electric current density and the electromagnetic force are transferred from ANSYS Multiphysics to ANSYS CFX computational fluid dynamics (CFD) software. A different mesh is required for the CFD simulation. Completely independent meshes can be used due to an interface program that was written to interpolate and transfer data seamlessly. ANSYS CFX was chosen because of the software's robustness in



Magnetized shell colored by magnetic flux density (in Gauss)



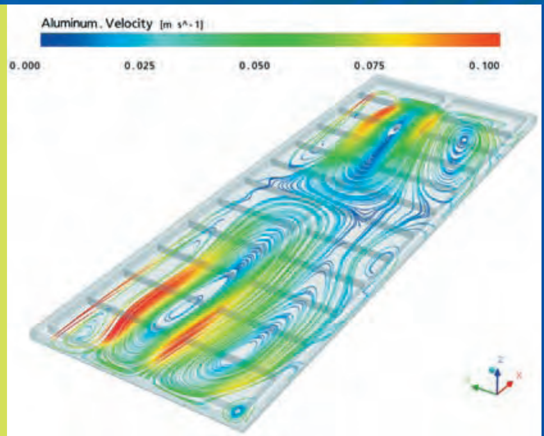
Magnetic model mesh with electric wireframe and surrounding air box dealing with multiphase flow, high computational performance and easy-to-use data import ability.

Due to the nature of the flow system in an electrolysis cell, the fluids are expected to be completely stratified, separated by a distinct interface. The interface shape was modeled as free-surface two-phase flow. ANSYS CFX uses the homogeneous VOF (volume of fluid) method for interface tracking. In this method, each finite volume of the mesh is either filled with metal or bath, or filled partially with metal and partially with bath. The physical properties for each finite volume are weighted by the volume fraction of each fluid. The shape of the interface is supplied by the geometric location of the finite volumes with 0.5 of volume fraction of each liquid. Steady-state models play an important role in cell MHD design, since they give relevant information about the mean values of flow patterns, the metal bath interface deformation and their symmetry. The flow within a reduction cell has to satisfy two contradictory requirements for the process efficiency. The alumina distribution and dissolution in the bath requires high bath flow, whereas the current efficiency suffers from high bath and metal flow. It is difficult or impossible to slow down the metal without slowing down the bath. In this situation, considering the importance of current efficiency, the criterion of minimizing the metal flow should prevail.

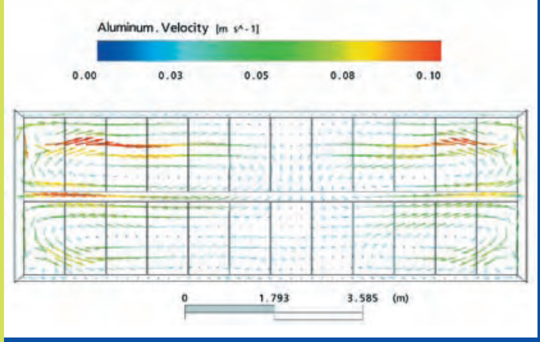
Most competitive smelters around the world are able to work with current efficiency up to 95 percent, and an increase of 1 percent at this value means hundreds of Megawatts/hour of energy savings and millions of dollars in increased aluminum production. Any modification in a live cell row demands hard and expensive logistical work. Up-front simulation allows for virtual testing of many designs and operating conditions in a short time and at low cost before expensive prototypes are constructed. A true multifield, coupled physics system involving fluids, electromagnetism and MHD in electrolysis cells is an area in which simulation-driven design is strategically necessary. By using ANSYS Multiphysics and ANSYS CFX, PCE is improving its understanding of this complicated process and reducing time and costs. ■

Reference:

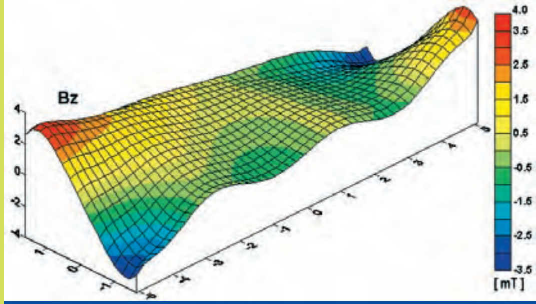
1. D. S. Severo, A. F. Schneider, E. C. V. Pinto, V. Gusberti, V. Potocnik, "Modeling Magnetohydrodynamics of Aluminum Electrolysis Cells with ANSYS and CFX," Light Metals, (2005).



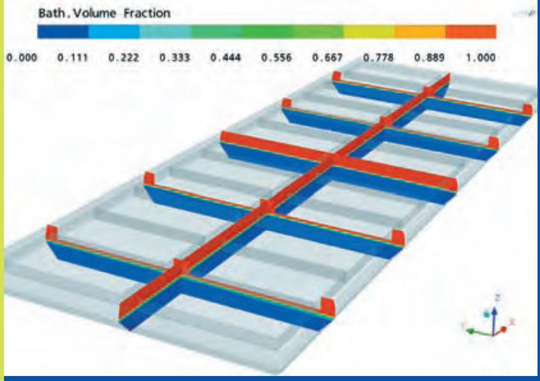
Stream lines of the aluminum flow inside the cell



Vectors of the aluminum flow in the middle high of the aluminum



Vertical magnetic field (in miliTesla) at the aluminum



Slices showing the metal and bath distribution inside the cell