Impact of the Vertical Potshell Deformation on the MHD Cell Stability behavior of a 500 kA Aluminum Electrolysis Cell

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Plan of the Presentation

- Introduction
- Previous Presentations
  - Thermo-electric design of a 740 kA cell, Is there a size limit?
  - Study of the thermally-induced shell deformation of high amperage Hall-Héroult cells
  - MHD and potshell mechanical design of a 740 ka cell
- Impact of Vertical Potshell Deformation on MHD Cell Stability
- Conclusions

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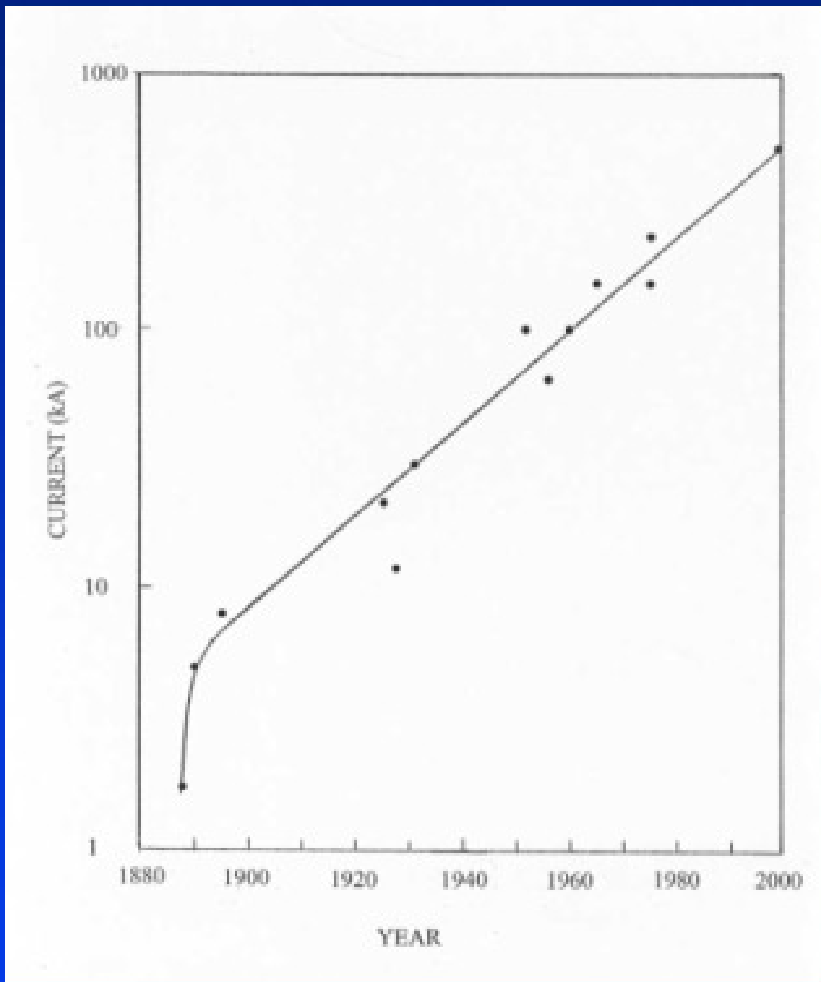
Introduction



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?

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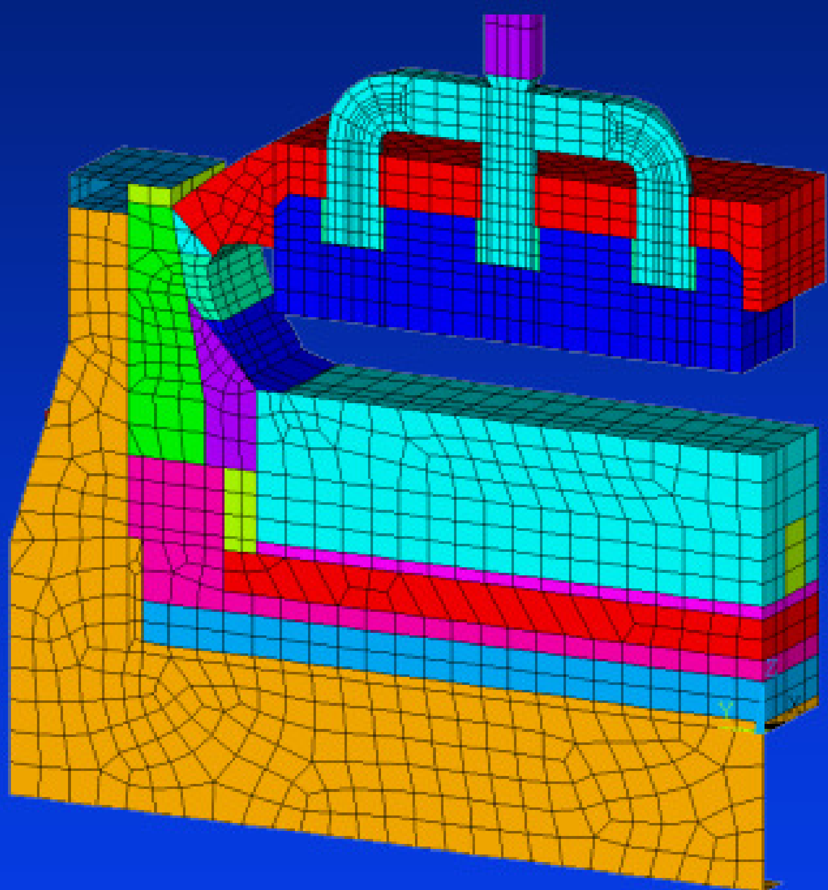
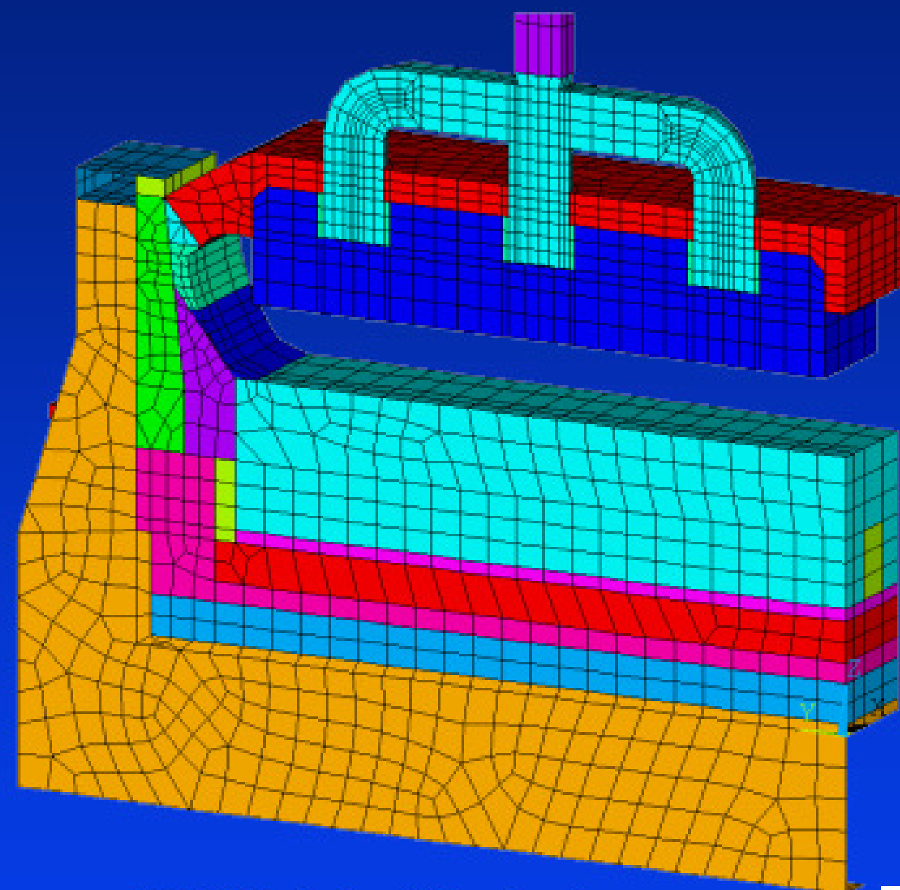
Thermo-Electric Design of a 740 kA Cell, Is There a Size Limit?



300 kA base case design



500/740 kA wider design

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

Results using an ANSYS® based 3D full cell slice modeling tool

	Base case					
Amperage	300 kA	265 kA	350 kA	400 kA	500 kA	740 kA
Anode drop	303 mV	273 mV	323 mV	328 mV	354 mV	349 mV
Cathode drop	285 mV	213mV	292 mV	301 mV	314 mV	310 mV
Anode panel heat loss	240 kW	183 kW	284 kW	322 kW	409 kW	611 kW
Cathode bottom heat loss	176 kW	132 kW	202 kW	226 kW	273 kW	395 kW
Operating temperature	973.2 °C	956.1 °C	960.4 °C	961.7 °C	963.1 °C	963.5 °C
Liquidus superheat	6.7 °C	2.4 °C	6.7 °C	8.0 °C	9.4 °C	9.8 °C
Bath ledge thickness	8.66 cm	23.5 cm	9.09 cm	7.32 cm	6.15 cm	5.84 cm
Metal ledge thickness	4.12 cm	9.01 cm	4.42 cm	3.39 cm	2.42 cm	2.15 cm
Current efficiency	94.0 %	95.7 %	96.1 %	96.1 %	95.9 %	95.8 %
Internal heat	628 kW	422 kW	713 kW	832 kW	1043 kW	1518 kW
Energy consumption	13.72 kWh/kg	11.93 kWh/kg	13.43 kWh/kg	13.57 kWh/kg	13.61 kWh/kg	13.51 kWh/kg

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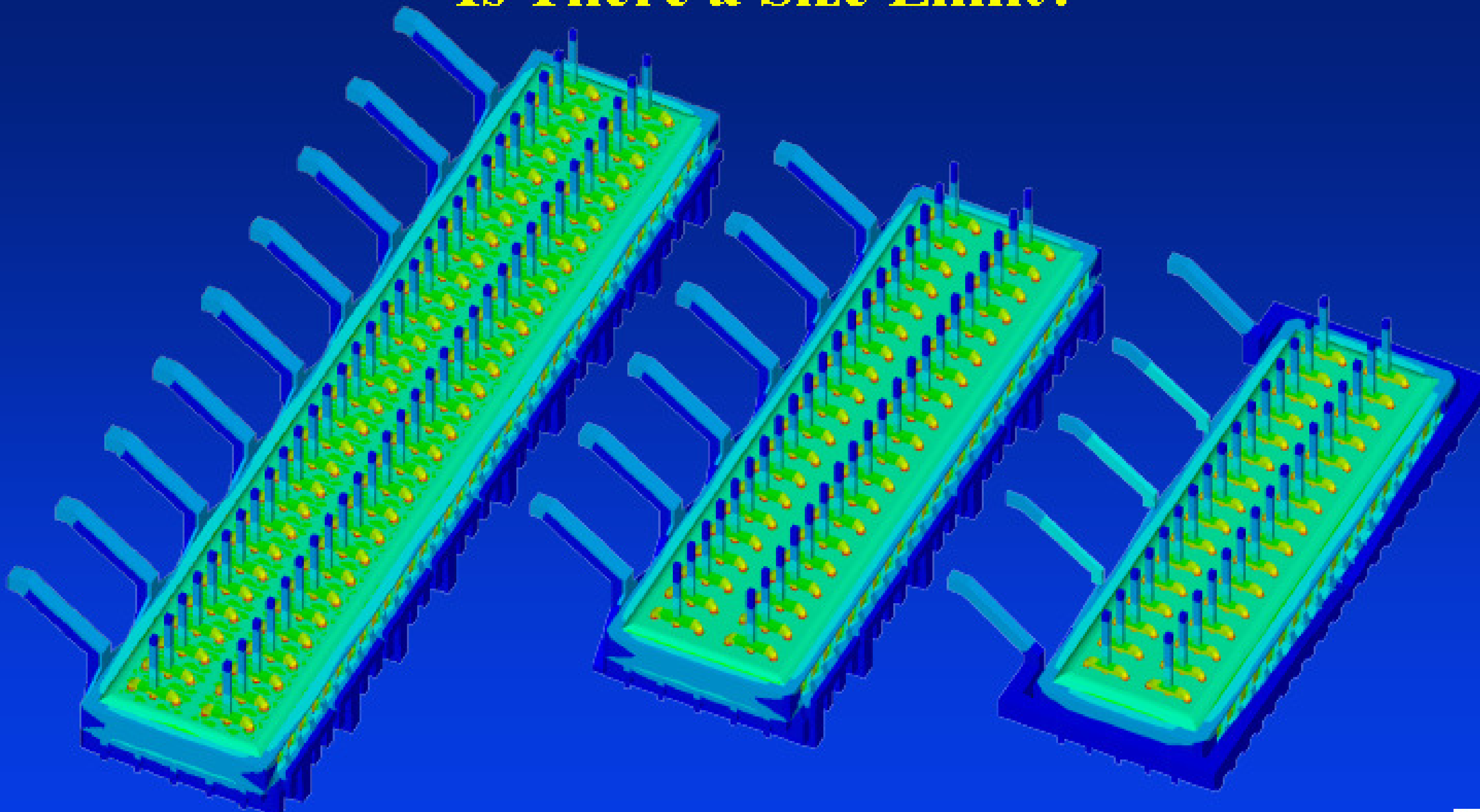
Thermo-Electric Design of a 740 kA Cell, Is There a Size Limit?



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

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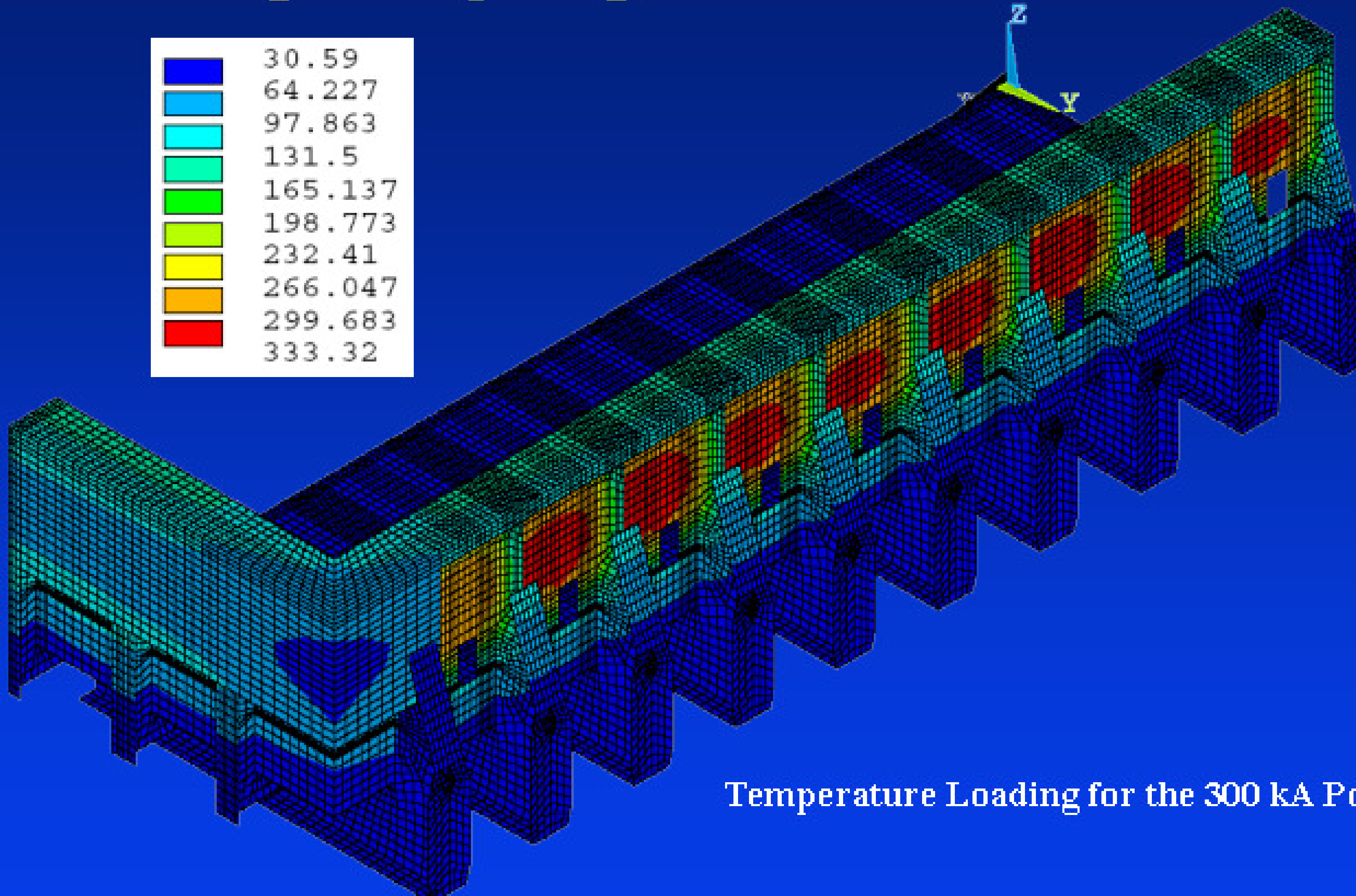
Study of the Thermally-Induced Shell Deformation of High Amperage Hall-Héroult Cells



Temperature Loading for the 300 kA Potshell

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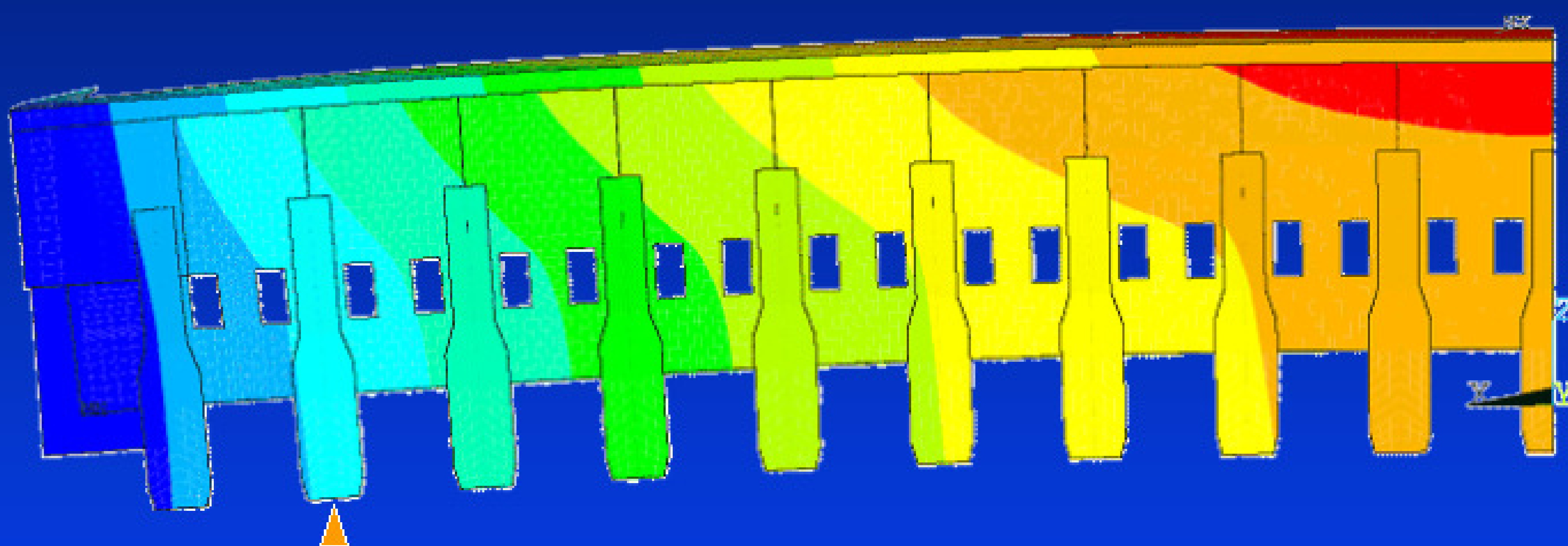
Study of the Thermally-Induced Shell Deformation of High Amperage Hall-Héroult Cells



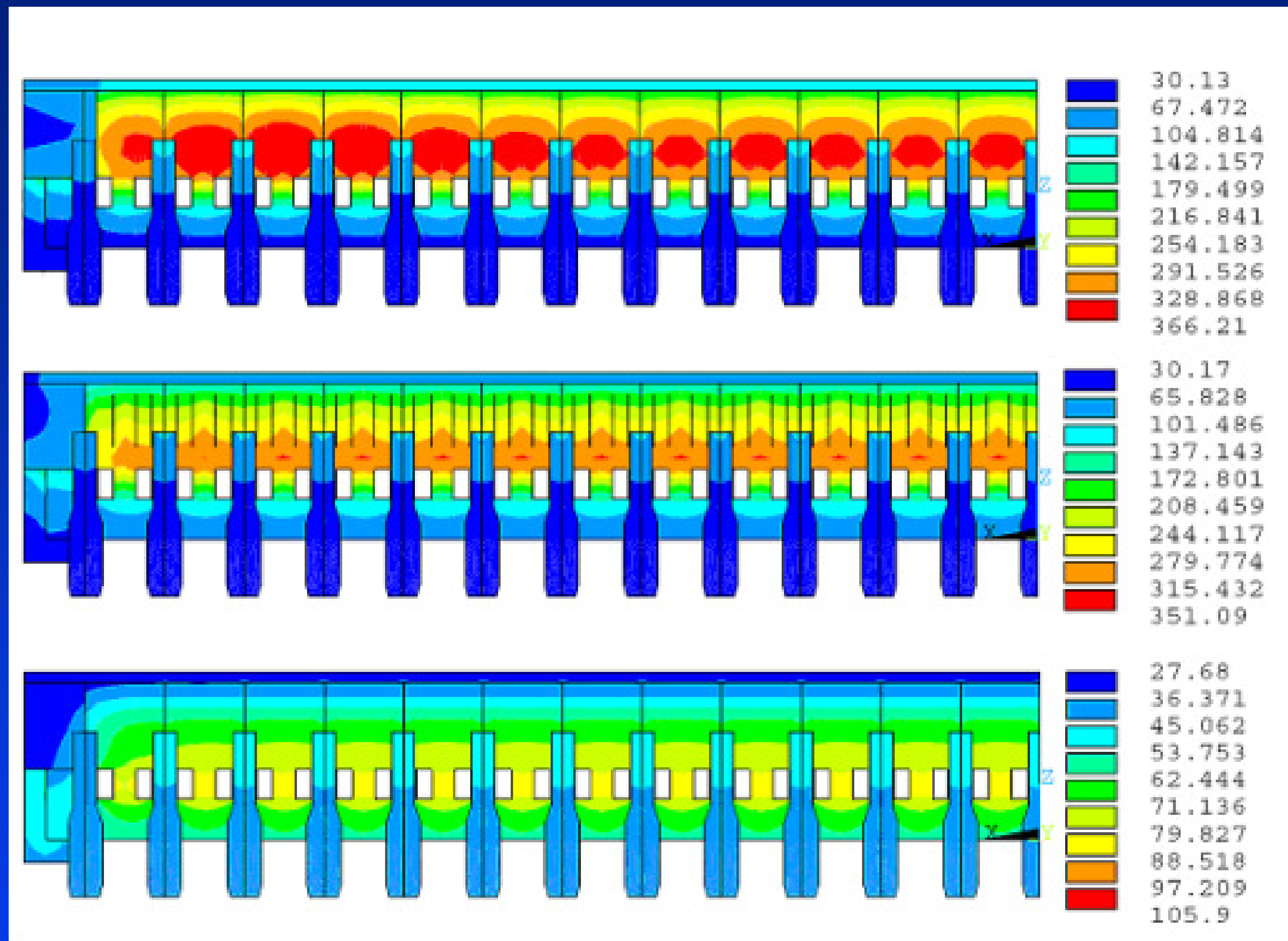
Relative Vertical Displacement for the 300 kA Potshell

Study of the Thermally-Induced Shell Deformation of High Amperage Hall-Héroult Cells

Base Case.

With Cooling Fins.

With Forced-Air Cooling.



Temperature distribution for the studied 500 kA cell configurations.

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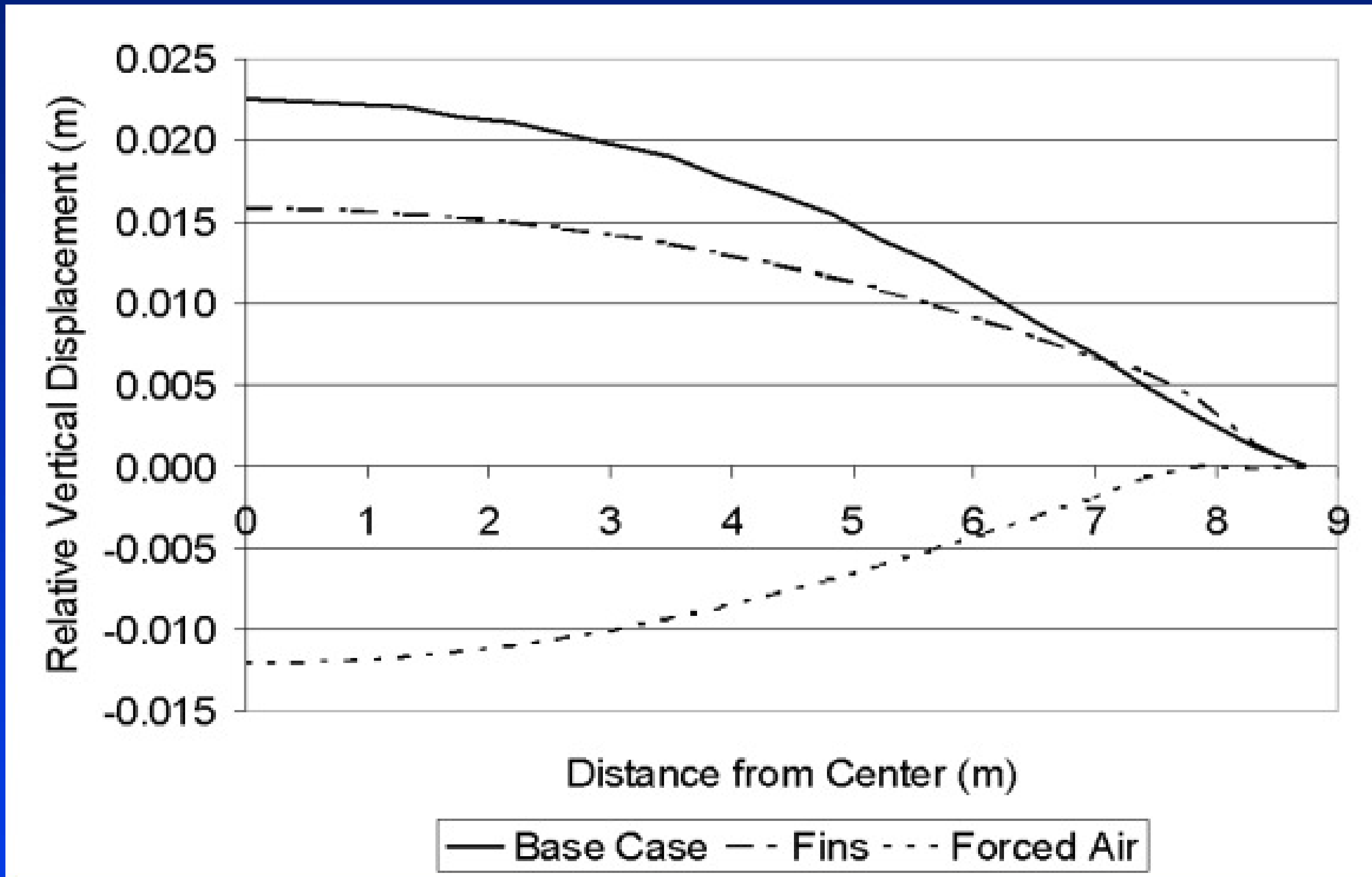
Study of the Thermally-Induced Shell Deformation of High Amperage Hall-Héroult Cells



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

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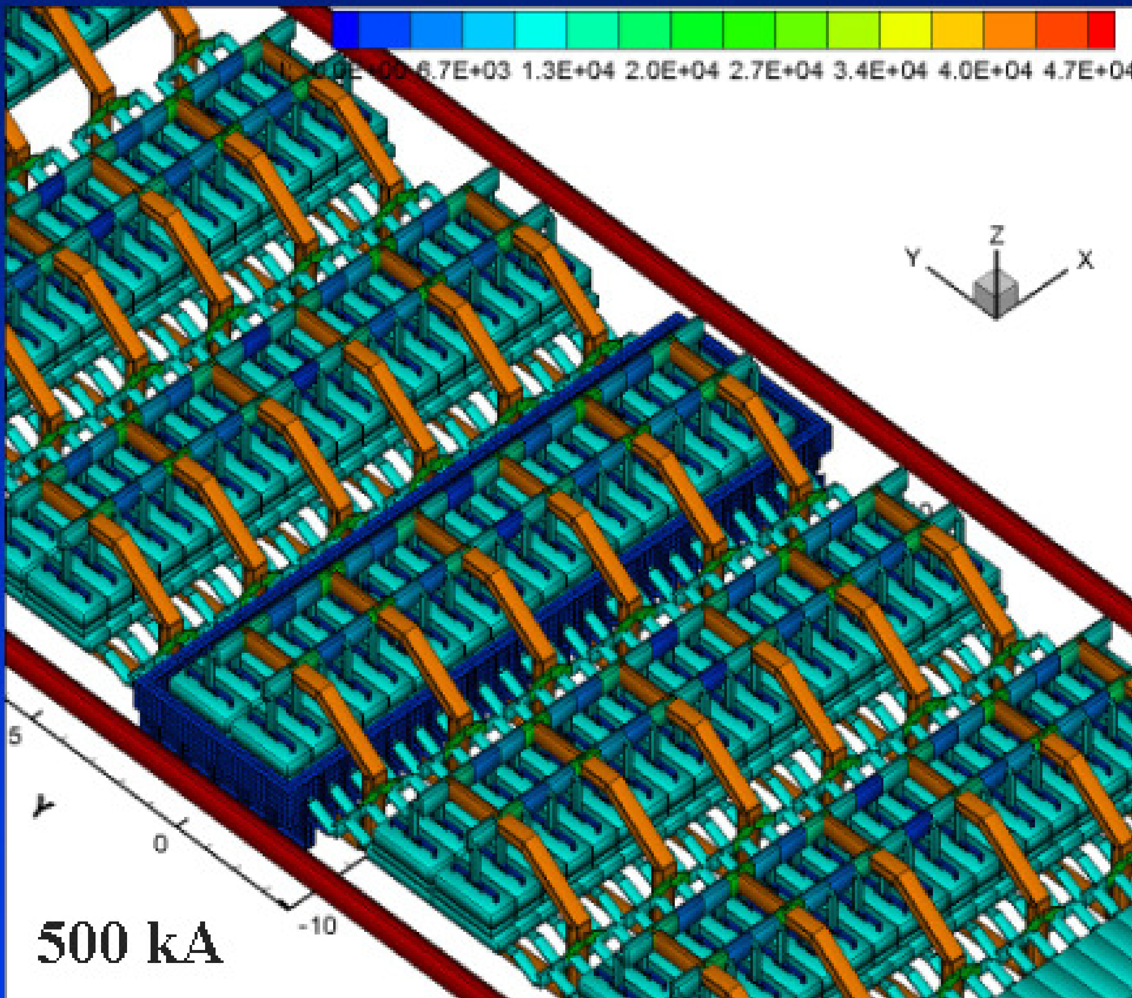
MHD and Potshell Mechanical Design of a 740 kA Cell



Using MHD-Valdis cell stability code, it is easy to build a model reproducing the Pechiney 1987 patent busbar layout for a 500 kA cell design

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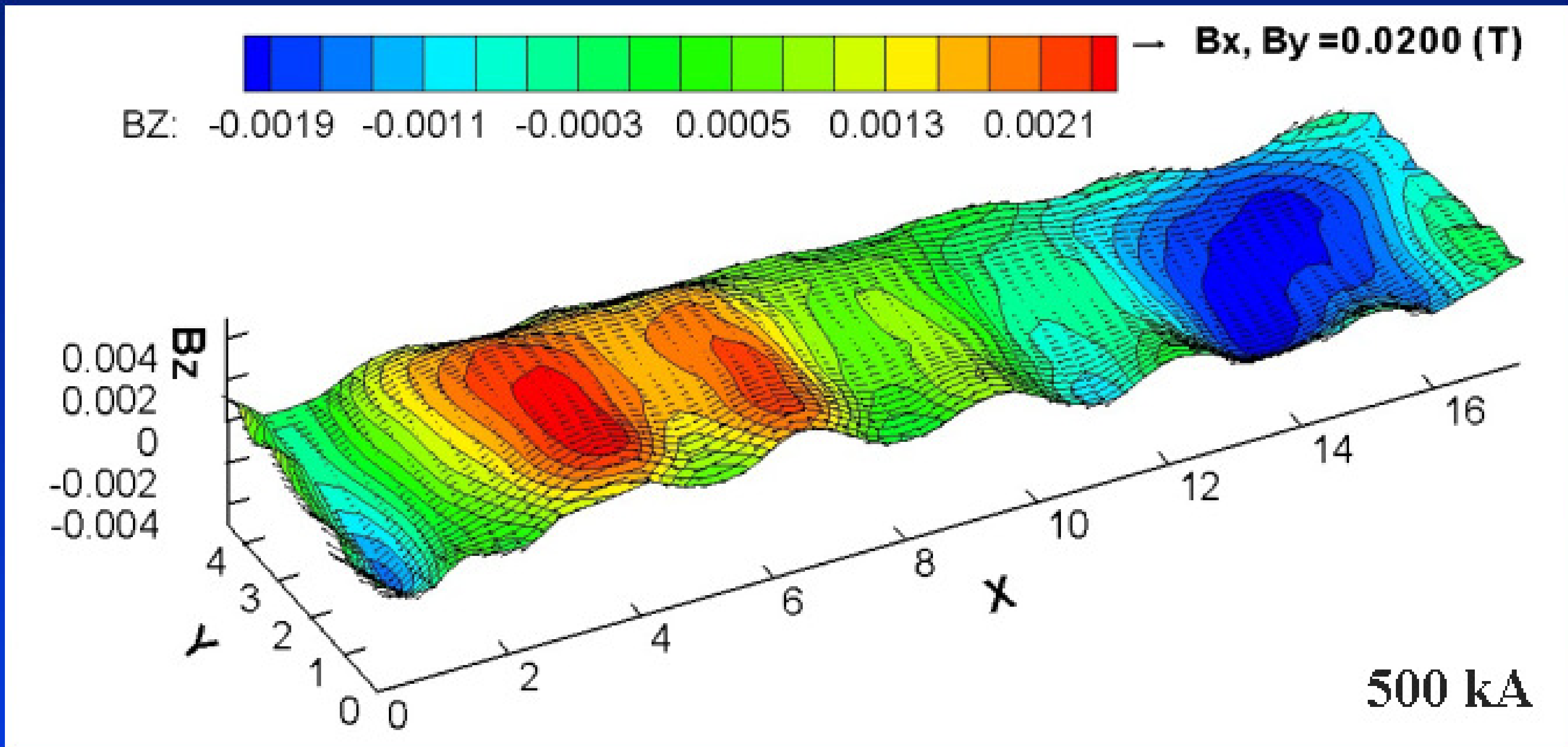
MHD and Potshell Mechanical Design of a 740 kA Cell



As claimed by Pechiney, the compensation busbars are doing a great job reducing the intensity of the Bz magnetic field

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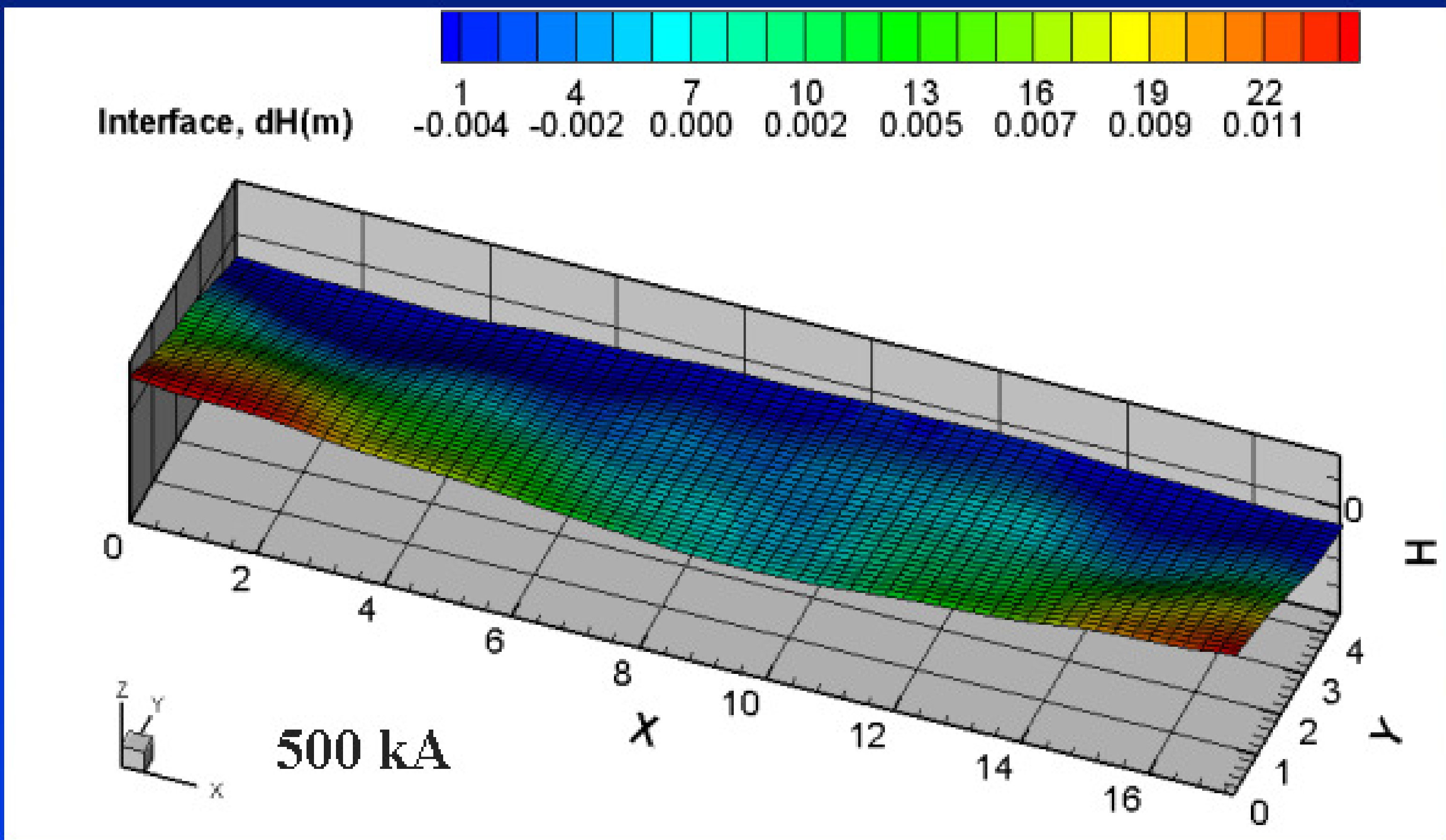
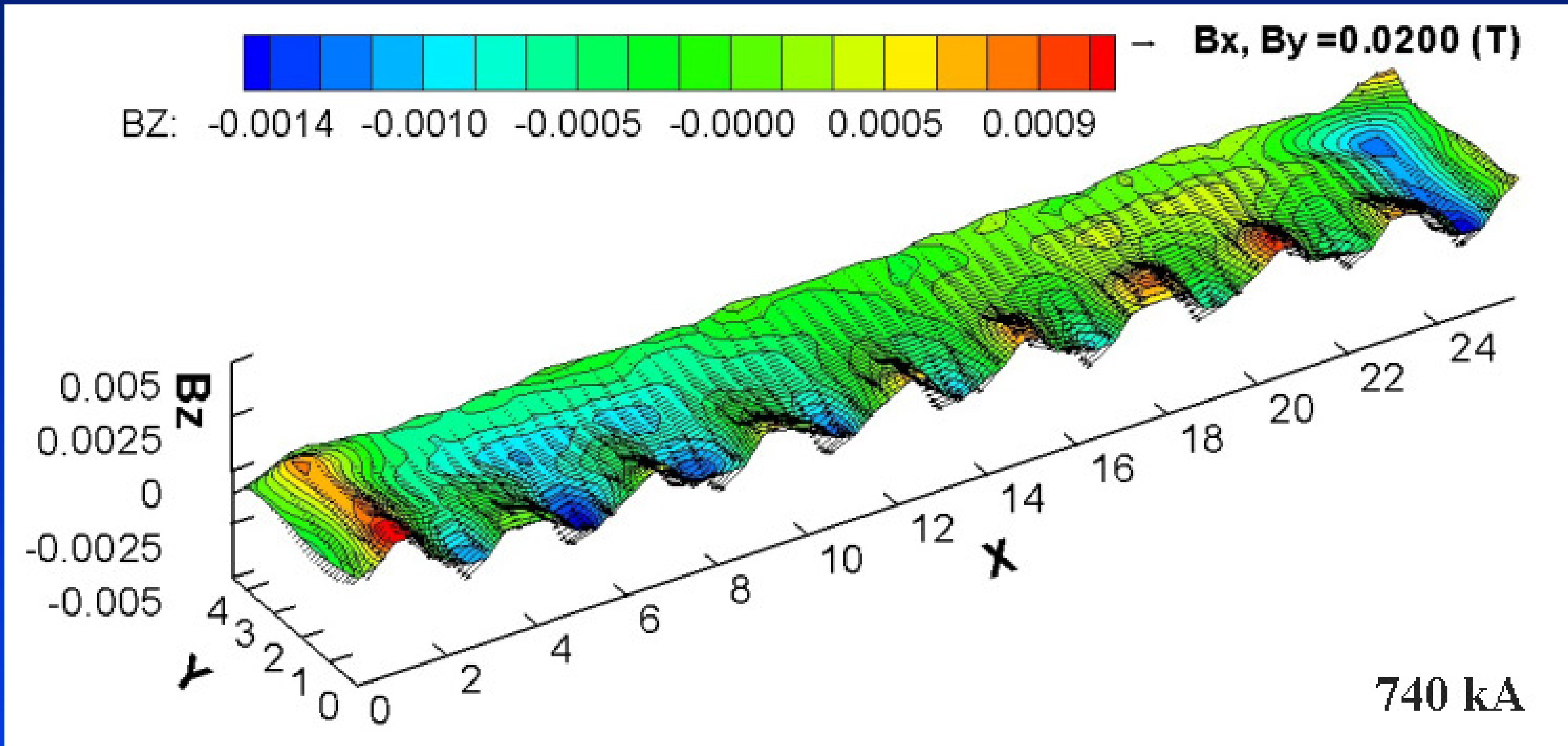
MHD and Potshell Mechanical Design of a 740 kA Cell



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

MHD and Potshell Mechanical Design of a 740 kA Cell



With new busbar design, no global Bz longitudinal gradient, so no MHD instability wave

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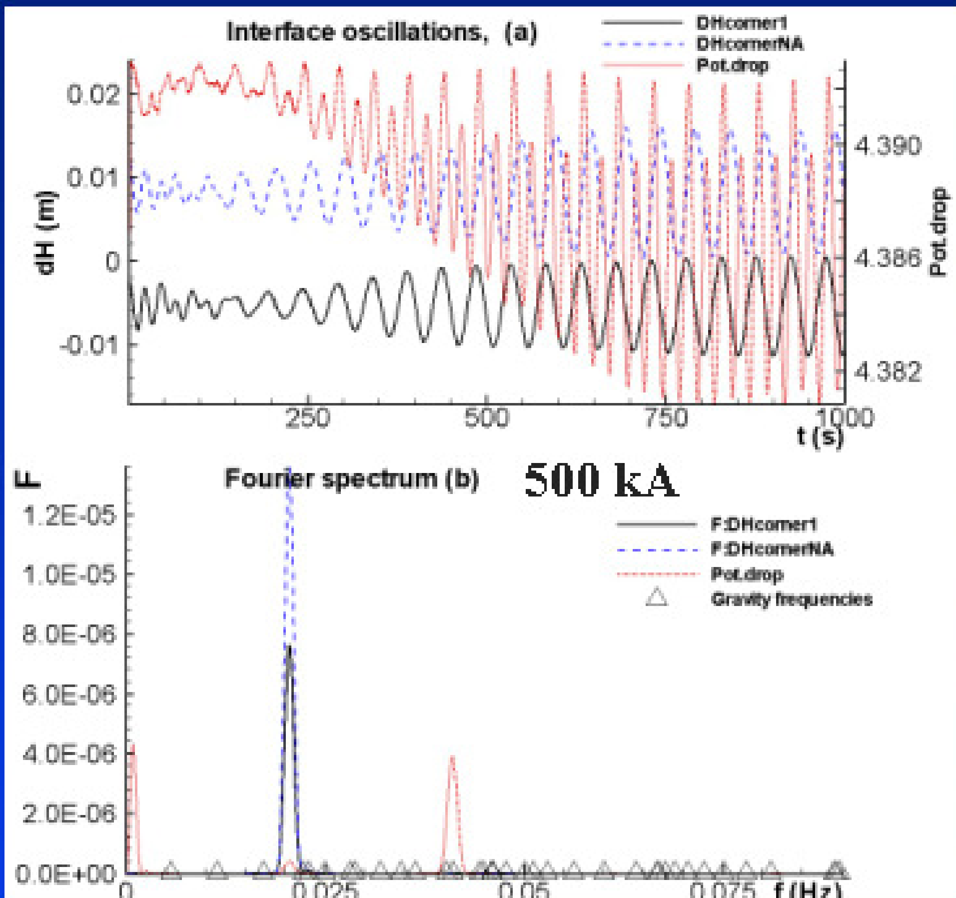
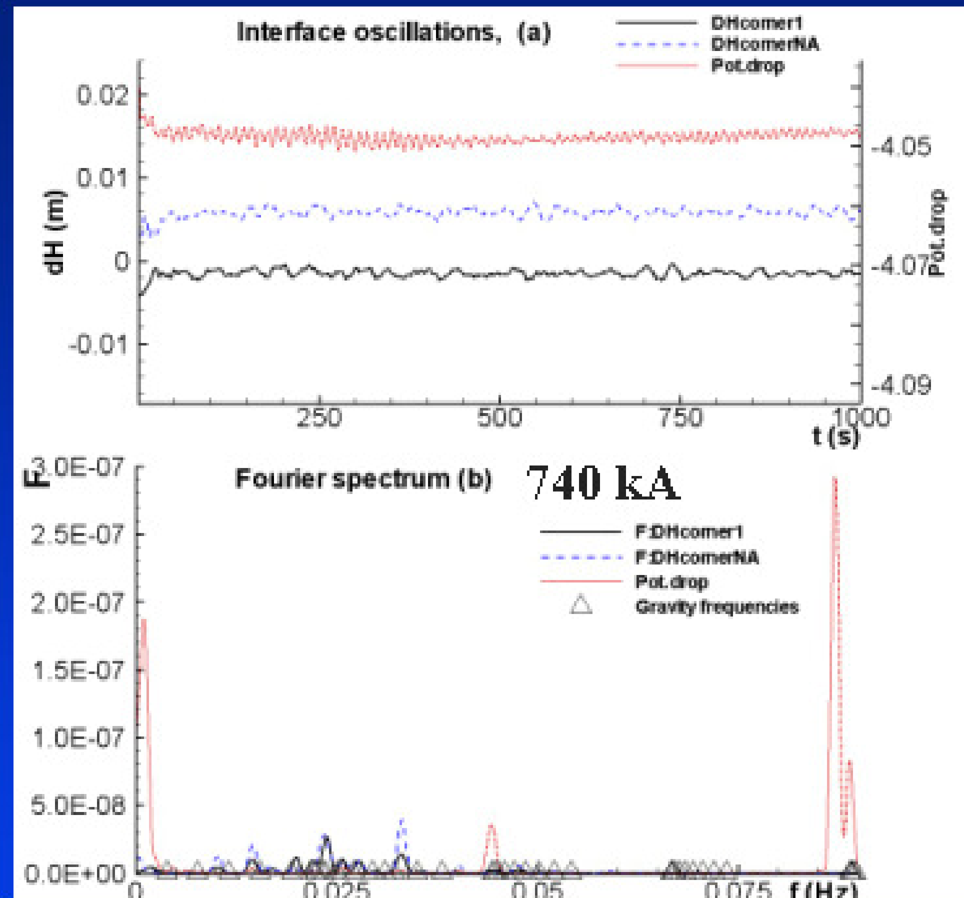
MHD and Potshell Mechanical Design of a 740 kA Cell





With new busbar design, no global Bz longitudinal gradient, so no MHD instability wave

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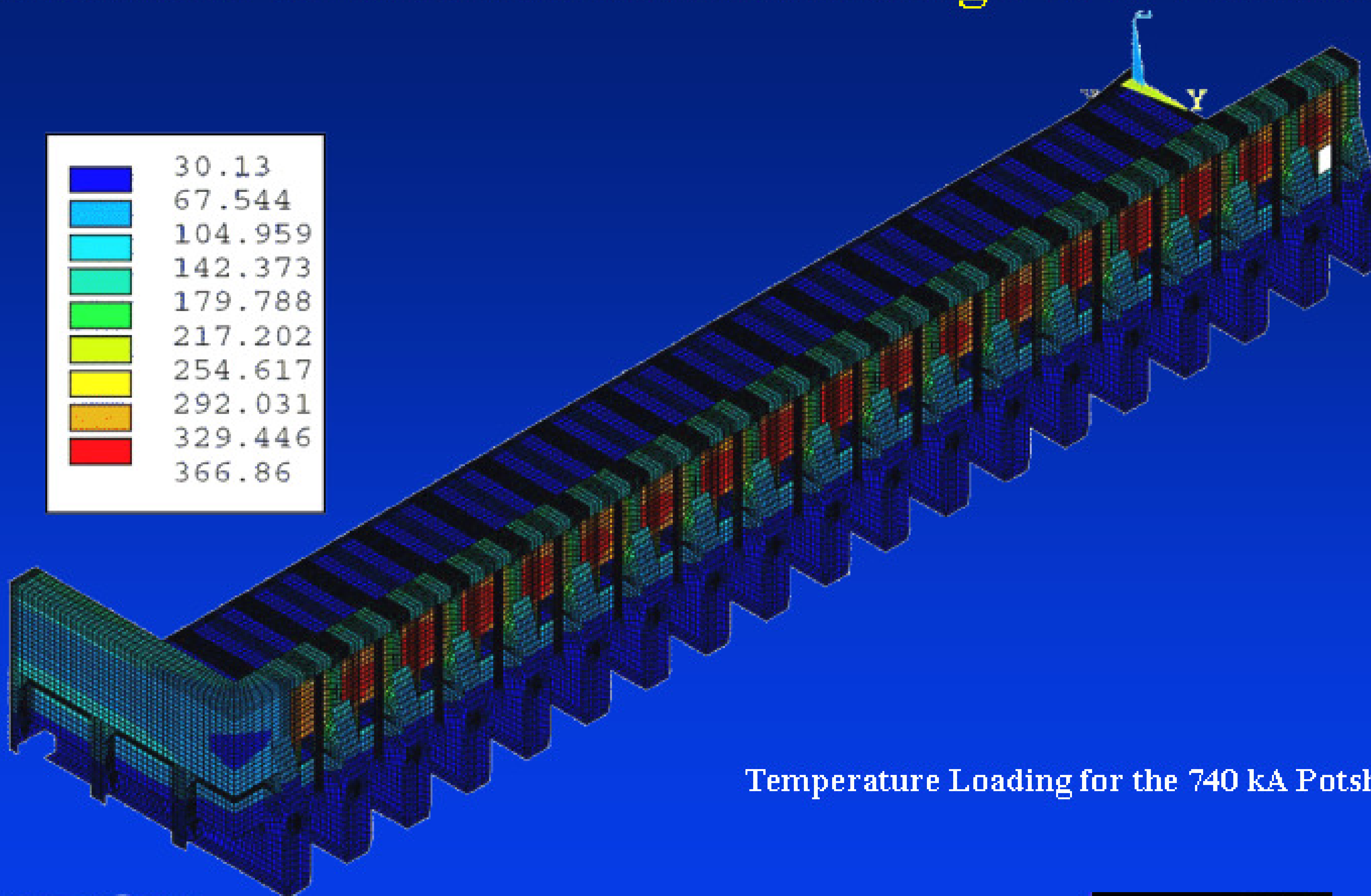
MHD and Potshell Mechanical Design of a 740 kA Cell



Temperature Loading for the 740 kA Potshell

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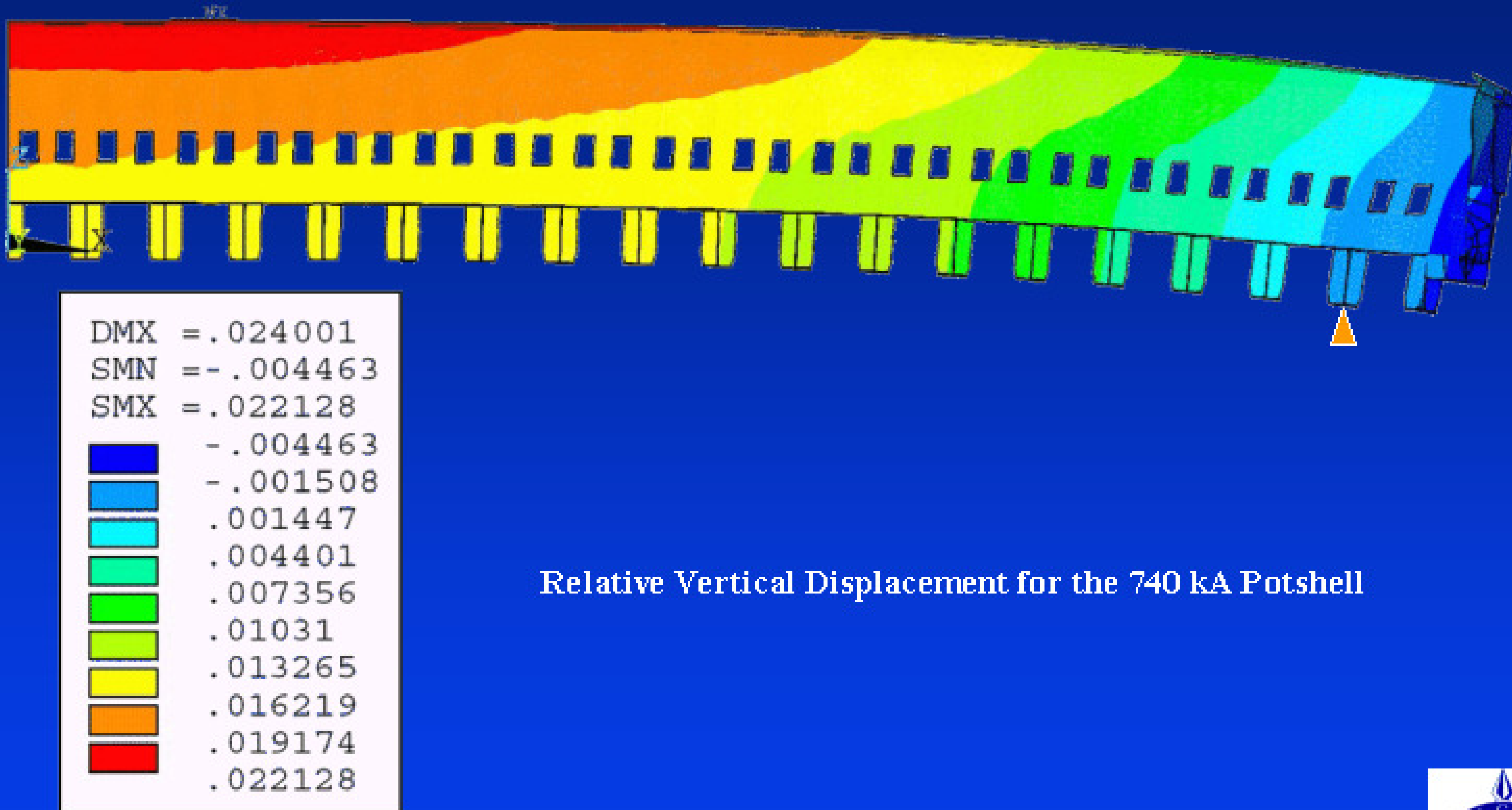
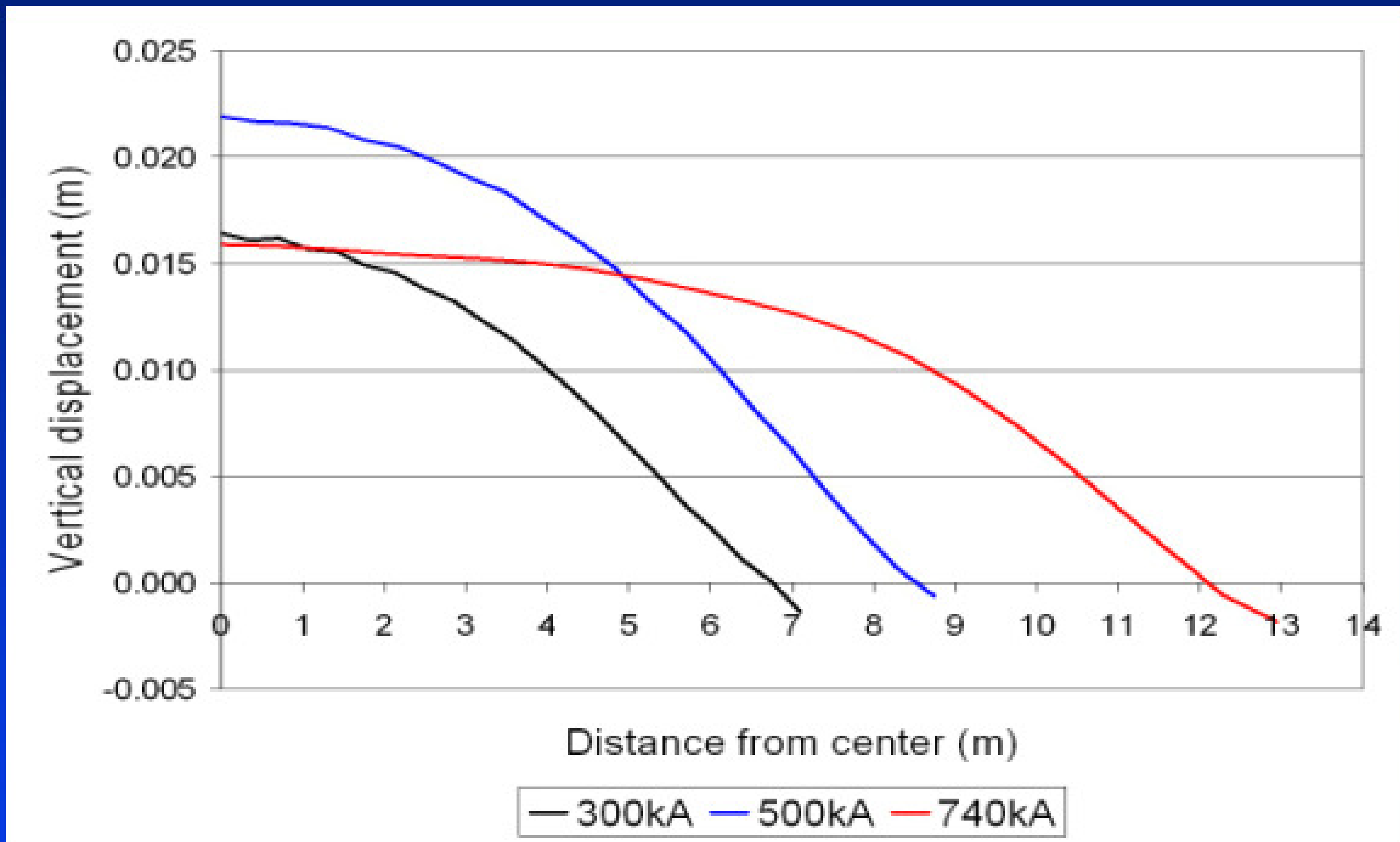
MHD and Potshell Mechanical Design of a 740 kA Cell



Relative Vertical Displacement for the 740 kA Potshell

MHD and Potshell Mechanical Design of a 740 kA Cell

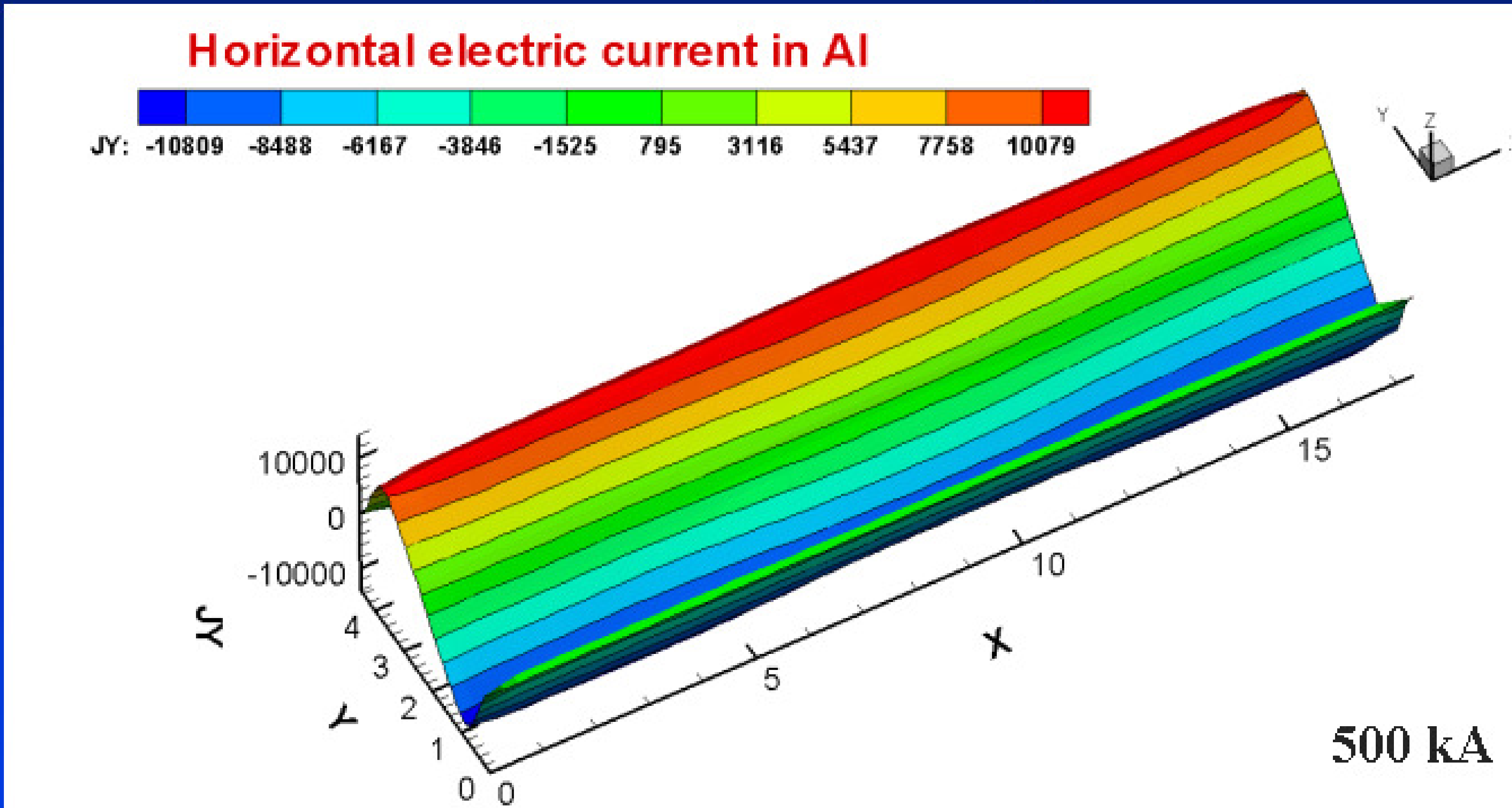


Comparison of the relative vertical displacement on the long axis.

Impact of Vertical Potshell Deformation on MHD Cell Stability

The MHD-Valdis non-linear Magneto-Hydro-Dynamic model has been extended to take into account the displacement of the potshell. The MHD cell stability behavior of a 500 kA cell with a 17.3 meters long potshell was then studied.

Impact of Vertical Potshell Deformation on MHD Cell Stability



Lateral (Y) horizontal metal pad current density initially calculated using a flat bath/metal interface and a flat bottom profile.

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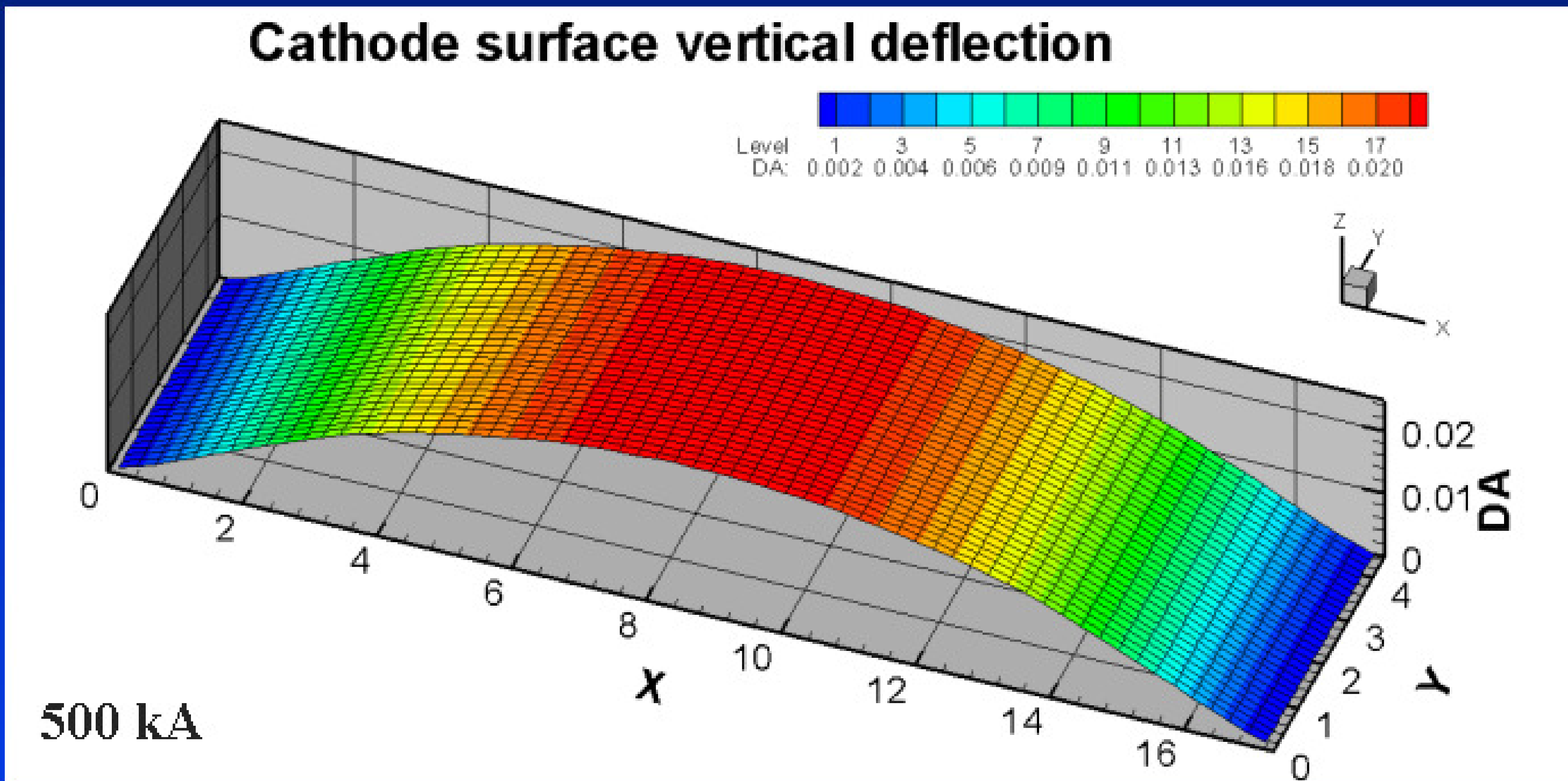
Impact of Vertical Potshell Deformation on MHD Cell Stability



Metal pad bottom profile input: case 1

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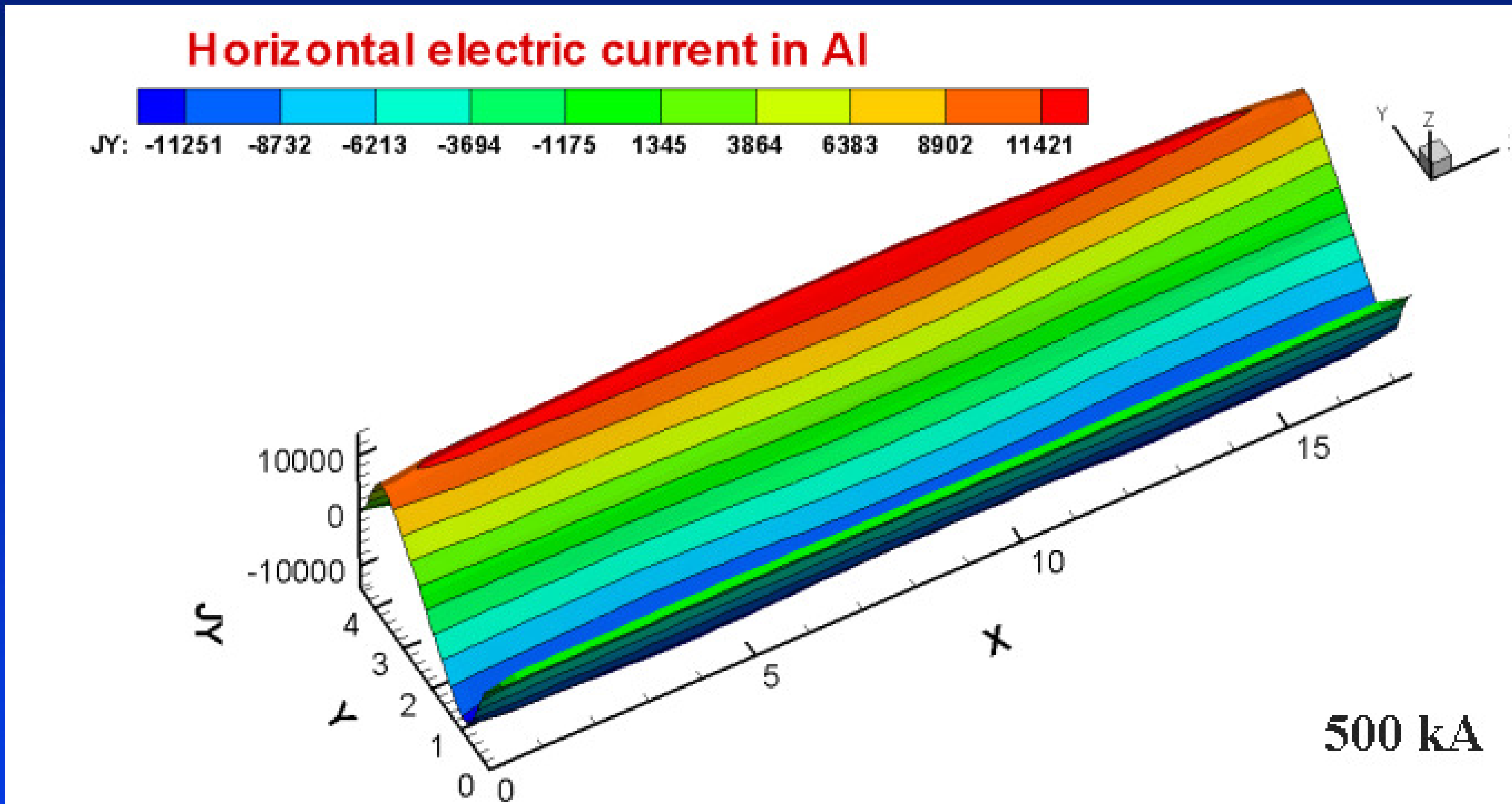
Impact of Vertical Potshell Deformation on MHD Cell Stability



Lateral (Y) horizontal metal pad current density initially calculated using a flat bath/metal interface and a deflected (2.25 cm max) bottom profile.

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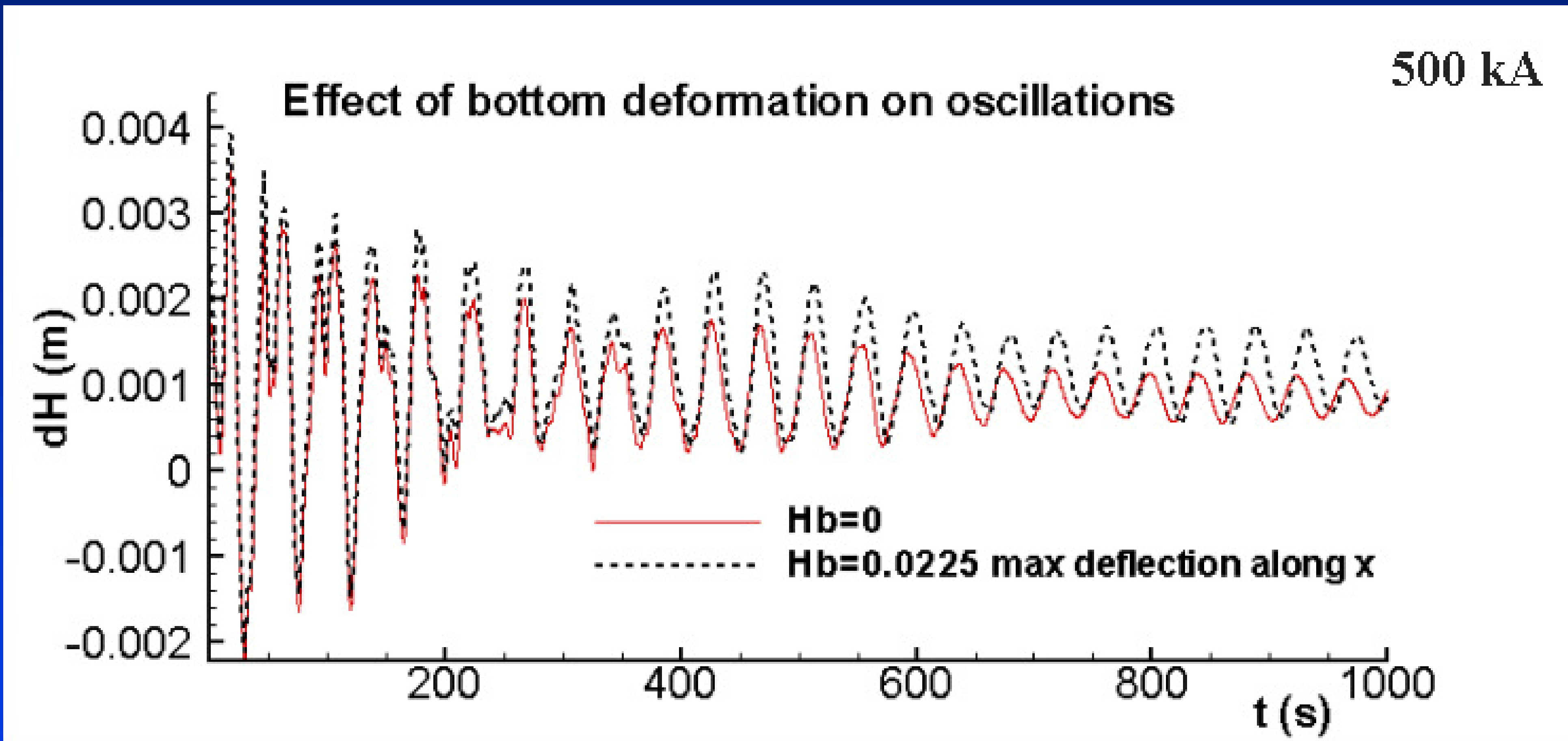
Impact of Vertical Potshell Deformation on MHD Cell Stability



The comparison of the MHD-VALDIS results with and without up to 2.25 cm of vertical displacement .

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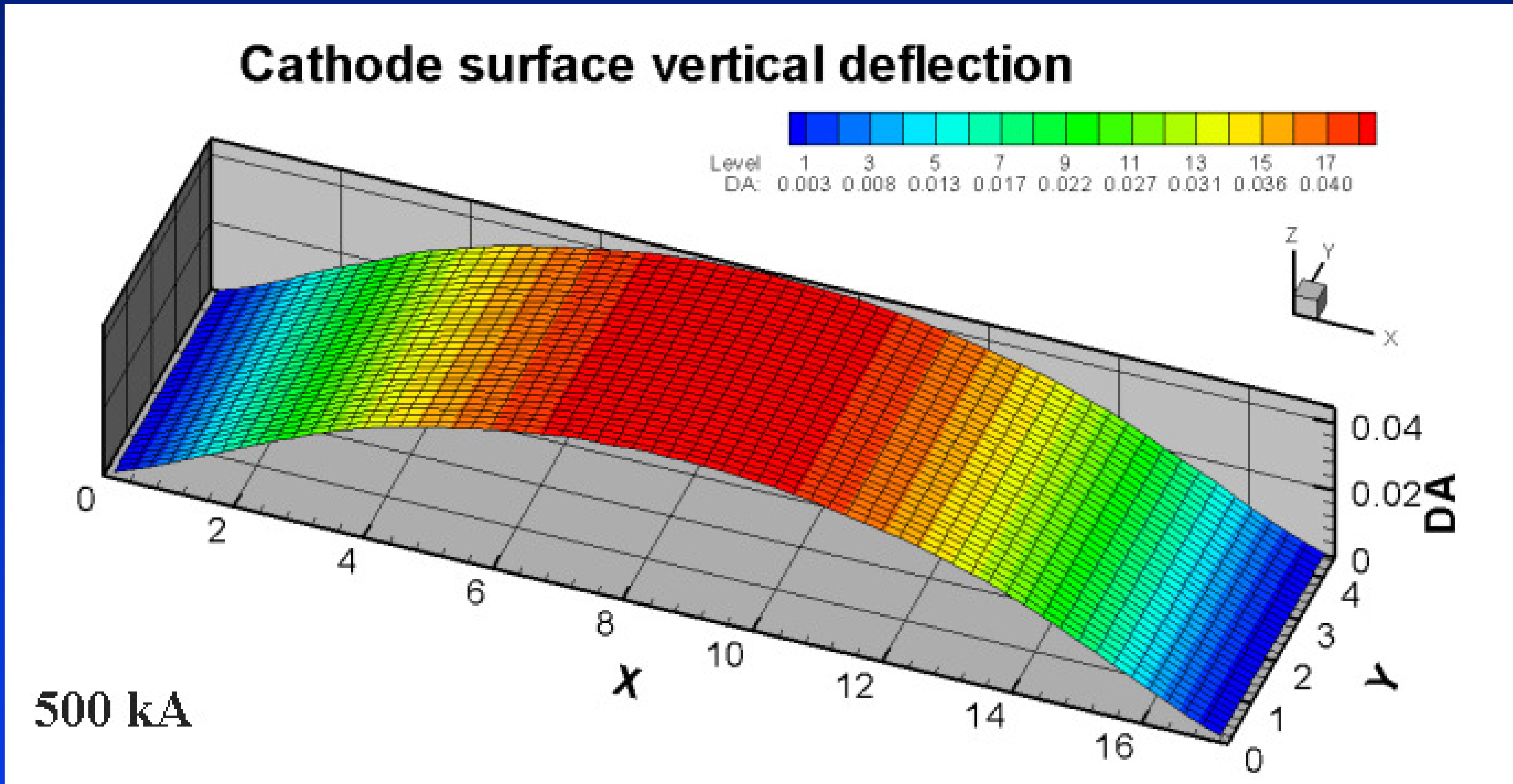
Impact of Vertical Potshell Deformation on MHD Cell Stability



Metal pad bottom profile input: case 2

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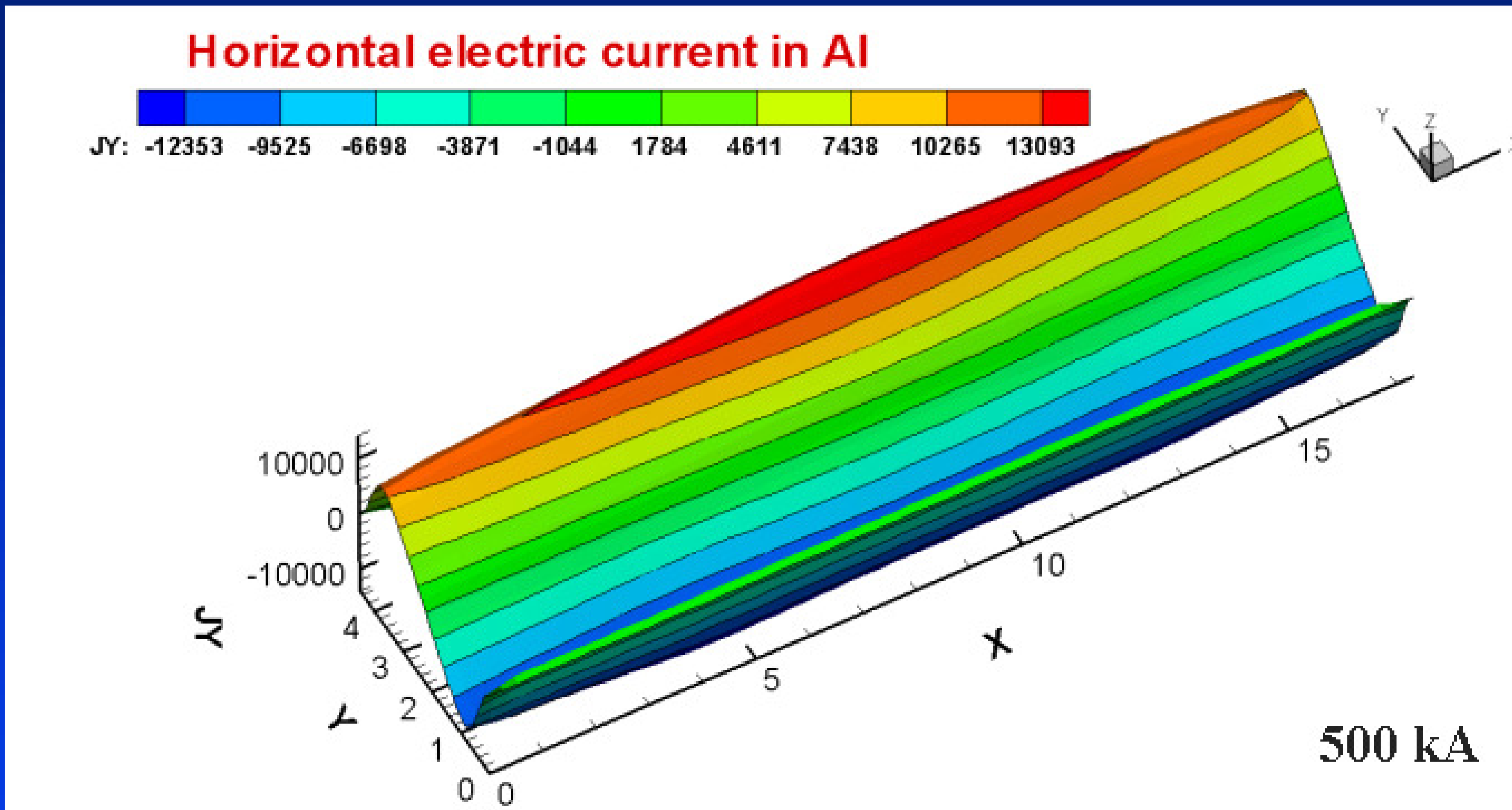
Impact of Vertical Potshell Deformation on MHD Cell Stability



Lateral (Y) horizontal metal pad current density initially calculated using a flat bath/metal interface and a deflected (4.5 cm max) bottom profile.

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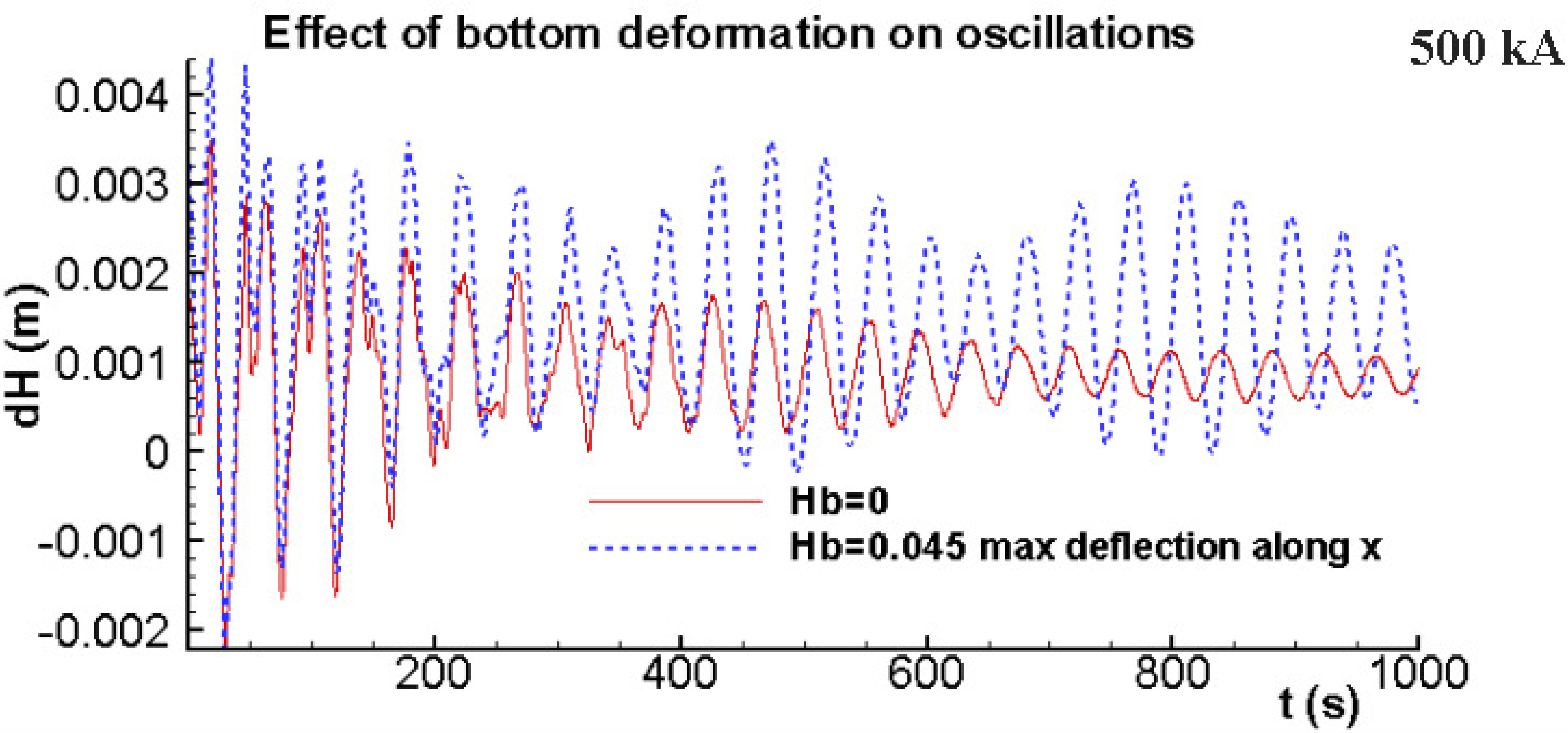
Impact of Vertical Potshell Deformation on MHD Cell Stability



The comparison of the MHD-VALDIS results with and without up to 4.5 cm of vertical displacement.

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Conclusions

- MHD-Valdis non-linear cell stability analysis software was successfully updated to be able to take into account the impact of having a non perfectly horizontal cathode surface.
- For the 500 kA demonstration cell, the non-linear cell stability analysis results show that vertical potshell displacement and hence the cathode block top surface displacement do affect the cell stability in a negative way.
- 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, the vertical potshell displacement problem can be treated if required, so there is no reason to believe that technically, we are facing a size limit.