MHD and Potshell Mechanical Design of a 740 kA Cell

Marc Dupuis

GENISIM

Valdis Bojarevics

University of Greenwich, School of Computing and Mathematics

Daniel Richard

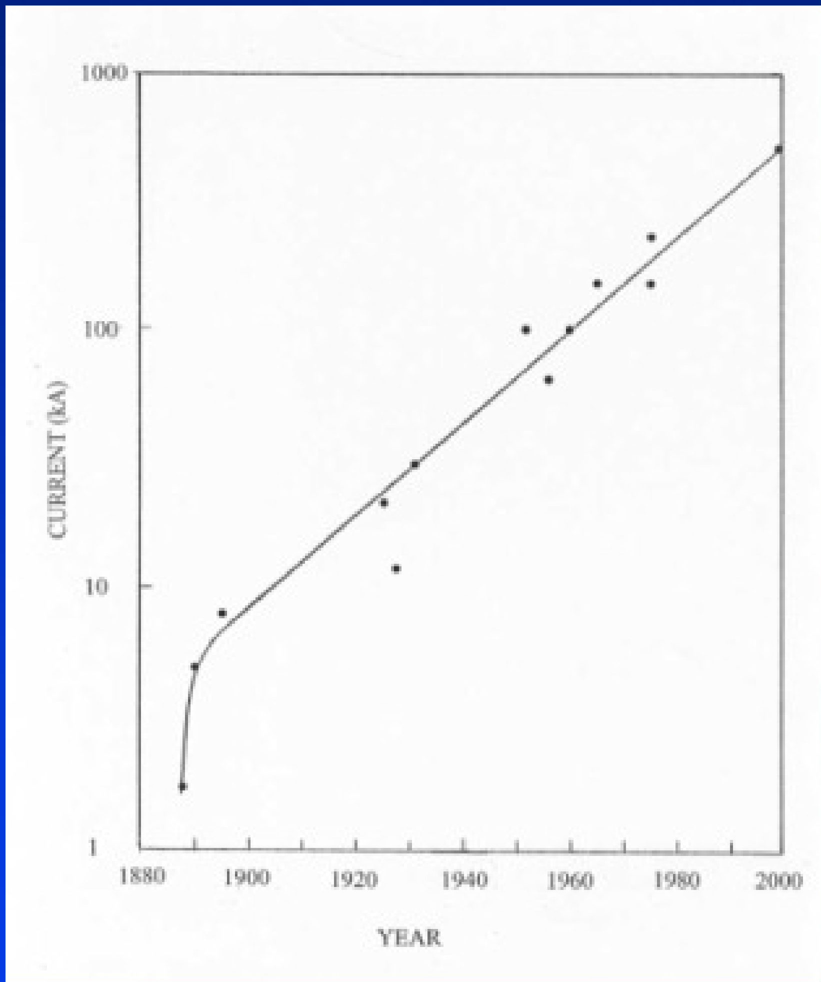
HATCH

GENISIM HATCH

Plan of the Presentation

- Introduction
- Thermo-Electric Design of a 740 kA Cell, Is There a Size Limit?
- Pechiney 500 kA cell MHD design
- New 500 kA cell MHD design
- New 740 kA cell MHD design
- 500 kA Cell Mechanical Model
- 740 kA Cell Mechanical Model
- Conclusions

Introduction



In the 20th century, the H-H cell size and hence amperage have increased following the following trend.

According to this trend, we should be already building smelters using 500 kA cell technology.

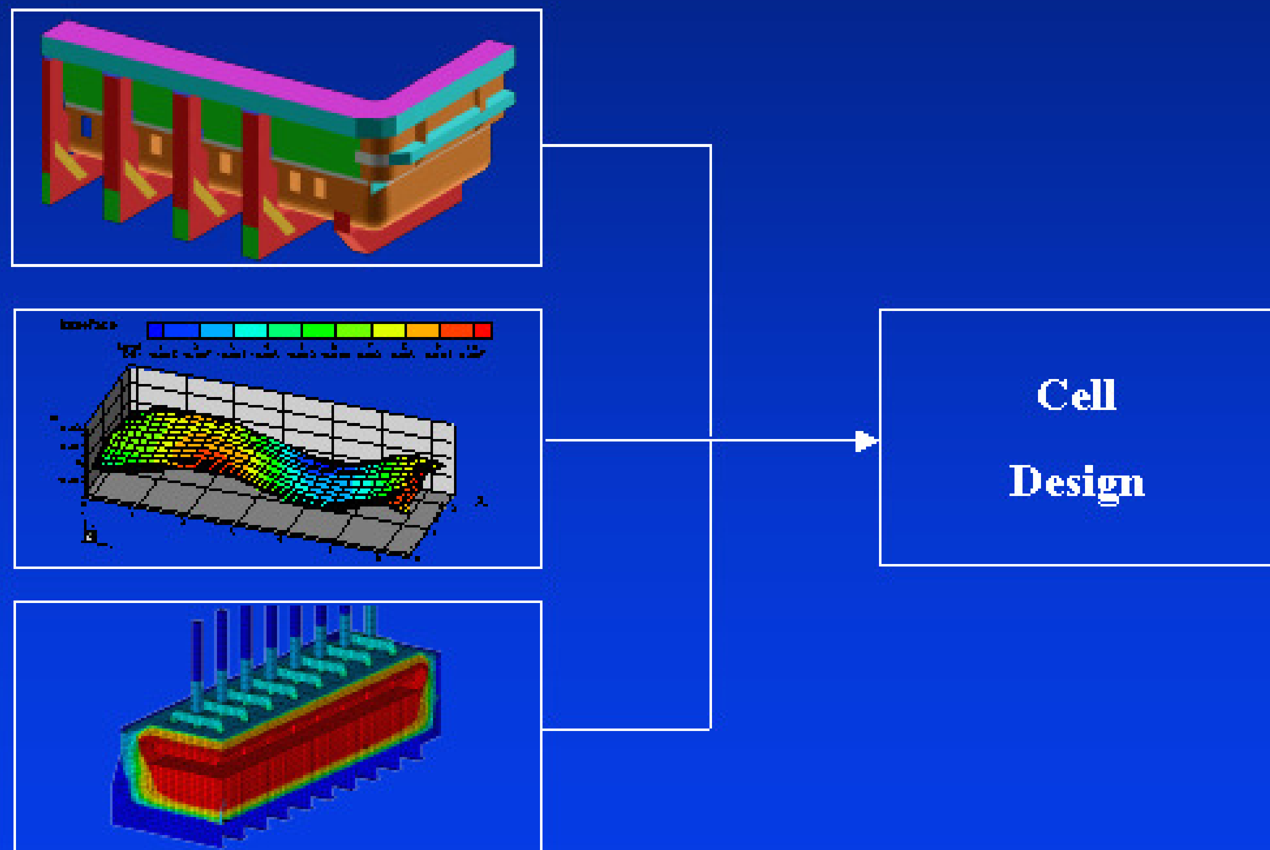
Is the recent slowdown in the increase rate the impact of reaching some kind of physical limitation or simply the consequence of a slowdown in R&D investments?

GENISIM HATCH

Introduction

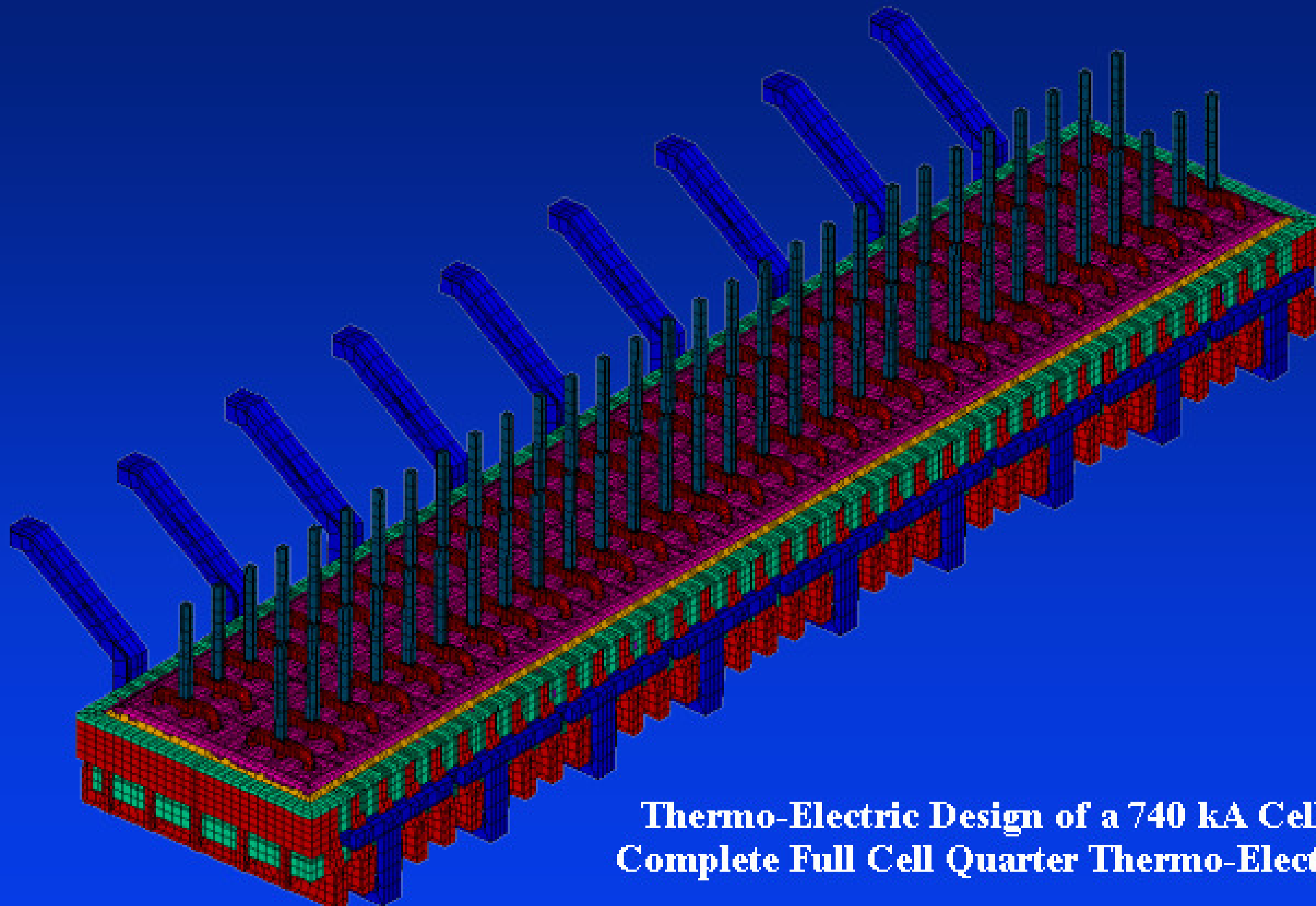
Currently, we can fit Hall-Héroult mathematical models into three broad categories:

- Stress models which are generally associated with cell shell deformation and cathode heaving issues.
- Magneto-hydro-dynamic (MHD) models which are generally associated with the problem of cell stability.
- Thermal-electric models which are generally associated with the problem of cell heat balance.



GENISIM HATCH

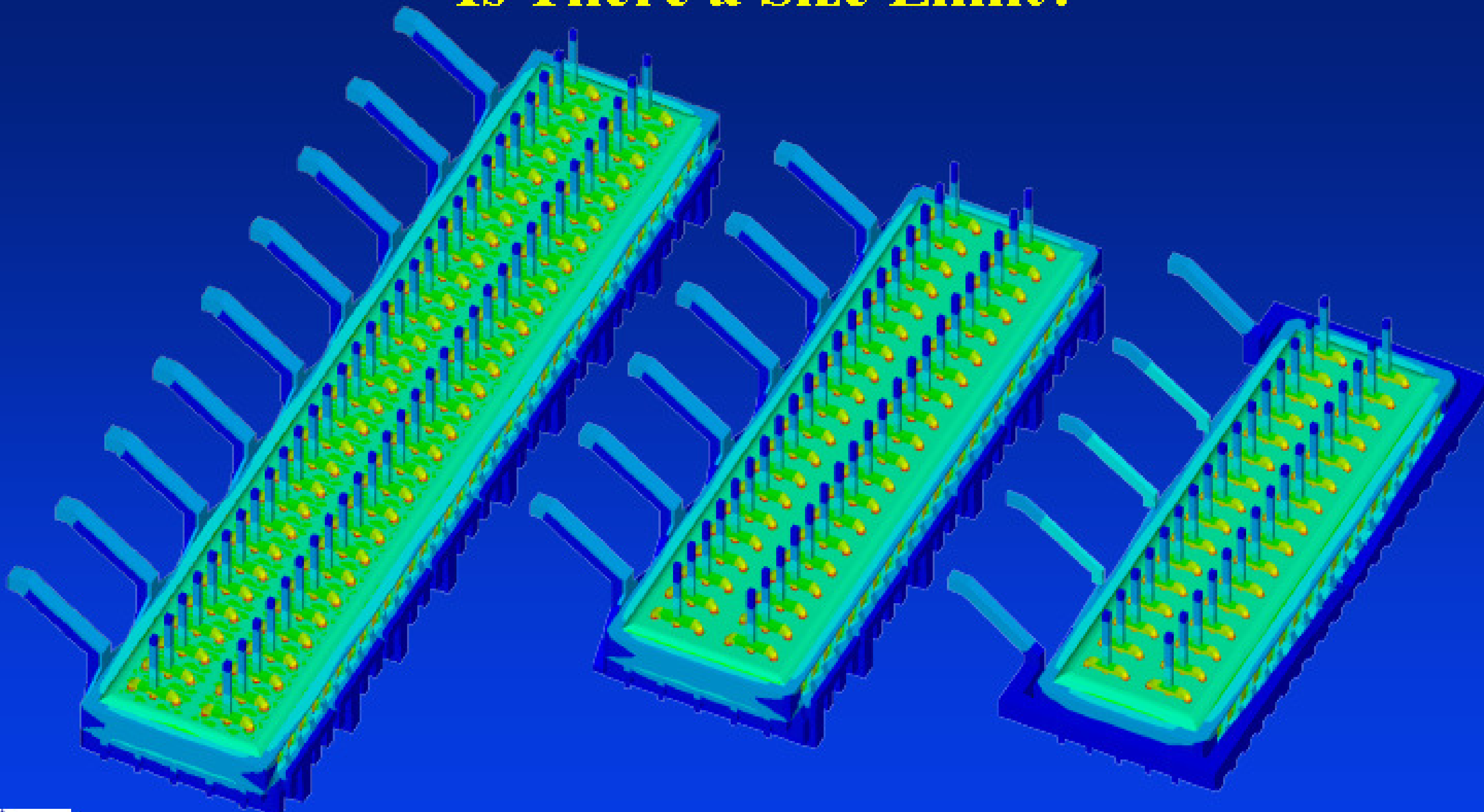
Thermo-Electric Design of a 740 kA Cell, Is There a Size Limit?



Thermo-Electric Design of a 740 kA Cell Using a Complete Full Cell Quarter Thermo-Electric Model

GENISIM HATCH

Thermo-Electric Design of a 740 kA Cell, Is There a Size Limit?

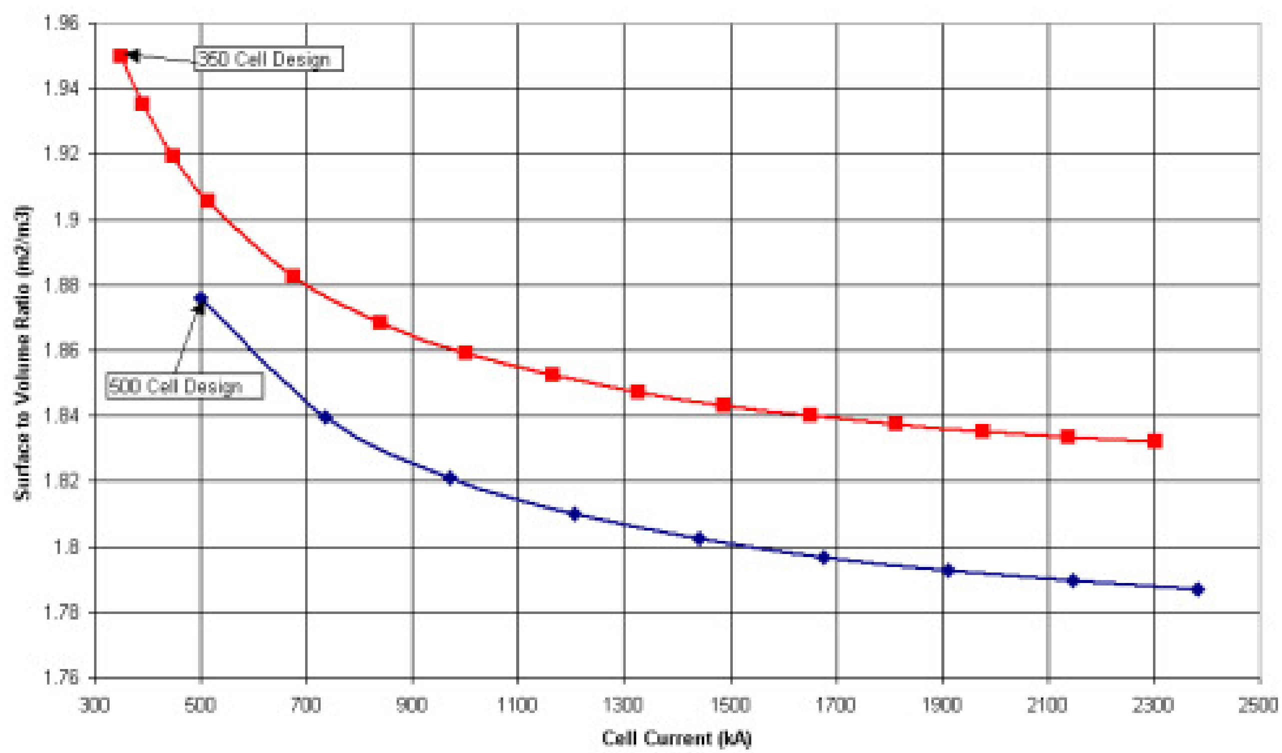


Thermally balanced cell operating respectively at 740, 500 and 300 kA

GENISIM HATCH

Thermo-Electric Design of a 740 kA Cell, Is There a Size Limit?

Figure 1: Extrapolation of the cell amperage vs the cell aspect ratio for the 350 kA and the 500 kA cell designs



As far as only the cell heat balance design issue is concerned, there is no limit to the size of cells that can be designed.

MHD Wave Problem Description

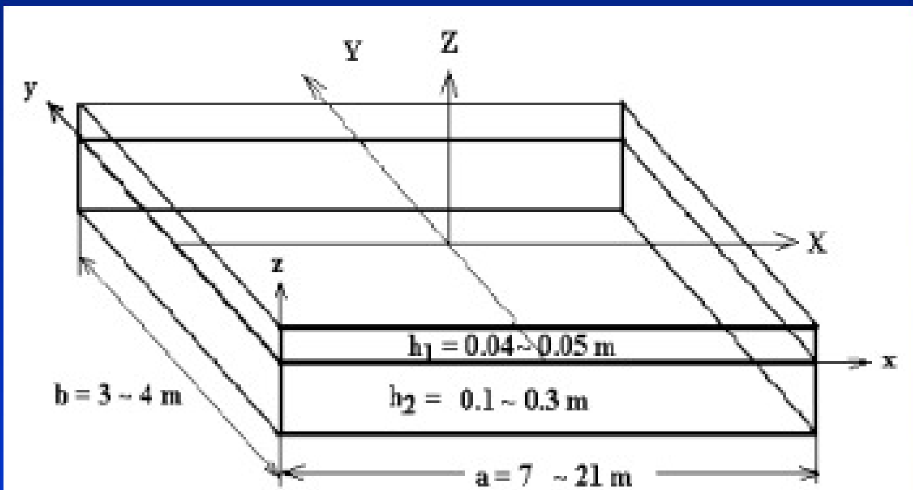
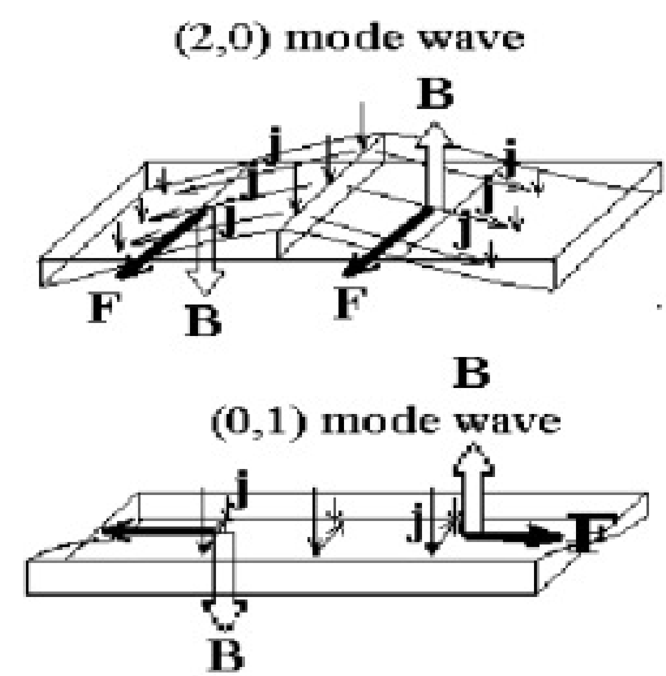
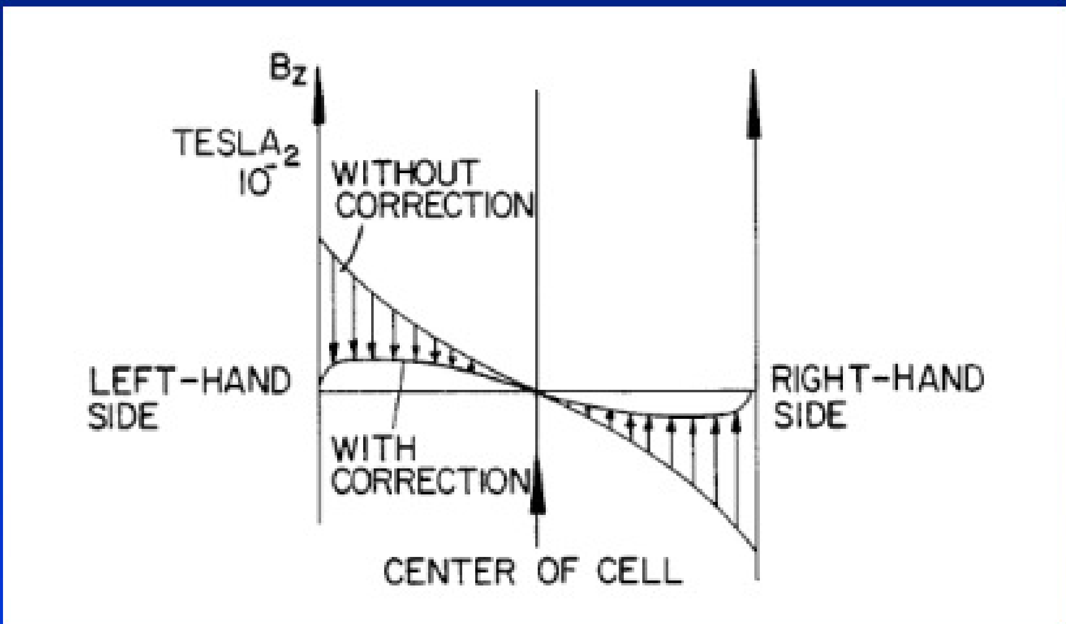


Figure 1 Container for electrolyte and liquid metal and the coordinate systems (Positive y is the direction of line current)



As very well explained by Urata in his 2005 TMS paper, in modern high amperage cell, the MHD wave is created by the presence of a longitudinal gradient (Cx) in the vertical component of the magnetic field (Bz)

Pechiney 1987 AP50 Busbar Patent



STATEMENT OF THE PROBLEM

Some arrangements are selected by the skilled person to cancel more or less perfectly the vertical component of the magnetic fields in the liquid metal and to render symmetrical and to reduce as far as possible the circulation of liquid metal and of liquid bath in the crucible.

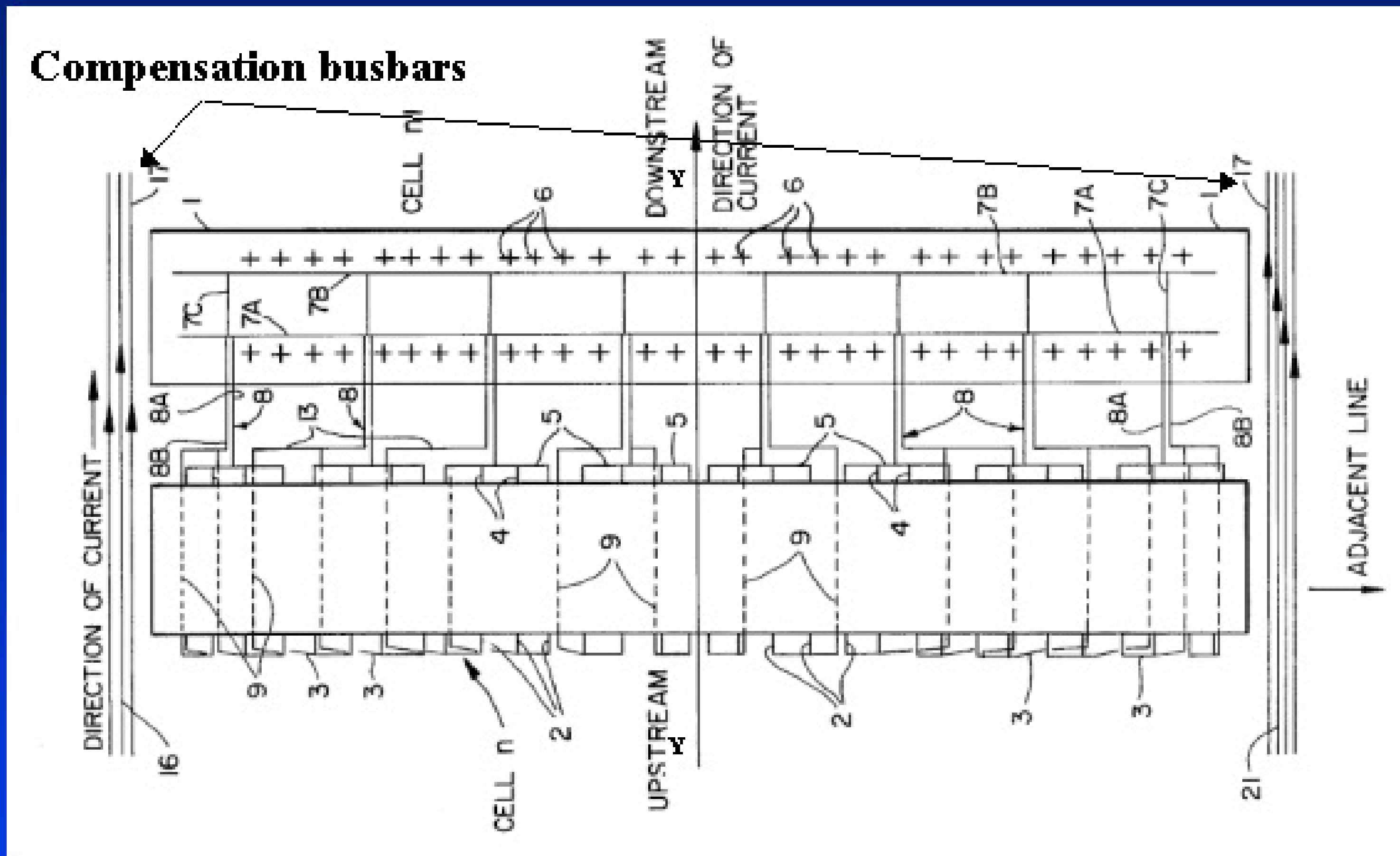
The more or less perfect cancellation of the vertical component of the magnetic field is necessary for the following reasons:

The passage of the electric current in the supply conductors and in the conducting portions of the cell produces magnetic fields which cause movements in the liquid bath and metal and deformation of the metal-electrolysis bath interface. These movements of metal which agitate the electrolytic bath placed beneath the anodes can, if they are too great, short-circuit this element of bath by contact between the liquid metal and the anode.

Not surprisingly, the aim of the Pechiney 1987 busbar layout design is to minimized the longitudinal gradient of the vertical component of the magnetic field

GENISIM HATCH

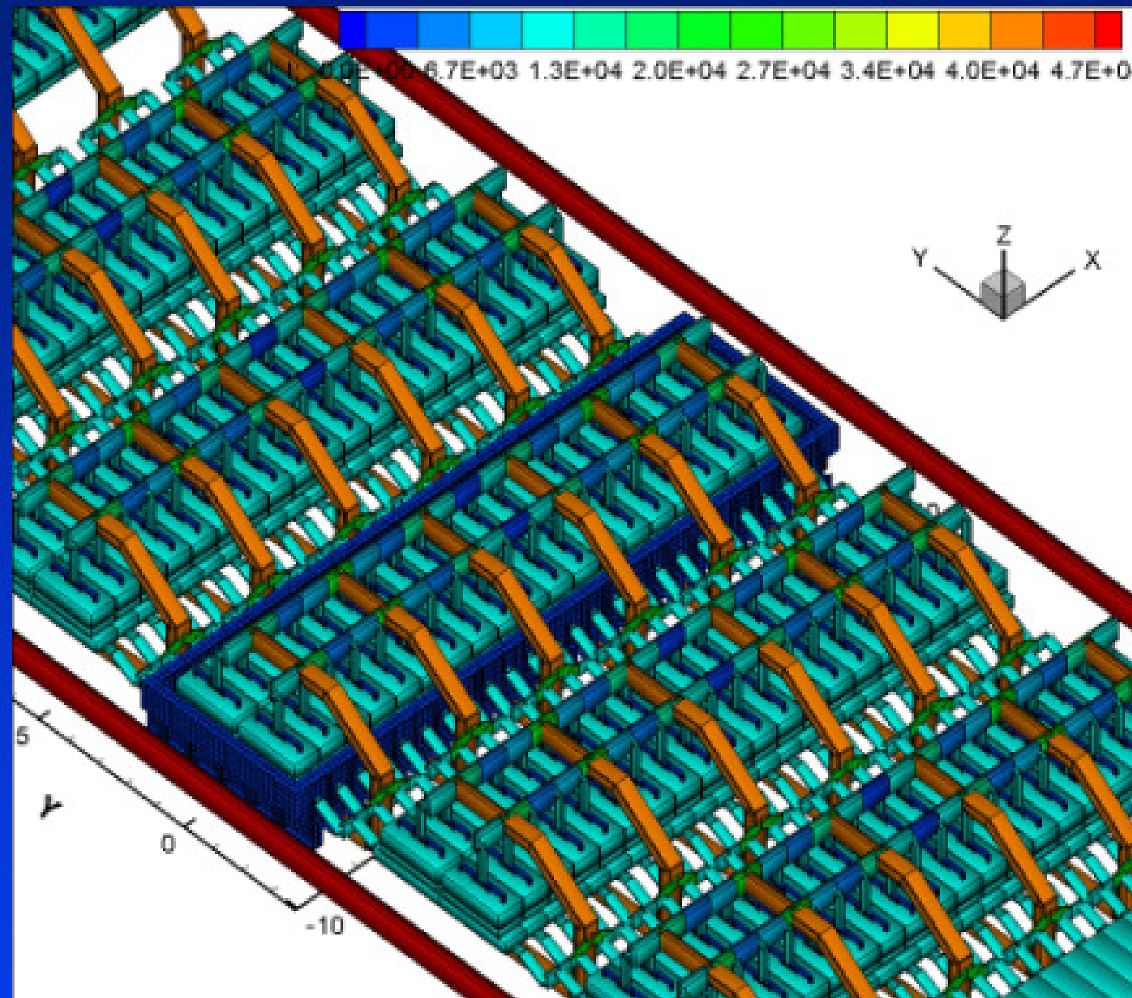
Pechiney 1987 AP50 Busbar Patent



This is done by having 2 compensation busbars running at each end of the cell, one carrying more current than the other in order to compensate for the impact of the return line while in order to minimize the busbar mass, all the busbars from the upstream side are running under the cell

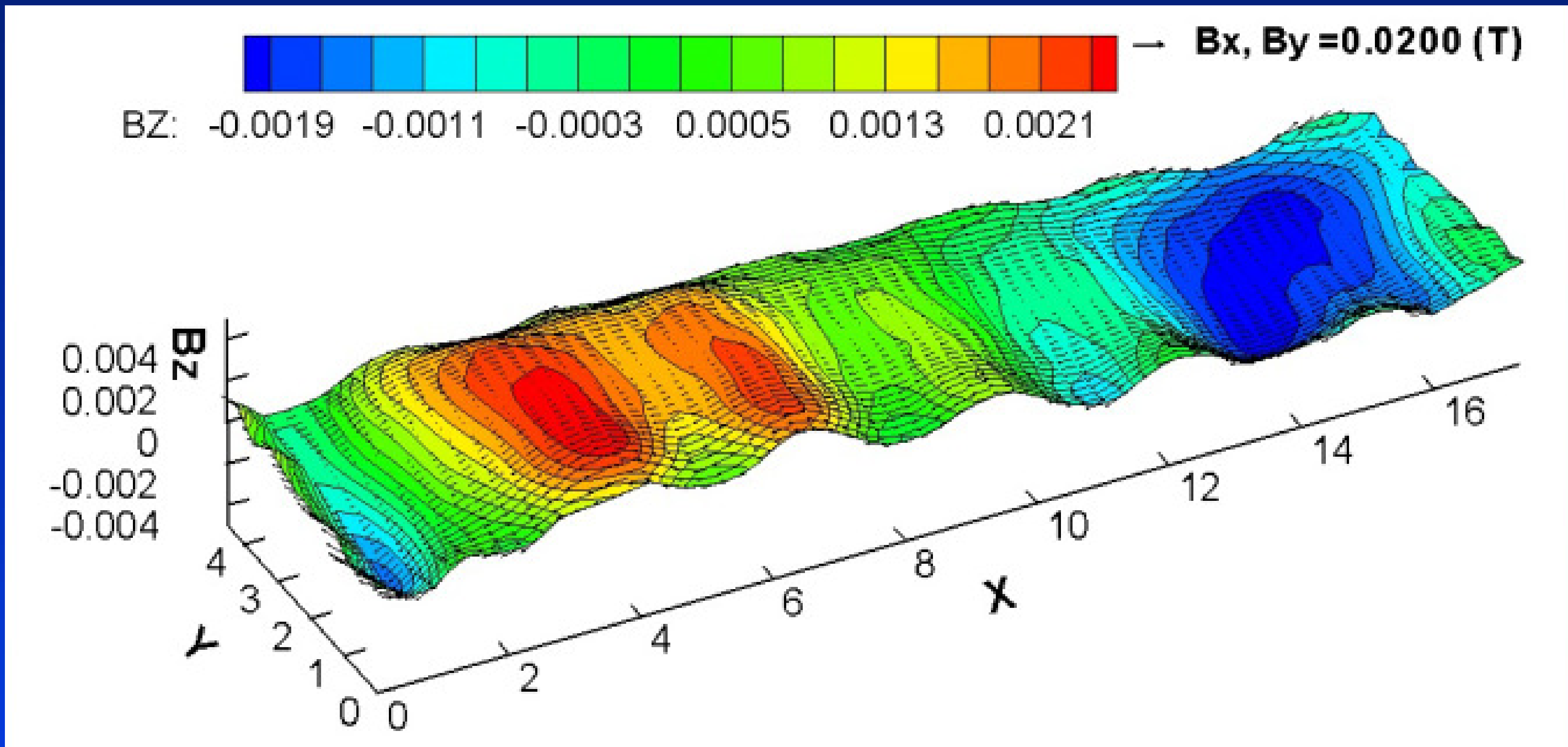
MHD-Valdis model of Pechiney Patent

Using MHD-Valdis cell stability code, it is easy to build a model reproducing the Pechiney 1987 patent busbar layout



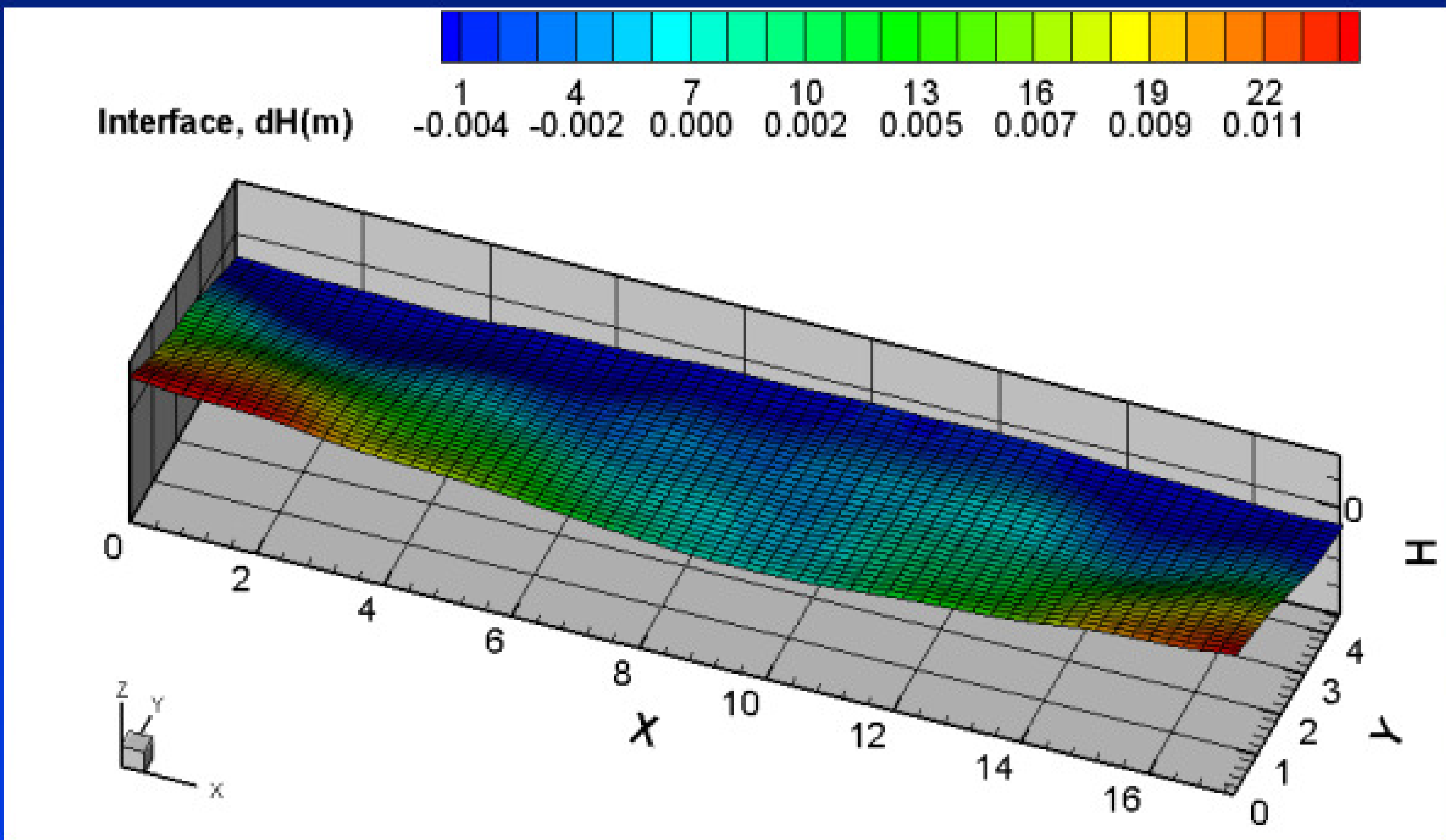
GENISIM HATCH

MHD-Valdis model of Pechiney Patent



As claimed by Pechiney, the compensation busbars are doing a great job reducing the intensity of the Bz magnetic field, but still a 40 gauss over 16.5 meters longitudinal gradient remains even with a return line at 60 meters

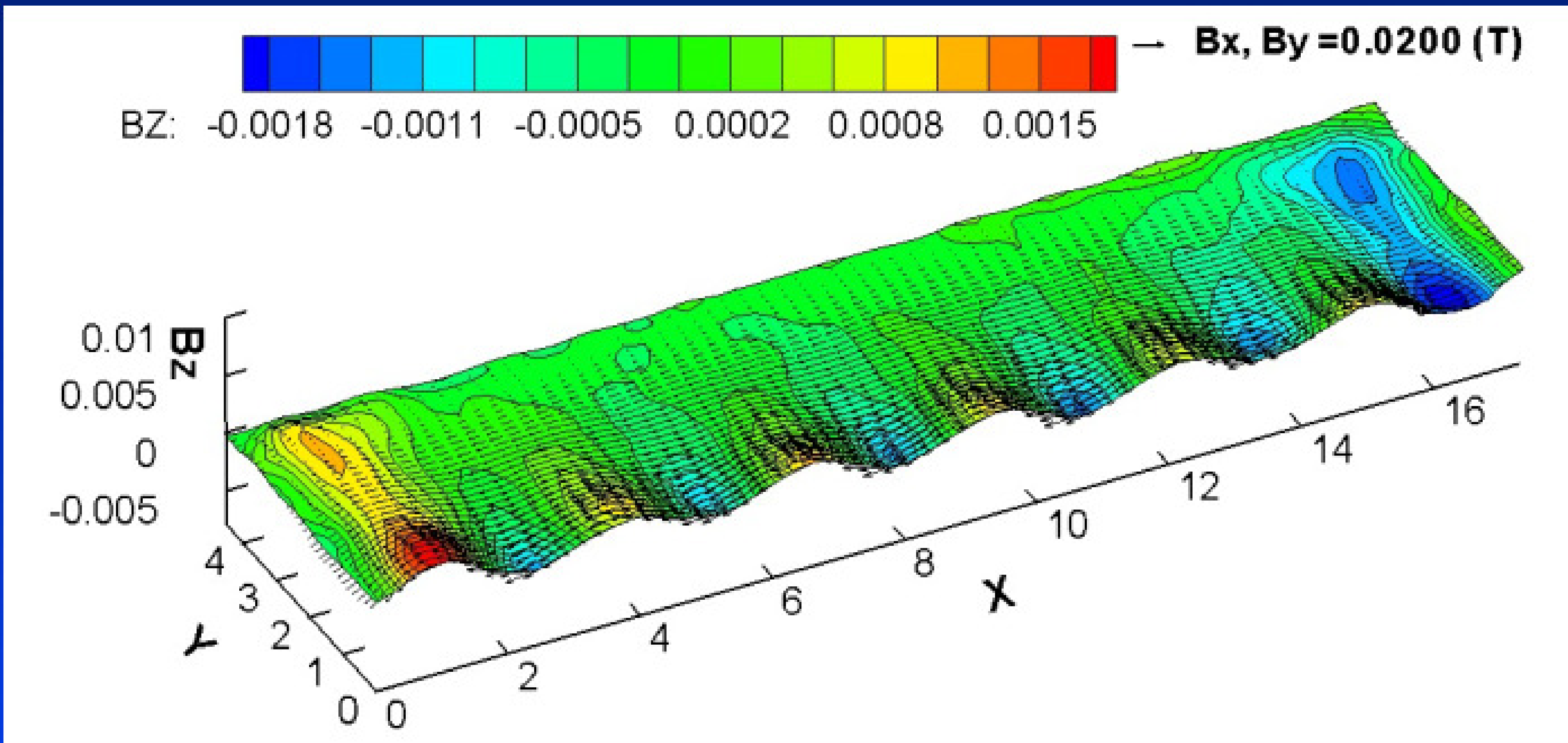
MHD-Valdis model of Pechiney Patent



According to MHD-Valdis, this small Cx is enough to generate a (2,0) (0,1) rotating wave of the type described by Urata

Clearly, this busbar layout design could not be use on cell of more than 500 kA

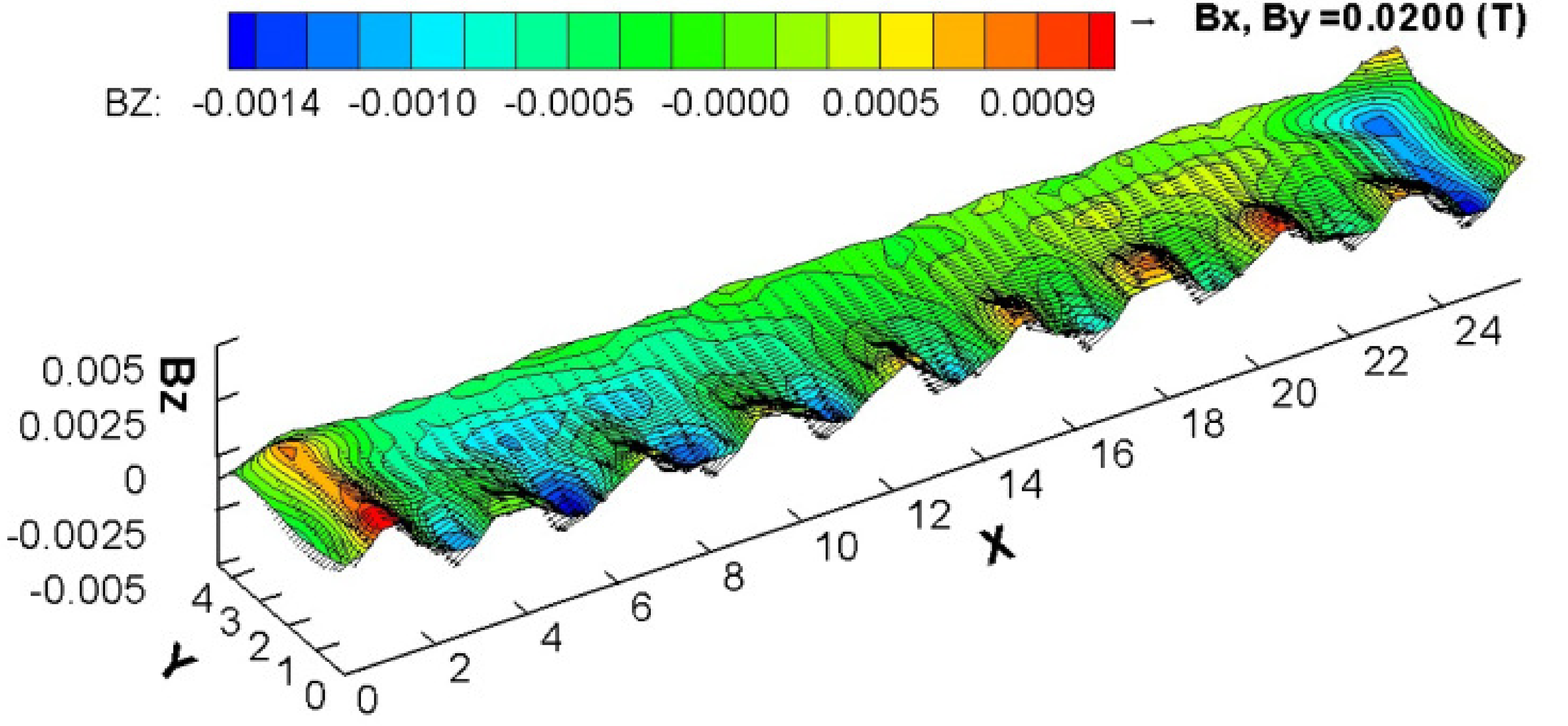
New 500 kA cell MHD design



No global Bz longitudinal gradient, so no MHD instability wave

GENISIM HATCH

New 740 kA cell MHD design



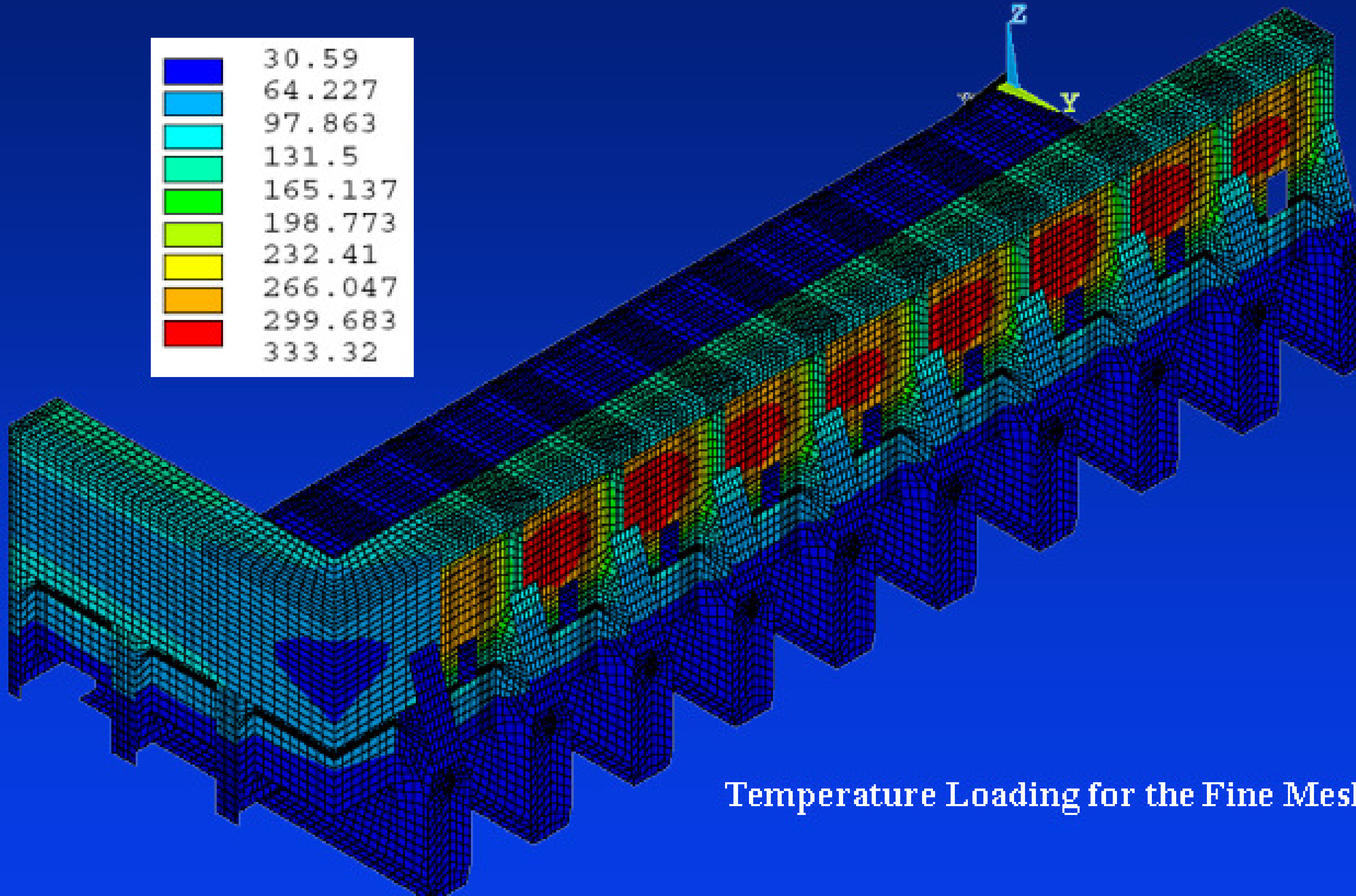
No global Bz longitudinal gradient, so no MHD instability wave

MHD design of a 740 kA cell, Is there a size limit?

The new compensation busbar configuration will equally well work for any reasonable length of potshell and any number of risers, for example a 85.8 meter long, 30 risers, 2380 kA cell could too be magnetically compensated using the same approach. So it is possible to conclude that as far as the MHD cell stability aspect of the cell design is concerned, there is no limit to the size of cells that can be designed.

GENISIM HATCH

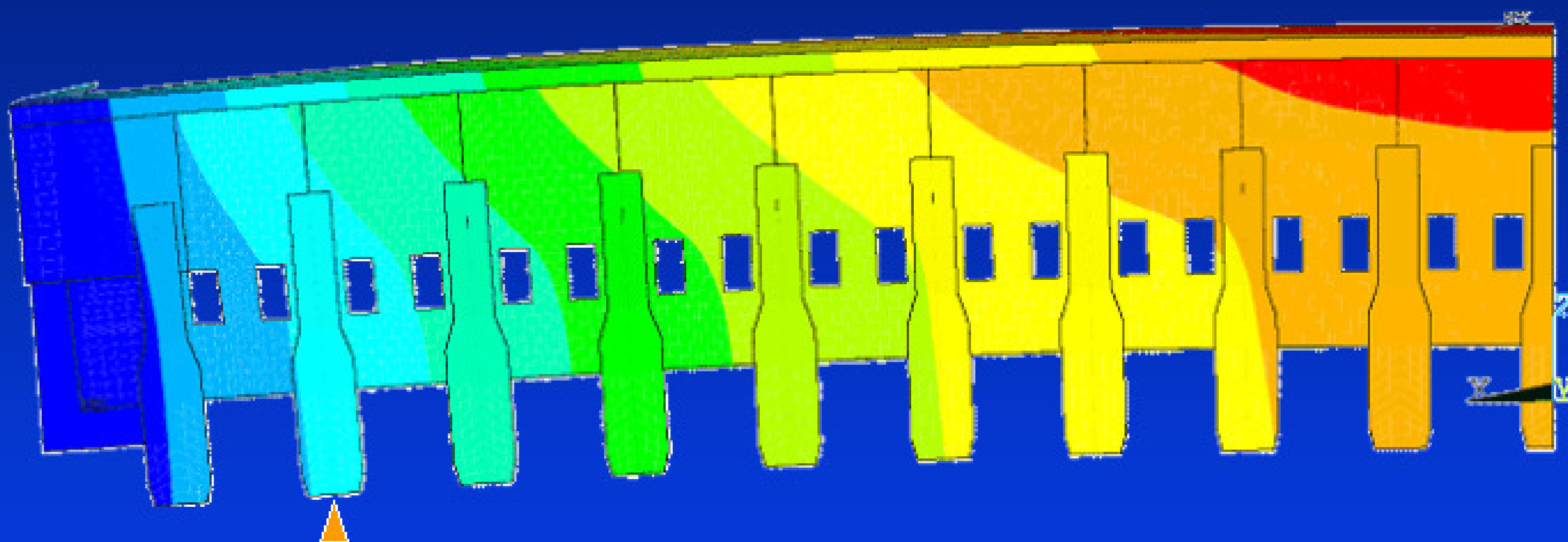
300 kA Cell Potshell Mechanical Design Model



Temperature Loading for the Fine Mesh Model

GENISIM HATCH

300 kA Cell Potshell Mechanical Design Model



Relative Vertical Displacement for the Fine Mesh Model

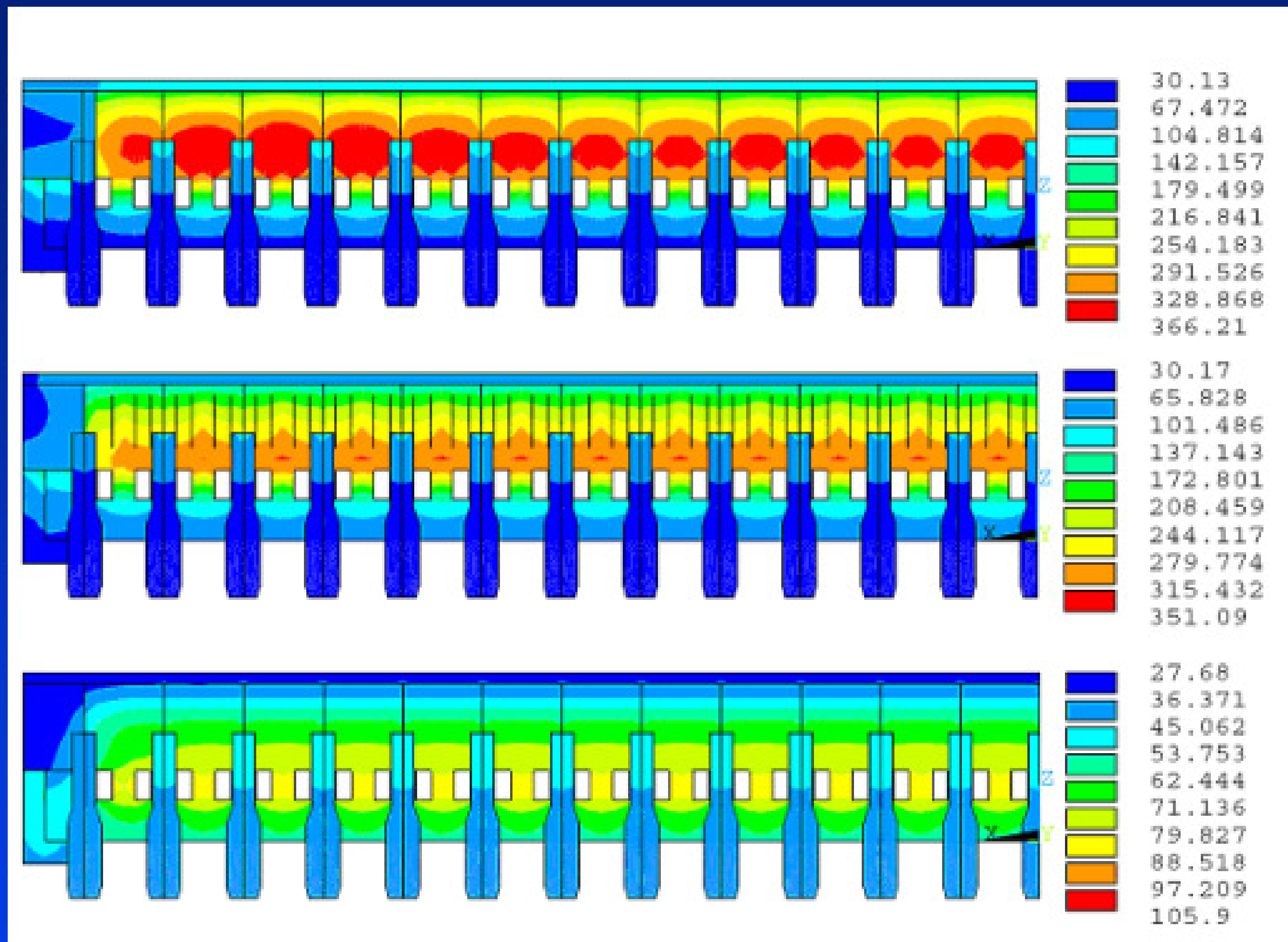
GENISIM HATCH

500 kA Cell Mechanical Model Results

Base Case.

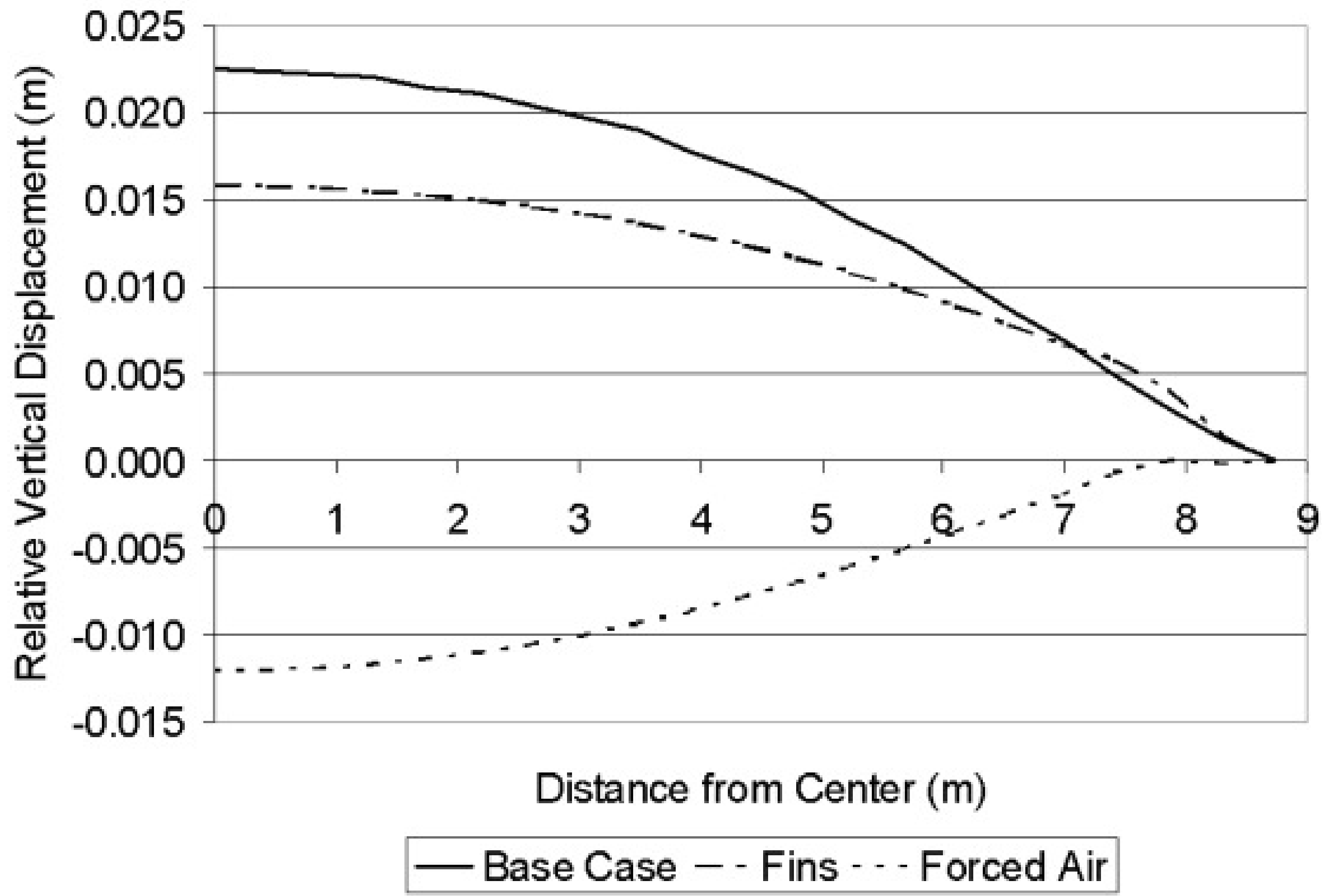
With Cooling Fins.

With Forced-Air Cooling.



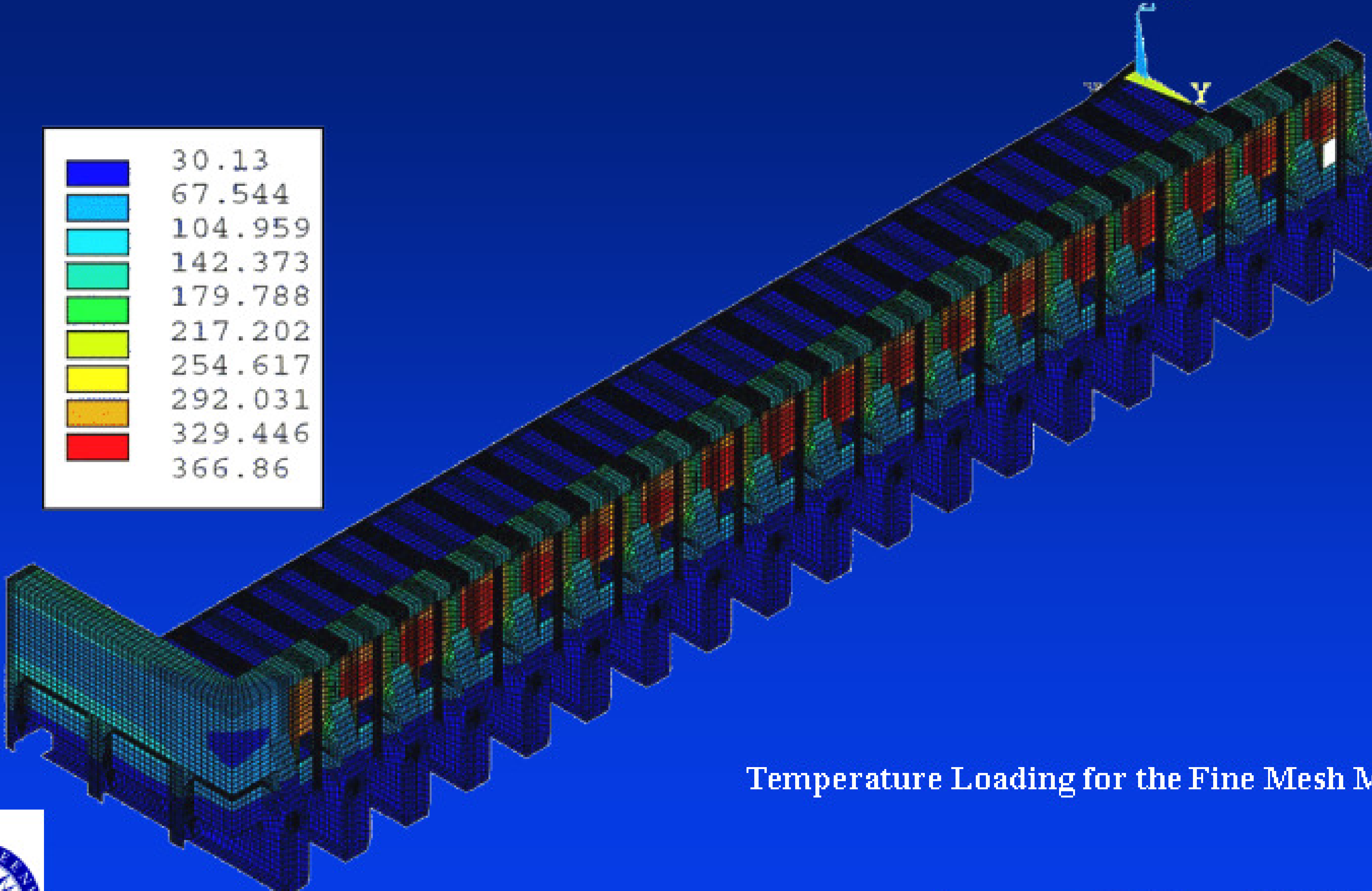
Temperature distribution for the studied 500 kA cell configurations.

500 kA Cell Mechanical Model Results



Comparison of the relative vertical displacement on the long axis of the 500 kA cell.

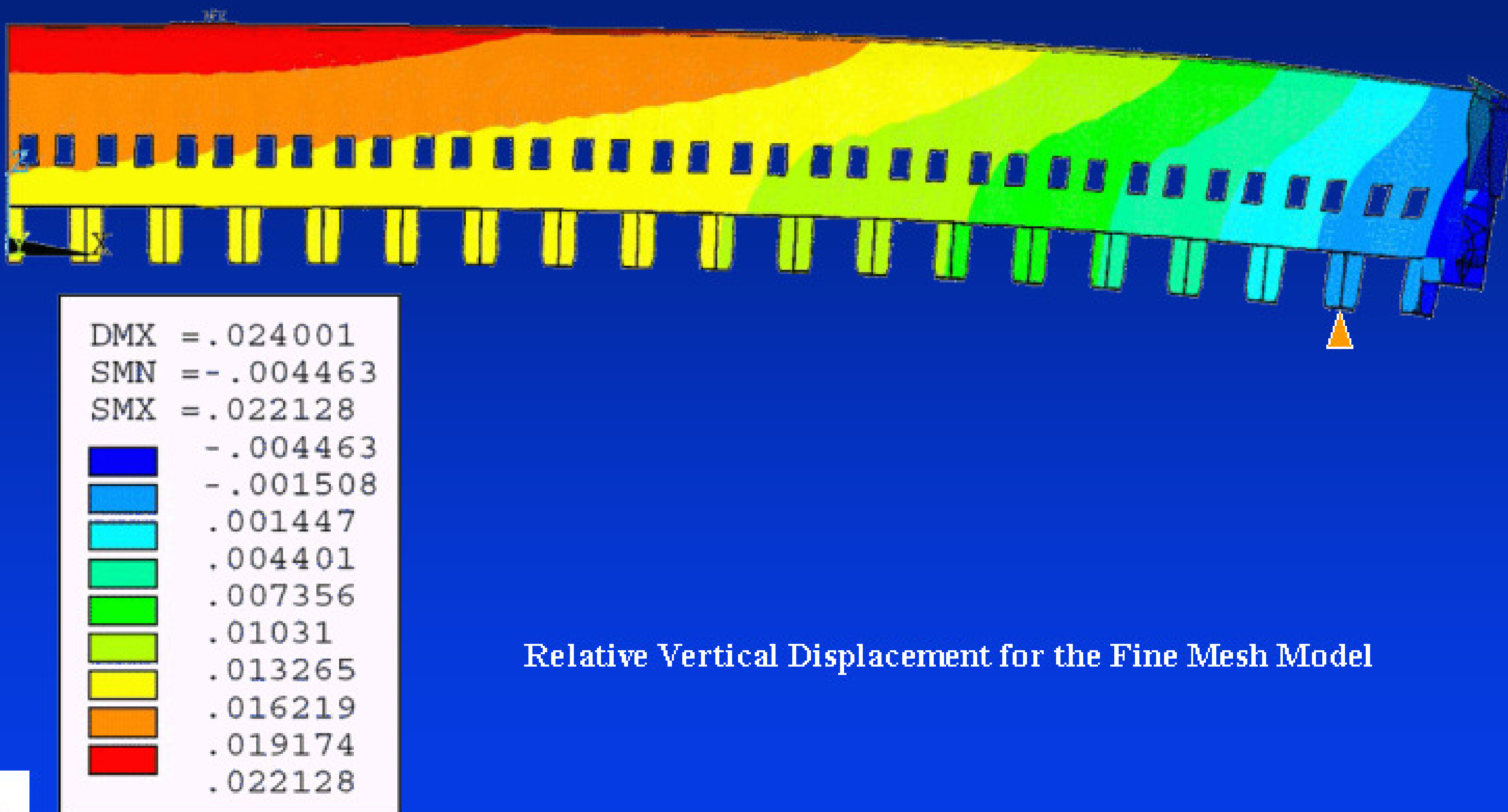
740 kA Cell Potshell Mechanical Design Model



Temperature Loading for the Fine Mesh Model

GENISIM HATCH

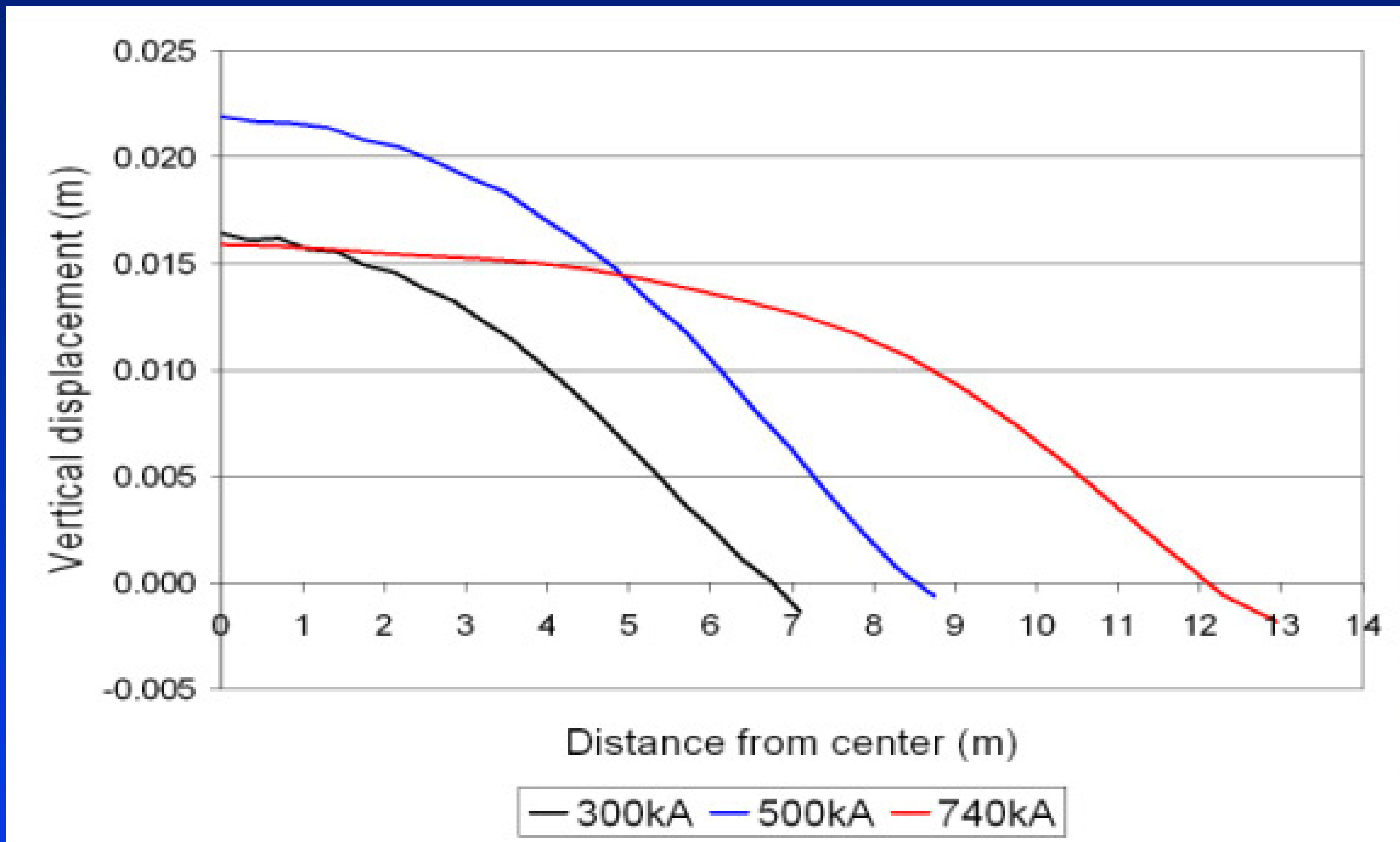
740 kA Cell Potshell Mechanical Model Results



Relative Vertical Displacement for the Fine Mesh Model

GENISIM HATCH

740 kA Cell Mechanical Model Results

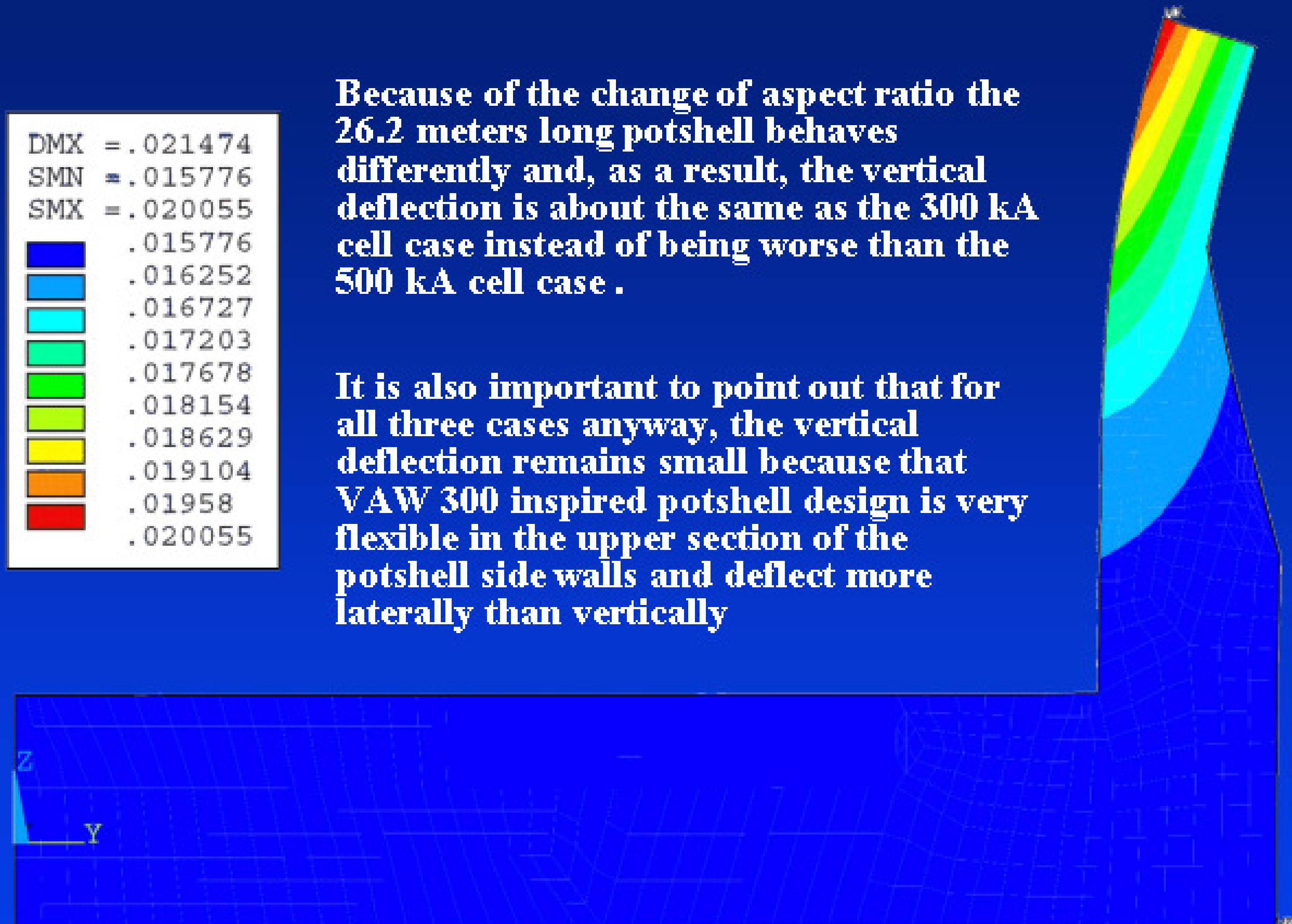


Comparison of the relative vertical displacement on the long axis.

740 kA Cell Mechanical Model Results

Because of the change of aspect ratio the 26.2 meters long potshell behaves differently and, as a result, the vertical deflection is about the same as the 300 kA cell case instead of being worse than the 500 kA cell case .

It is also important to point out that for all three cases anyway, the vertical deflection remains small because that VAW 300 inspired potshell design is very flexible in the upper section of the potshell side walls and deflect more laterally than vertically



Conclusions

- On the cell heat balance and MHD aspect of the cell design, it is clear that there is no limit to the size of cells that could be designed .
- On the potshell mechanical design aspect, we don't have the data in hand to be so assertive, but there is no reason to believe that technically, we are facing a size limit .
- On the other hand, if for very high amperage cells, the solution to the potshell vertical deflection problem can only be solved by using expensive forced air convection devices, it is possible that the usage of those devices annihilates the financial incentive to keep designing bigger and bigger cells.

GENISIM HATCH