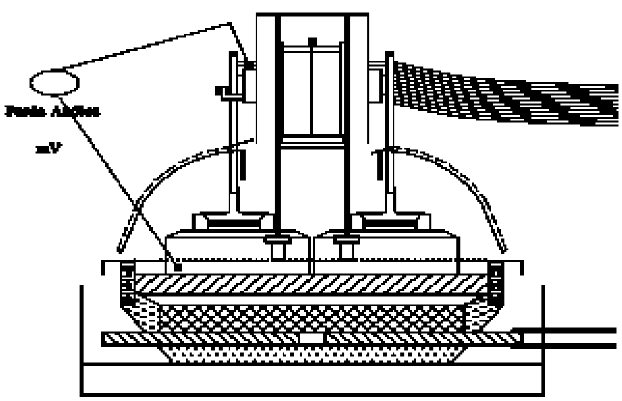
THERMAL-ELECTRIC-STRUCTURAL ANALYSIS OF YOKE ARM AND ANODE IN PREBAKE ALUMINUM CELLS

This work consisted in a thermal-electric-structural simulation by the finite elements method in the set Anode/Yoke used in aluminum reducing by ALUMAR in São Luis, MA. This analysis was made using the commercial software from ALGOR.

The Hall-Héroult is the only method used today for the industrial production of aluminum. This process produces liquid aluminum by the electrolytic reduction of alumna (Al_2O_3) in molten aluminum in the prebake cells.

The electrolytic reduction cells consists of a rectangular steel "open box" that serves as containment vessel for the electrolyte (bath) and the liquid metal being produced. Immersed in the bath are the anodes, suspended by copper yokes. The cathode strays on the bottom of the box. The reduction is obtained by feeding an electrical current that flows from the anode to the cathode through the molten aluminum. By this way, there is a gap between anode and cathode witch its size should be the smaller as possible for a minimum voltage, but not so small that it causes a short circuit. The current exits the cell via collectors bars under the cathode blocks.

In the finite element analysis were used solid elements with 8/6 nodes (Type 39, brick/wedge in Algor). The generated mesh resulted in 37638 elements and 32874 nodes.



Sketch of a reducing aluminum cell

The steady electrical current flow in god conductors obeys Poisson equation. In three dimensions the equation is:

$$\frac{\partial}{\partial x}\left(\frac{1}{\rho}\frac{\partial \Phi}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{1}{\rho}\frac{\partial \Phi}{\partial y}\right)+\frac{\partial}{\partial z}\left(\frac{1}{\rho}\frac{\partial \Phi}{\partial z}\right)=0$$

Where Φ is the electrical potential (V) and ρ is the electrical resistivity (Ω.m)

The electrical analysis made in Algor consist in obtaining the potential difference (voltage) between its extremities being known the current that flows through the modeled geometry. The electrical resistance of the set can than be calculated by Ohm's law.

The current that flows through de Anode/Yoke set, due its electrical resistance, generate a certain amount of heat, known as Joule's effect.

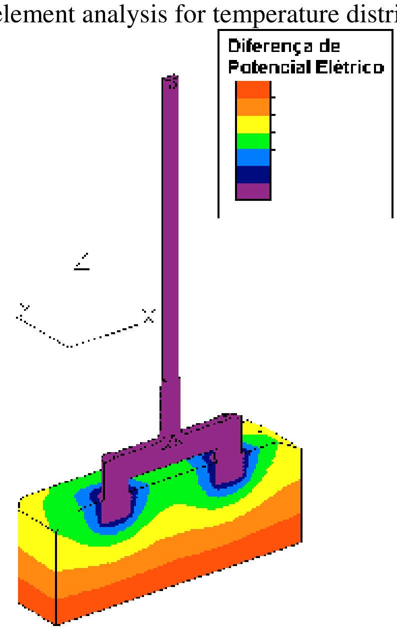
Knowing that current density J is given by the vector form of Ohm's law:

$$\bar{J} = \frac{1}{\rho} * \bar{E}$$

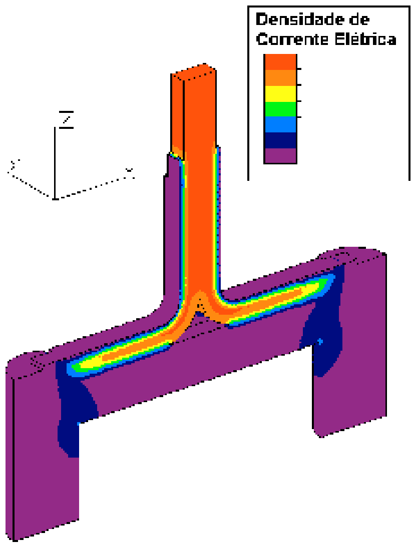
Power loss per unit volume p is given by:

$$p = J^2 * \rho$$

This power loss is equal to the generated heat per volume unit, serving as input to a thermal finite element analysis for temperature distribution.



Potential difference distribution in the anode/yoke set



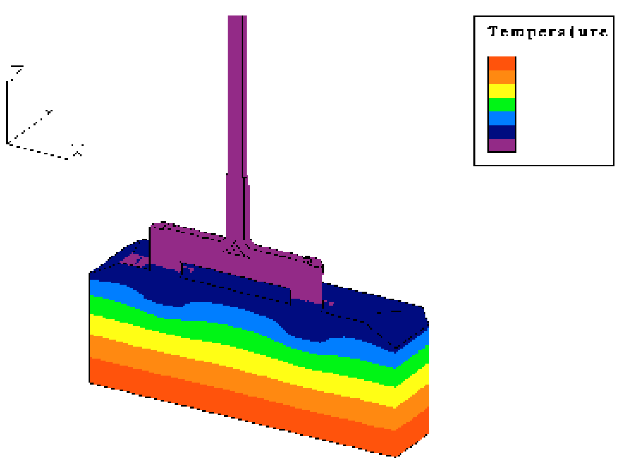
Current density in the yoke

The objective of the thermal analysis is getting the temperature distribution in the anode / yoke set during the aluminum reducing operation. These temperature profiles are used as inputs in the finite elements stress analysis, to calculate the stress due thermal origin.

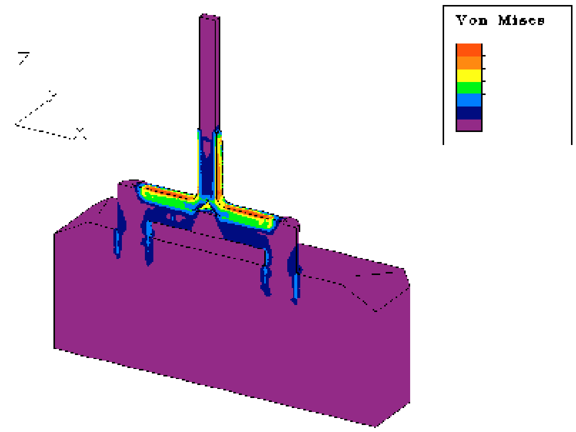
The field equation used by the ALGOR to solve steady state heat transfer problems in three dimensions is the Poisson's equation:

$$\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial y}\left(k\frac{\partial T}{\partial y}\right)+\frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right)=-I$$

Where T is the temperature (^{0}C), k is thermal conductivity (W/m^{0}C) and I is the internal generated heat rate per volume unit (W/m^3).



Temperature distribution map (^{0}C)



Stress map by Von Mises criteria (N/mm^2)

The anodic loss finite elements analysis allows us optimize the distribution of the electrical current density, reducing the potential loss and improving its electrical efficiency. That reduces power consumption in aluminum production, power that represents circa of 20% of the operational costs.

The stress on the anode yoke is mainly caused by a thermal originated load. The difference between thermal expansion coefficients of the several materials that compound the yoke are the cause of this stress.

PCE proposed an optimized model, wich resulted in gain near 60mV per cell in relation to the anode/yoke set actually in use. Also the maximum stress level was lowered to around 25%.

PCE Ltda. – Email: pceltda@portoweb.com.br - URL: www.pce.com.br
Rua Felix da Cunha, 332 - Porto Alegre, RS Brazil - Phone: +55.51.3346.5205 - Fax: +55.51.3346.1287