Influence of the Cathode Surface Geometry on the Metal Pad Current Density and MHD Cell Stability

Marc Dupuis

GENISIM

Valdis Bojarevics

University of Greenwich,
School of Computing and Mathematics

Plan of the Presentation

- Introduction
  - Examples of Irregular Cathode Surface Design
  - Example of Retrofit Study with Irregular Cathode Surface
  - Results of the First MHD Cell Stability Study
- Study of the Impact of Cathode Surface Geometry on the Cathode Surface Current Density
  - Study of the Impact of Longitudinal Ridges
  - Study of the Impact of Transversal Ridges
- Study of the Impact of Cathode Surface Geometry on the Cell Stability
  - 500 kA Flat Cathode Surface Base Case Model
  - 500 kA with Transversal Ridges Case Model
  - 500 kA Base Case Model with Less Metal and More Ledge
- Conclusions

Introduction

Examples of irregular cathode surface design in use in China: cylindrical ridges

Ref: N. Feng et al., "Research and Application of Energy Saving Technology for Aluminum Reduction in China," TMS Light Metals 2012, 563-568.

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Introduction

Examples of irregular cathode surface design in use in China: longitudinal ridges

Ref: N. Feng et al., "Research and Application of Energy Saving Technology for Aluminum Reduction in China," TMS Light Metals 2012, 563-568.

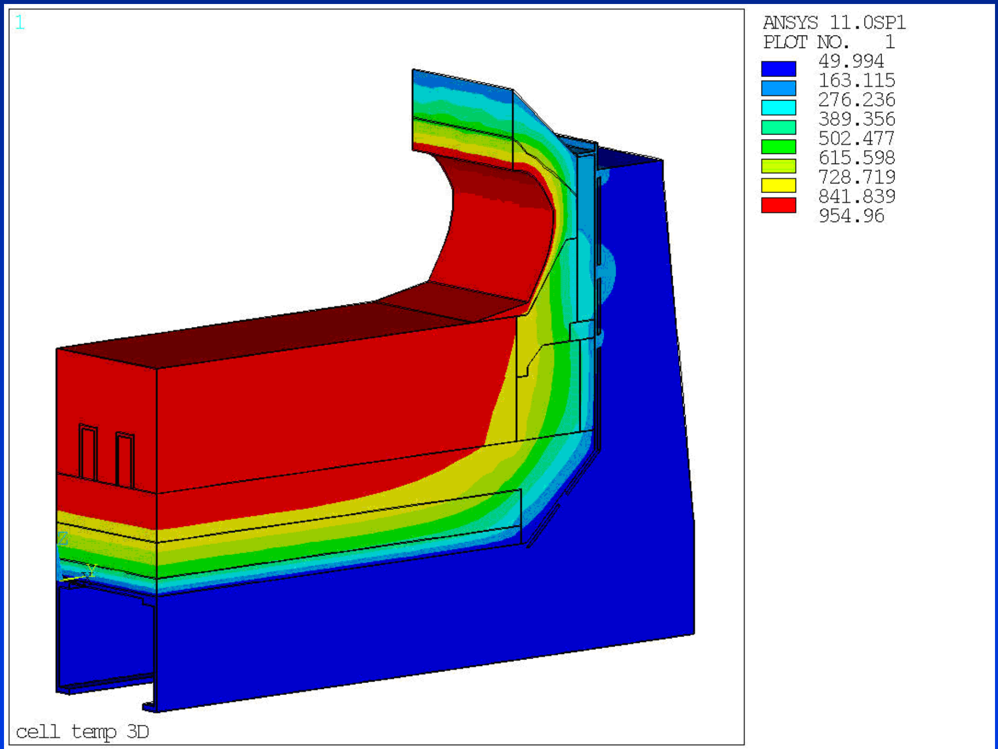
Introduction

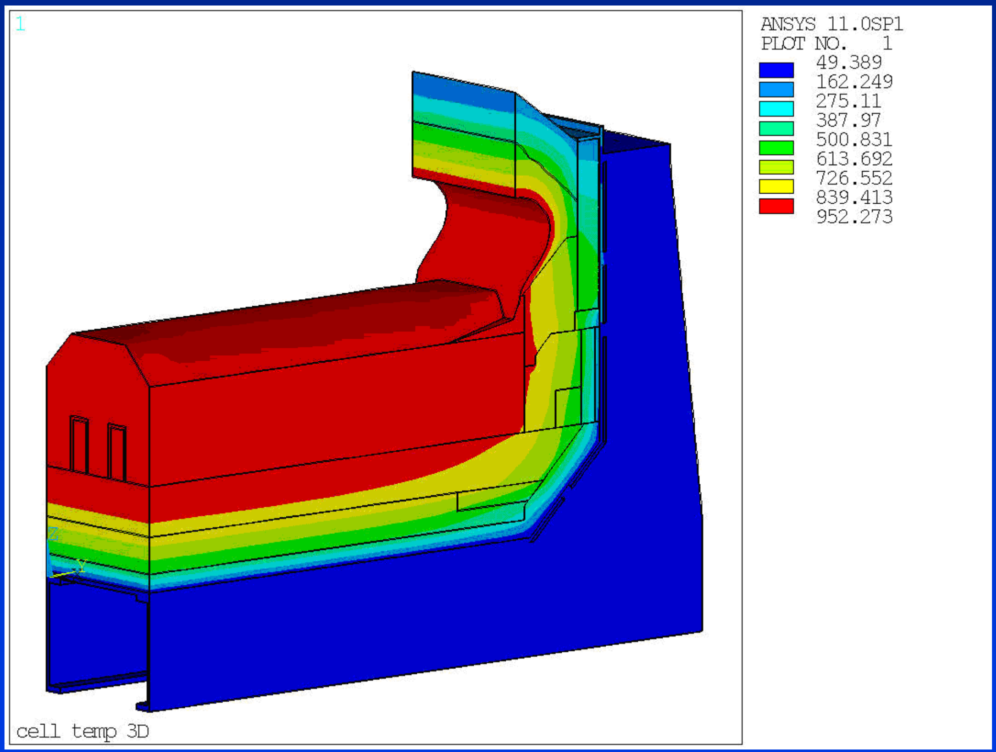
Examples of irregular cathode surface design in use in China: transversal ridges

Ref: N. Feng et al., "Research and Application of Energy Saving Technology for Aluminum Reduction in China," TMS Light Metals 2012, 563-568.

Introduction

Example of retrofit study with irregular cathode surface: change of cathode geometry





Ref: J. Zhou et al., "Depth Analysis and Potential Exploitation of Energy-Saving and Consumption-Reduction of Aluminum Reduction Pot," TMS Light Metals, 2012, 601-606

Introduction

Example of retrofit study with irregular cathode surface: change of cell voltage drops

Conventional lining structure

Anode voltage drop:	346	(mv)
Clamp voltage drop:	15	(mv)
Guide rod voltage drop:	26	(mv)
Explosive welding voltage drop:	8	(mv)
Anode stub voltage drop:	42	(mv)
Voltage drop of iron/carbon joint:	105	(mv)
Carbon block voltage drop:	150	(mv)
Bath layer voltage drop:	1502	(mv)
Bubble layer voltage drop:	170	(mv)
Cathode voltage drop:	284	(mv)
Cathode steel bar voltage drop:	109	(mv)
Cathode joint voltage drop:	106	(mv)
Cathode carbon block voltage drop:	69	(mv)
Counteraction electric potential:	1672	(mv)
Voltage drop for busbar around pot:	200	(mv)
Pot working voltage:	4.174	(V)

New thermal insulation lining structure

Anode voltage drop:	347	(mv)
Clamp voltage drop:	15	(mv)
Guide rod voltage drop:	26	(mv)
Explosive welding voltage drop:	8	(mv)
Anode stub voltage drop:	42	(mv)
Voltage drop of iron/carbon joint:	104	(mv)
Carbon block voltage drop:	151	(mv)
Bath layer voltage drop:	1228	(mv)
Bubble layer voltage drop:	170	(mv)
Cathode voltage drop:	229	(mv)
Cathode steel bar voltage drop:	106	(mv)
Cathode joint voltage drop:	64	(mv)
Cathode carbon block voltage drop:	59	(mv)
Counteraction electric potential:	1672	(mv)
Voltage drop for busbar around pot:	200	(mv)
Pot working voltage:	3.846	(V)

Ref: J. Zhou et al., "Depth Analysis and Potential Exploitation of Energy-Saving and Consumption-Reduction of Aluminum Reduction Pot," TMS Light Metals, 2012, 601-606

Introduction

Example of retrofit study with irregular cathode surface: change operating conditions

Conventional lining structure

Current density:	350000	(A)
Metal level:	22.0	(cm)
Bath level:	18.0	(cm)
ACD (anode cathode distance):	5.4	(cm)
Covering material thickness:	18	(cm)
Al_2O_3:	2.5	(%)
AlF_3:	10	(%)
LiF:	1	(%)
MgF_2:	0.4	(%)
CaF_2:	5.6	(%)
Liquidus temperature:	945.32	(°C)
Superheat:	8.0	(°C)

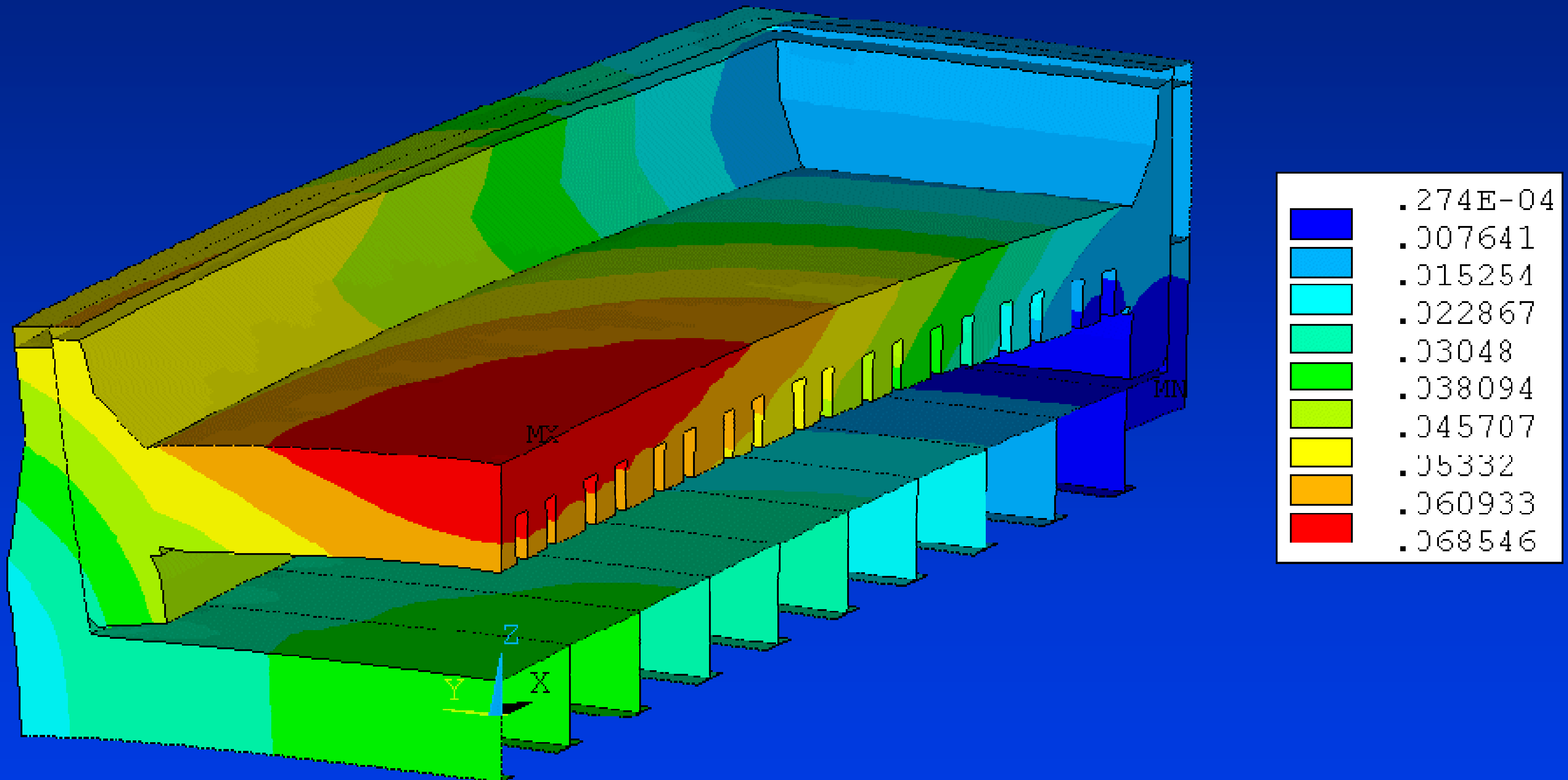
New thermal insulation lining structure

Current density:	350000	(A)
Metal level:	12.0	(cm)
Bath level:	18.0	(cm)
ACD (anode cathode distance):	4.5	(cm)
Covering material thickness:	18	(cm)
Al_2O_3:	2.5	(%)
AlF_3:	10	(%)
LiF:	1	(%)
MgF_2:	0.4	(%)
CaF_2:	5.6	(%)
Liquidus temperature:	945.32	(°C)
Superheat:	7.0	(°C)

Ref: J. Zhou et al., "Depth Analysis and Potential Exploitation of Energy-Saving and Consumption-Reduction of Aluminum Reduction Pot," TMS Light Metals, 2012, 601-606

Introduction

Results of the first MHD cell stability study



Ref: M. Dupuis, "Mathematical Modeling of Aluminum Reduction Cell Potshell Deformation," TMS Light Metals 2010, 417-422.

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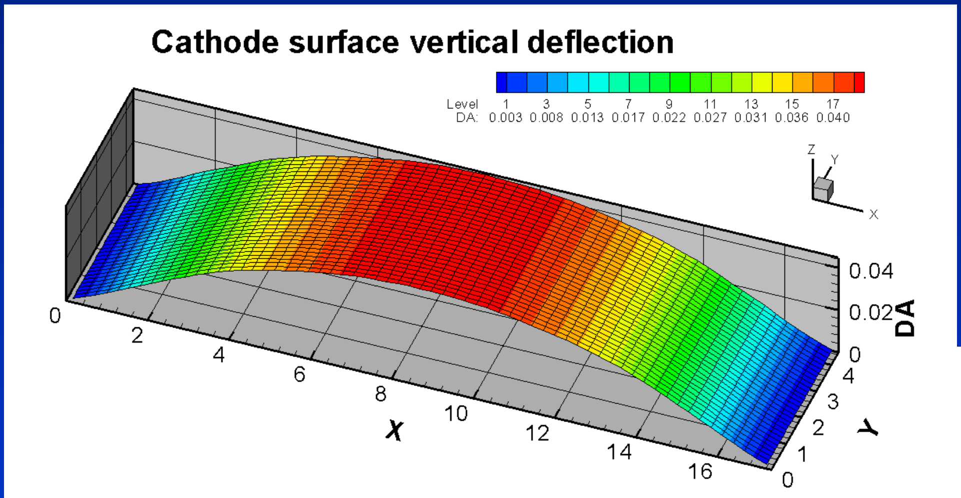
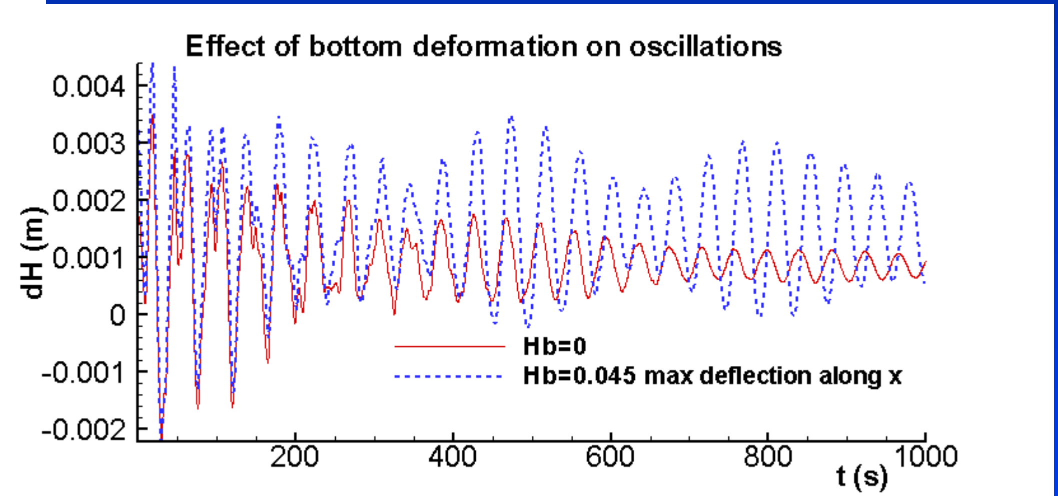
Results of the first MHD cell stability study



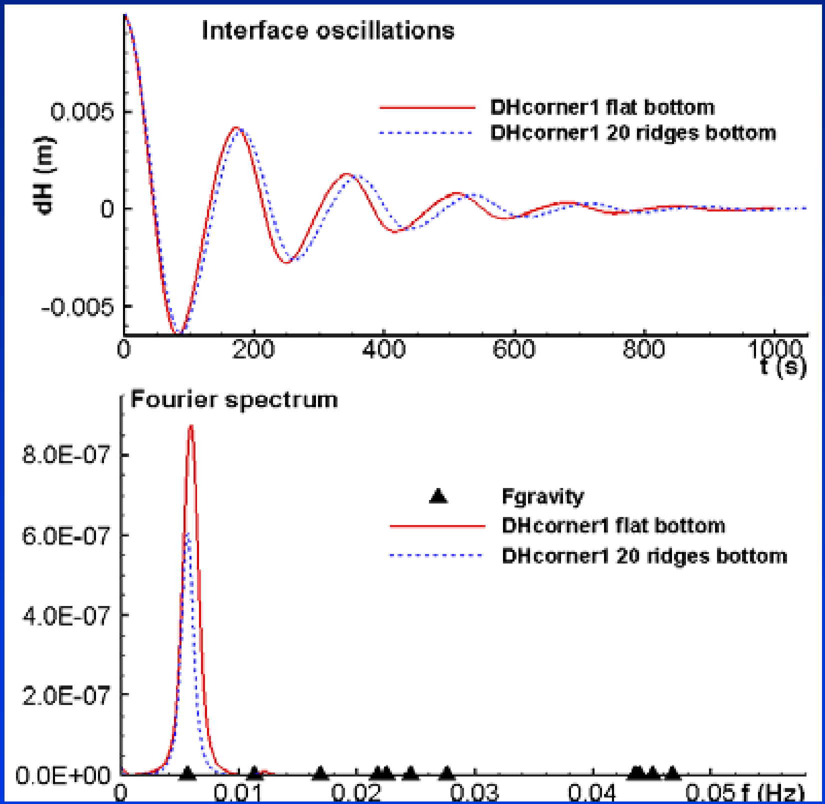


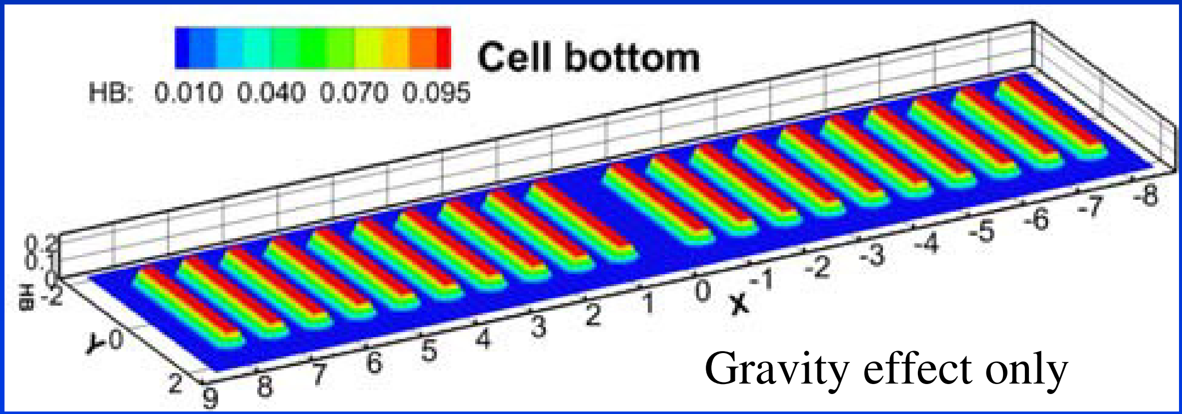
Ref: M. Dupuis, V. Bojarevics and D. Richard, "Impact of the Vertical Potshell Deformation on the MHD Cell Stability Behavior of a 500 kA Aluminum Electrolysis Cell," TMS Light Metals 2008, 409-412.

Introduction

Results of the first MHD cell stability study

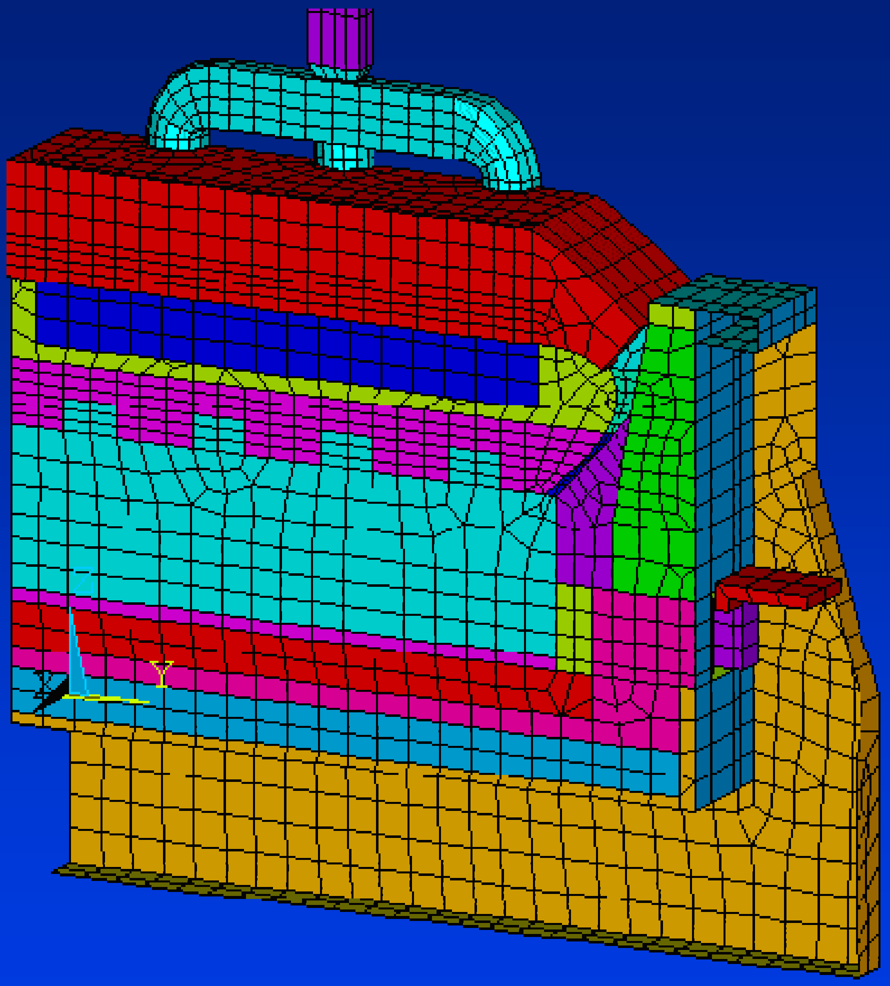
The effect of bottom friction enhancing elements is evaluated using the depth sensitive turbulent velocity model. The sloshing gravity wave without MHD interaction is confirmed to be damped moderately in the presence of the bottom ridge elements.





Ref: V. Bojarevics, "MHD of Aluminium Cells with the Effect of Channels and Cathode Perturbation Elements," TMS Light Metals 2013, 609-614.

Study of the Impact of Longitudinal Ridges



3D full cell side slice thermo-electric model geometry with four longitudinal ridges

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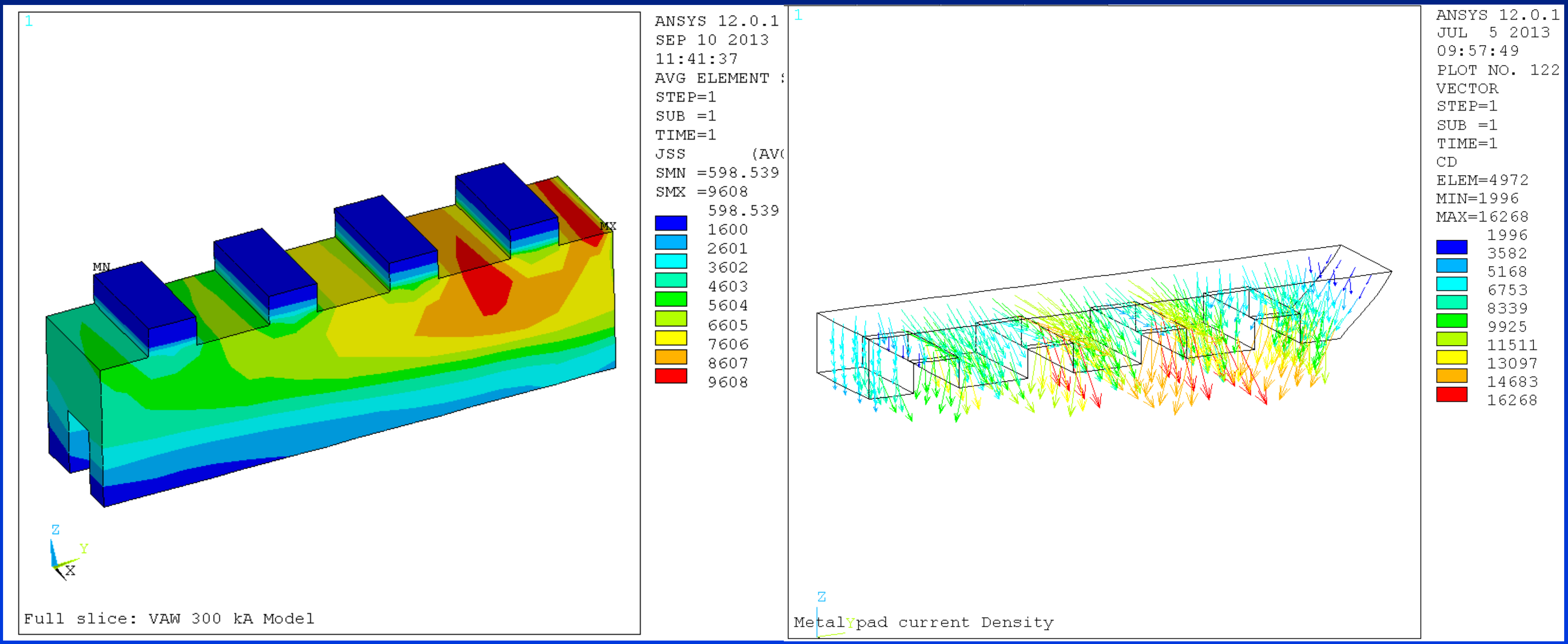
Study of the Impact of Longitudinal Ridges



Current density in the cathode block and the metal pad in A/m^2

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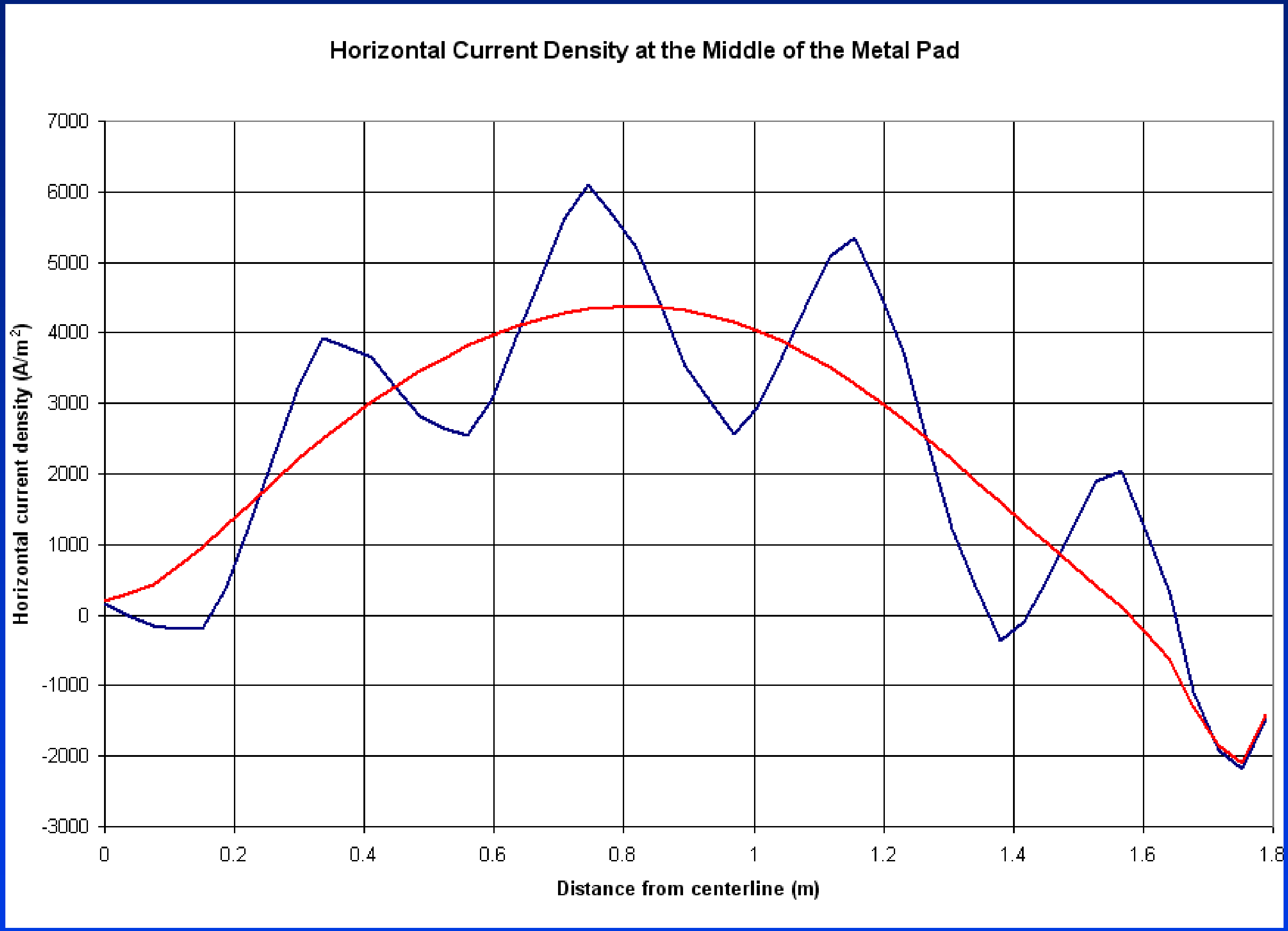
Study of the Impact of Longitudinal Ridges



Comparison of the current density in the metal pad with and without ridges in A/m^2

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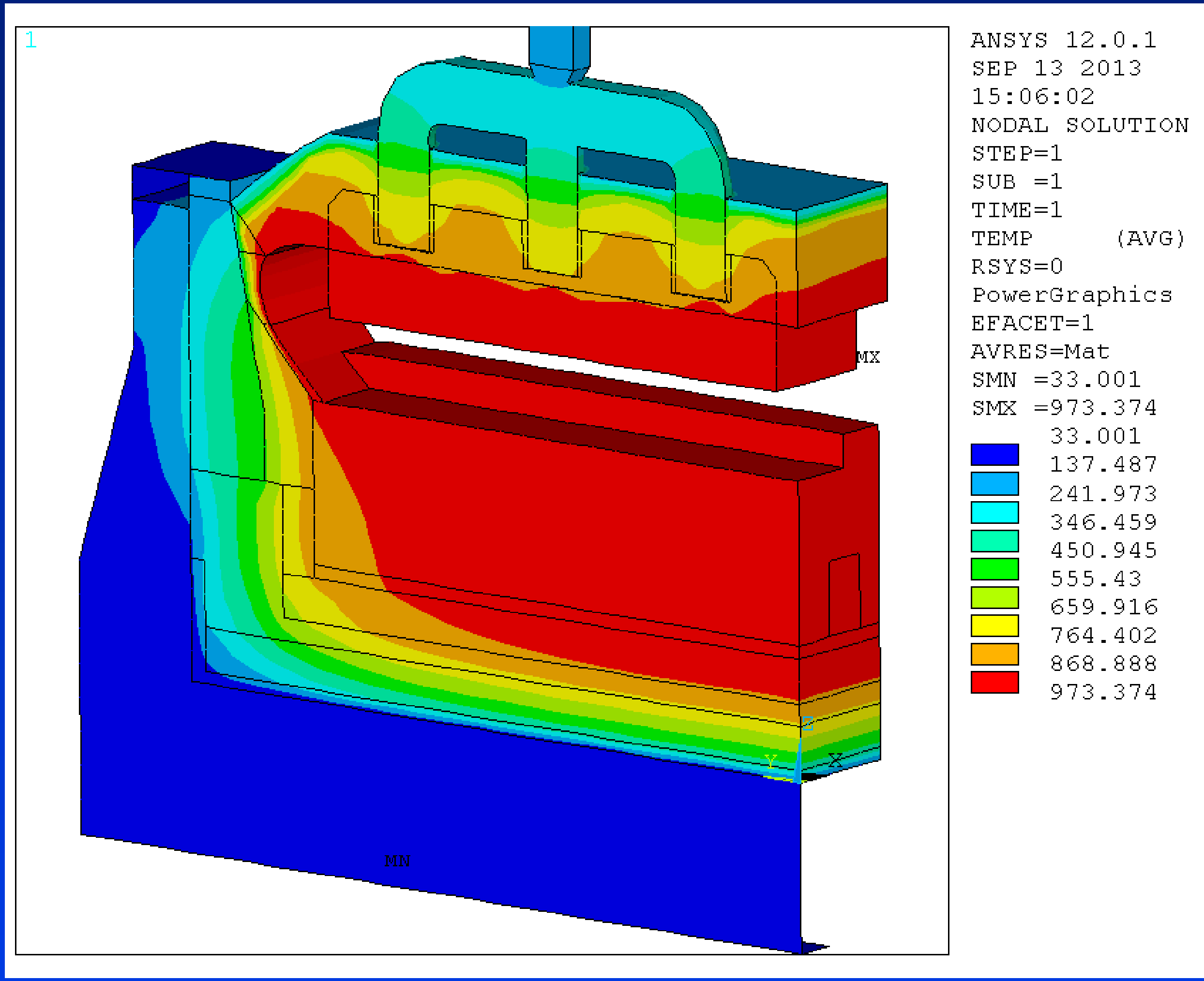
Study of the Impact of Transversal Ridges



3D full cell side slice thermo-electric model thermal solution with a transversal ridge

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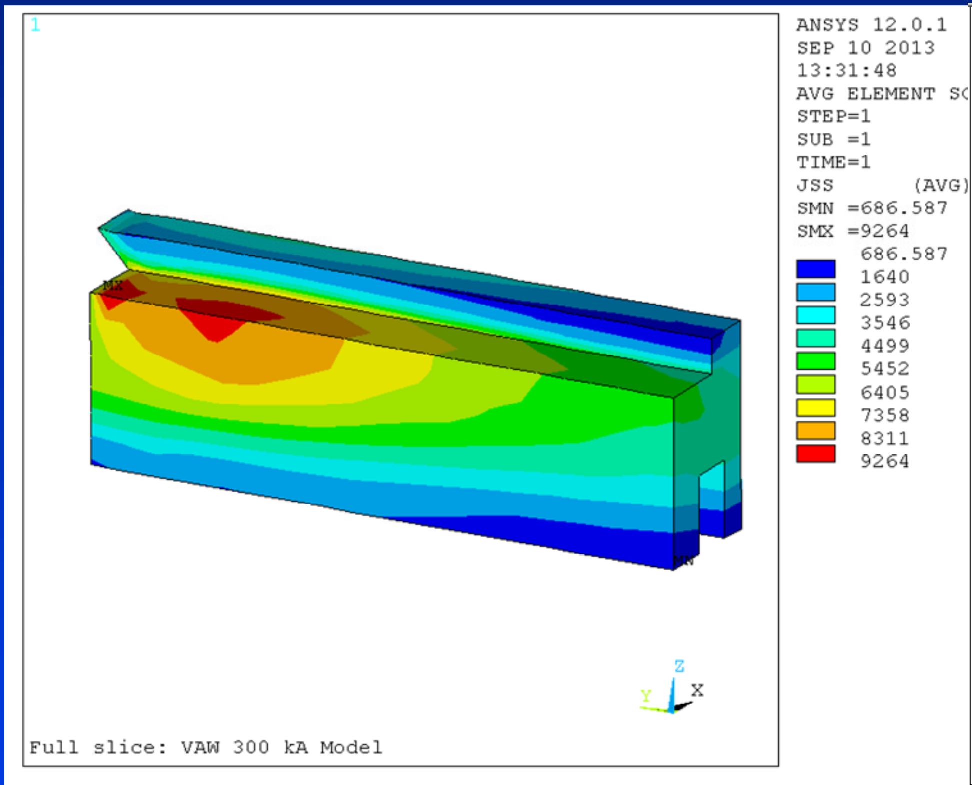
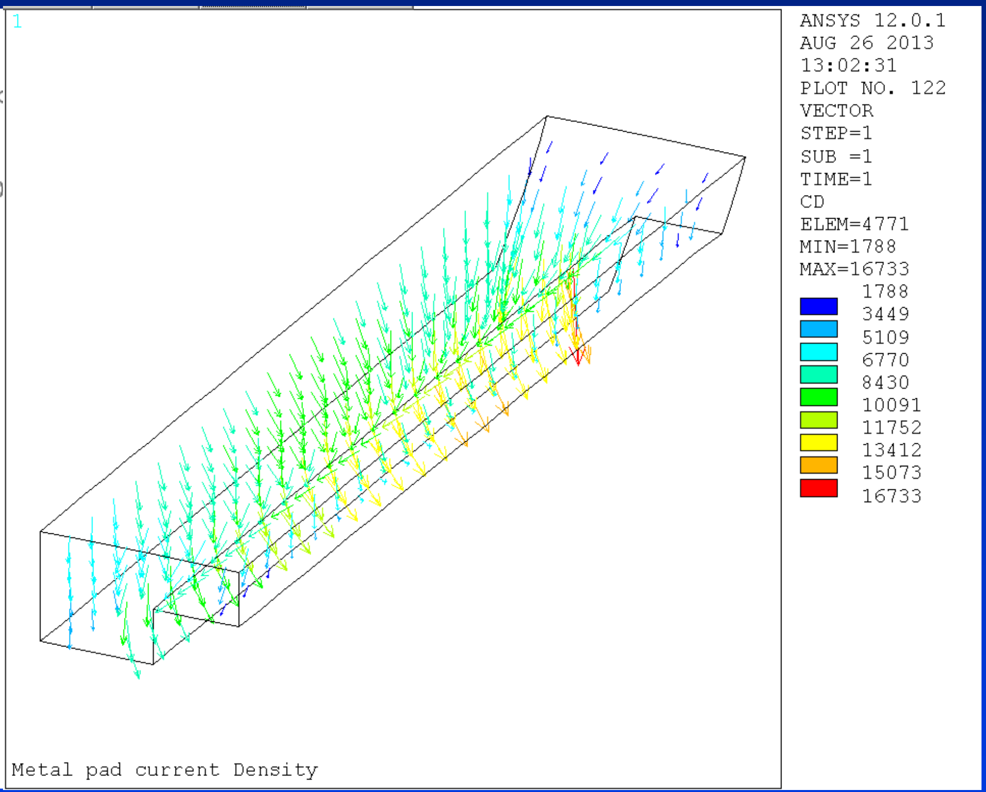
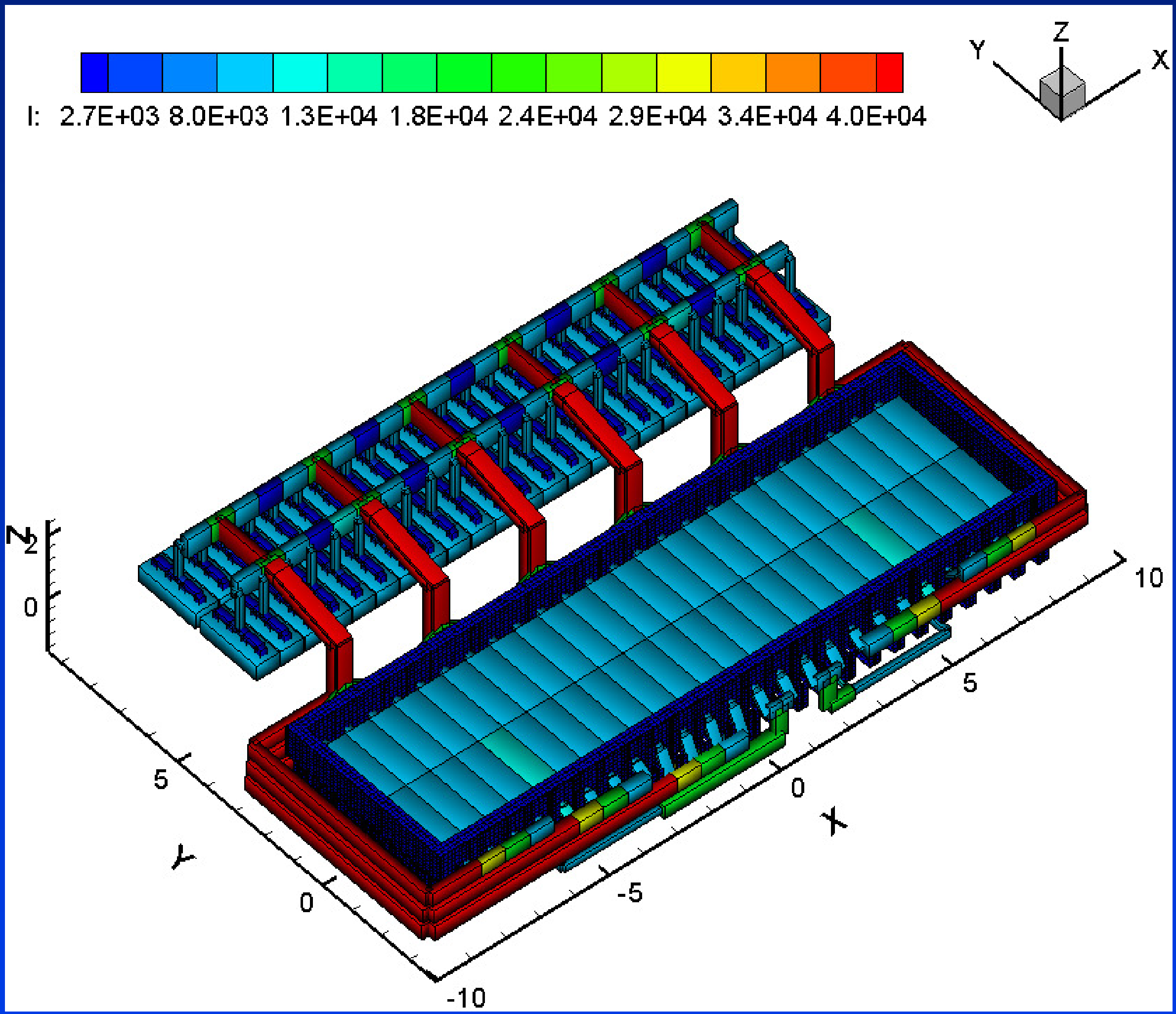
Study of the Impact of Transversal Ridges





Current density in the cathode block and the metal pad in A/m^2

Study of the Impact of Cathode Surface Geometry on the Cell Stability: 500 kA Flat Cathode Surface Base Case Model



Geometry of the 500 kA base case model showing the current intensity solution in each conductor in A

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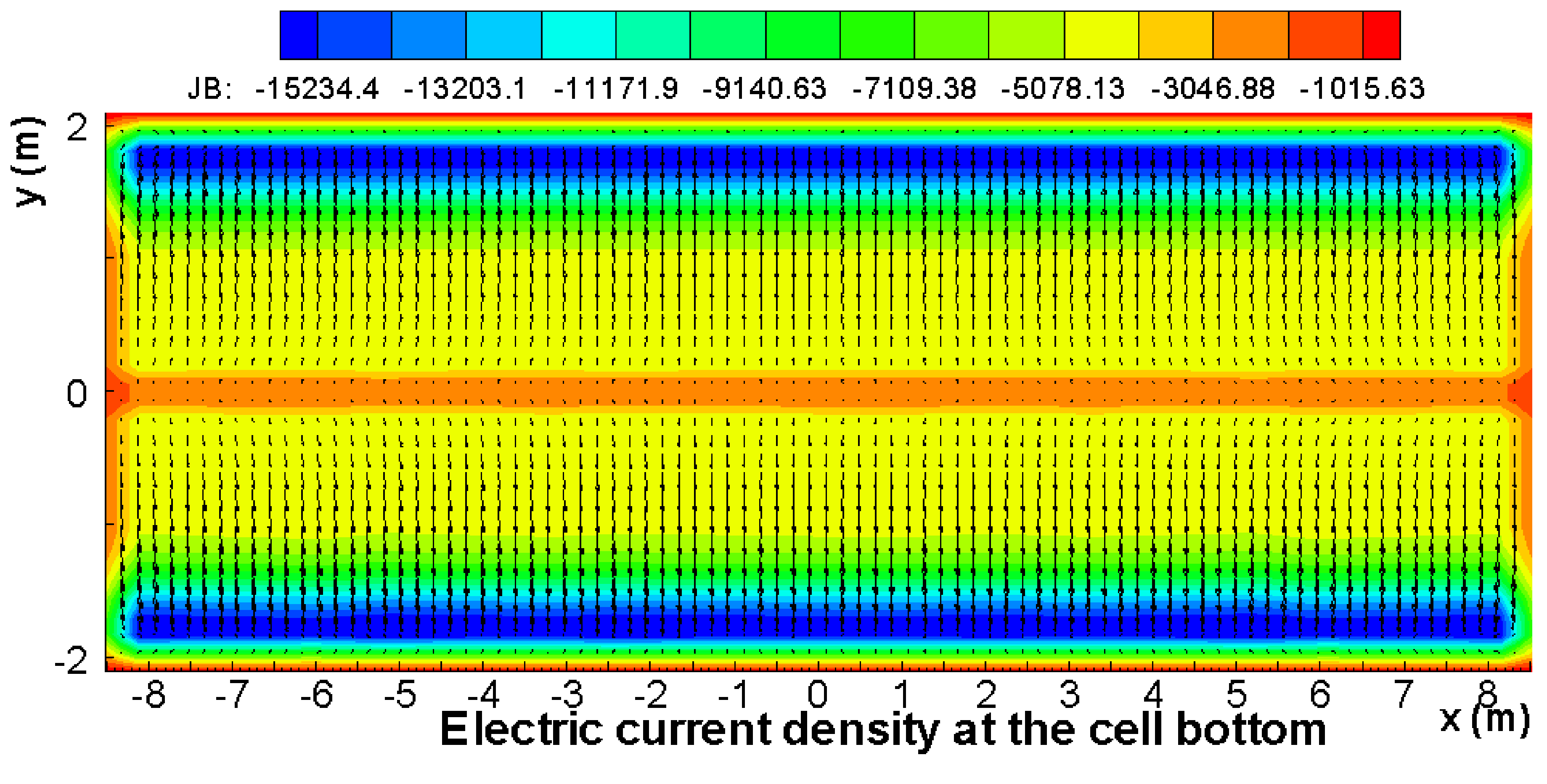

Current density solution on the top surface of the cathode in A/m^2

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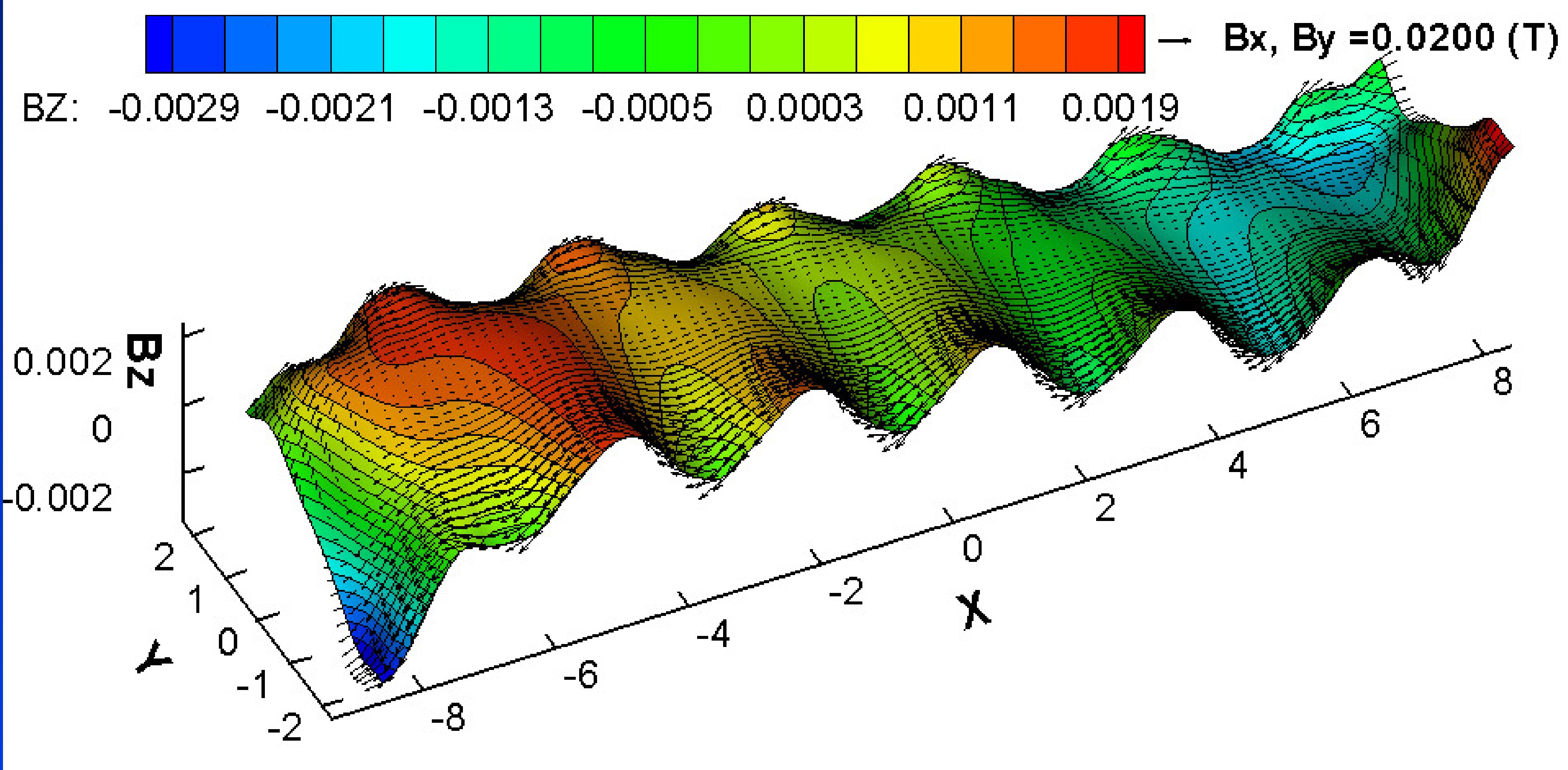

Vertical component of the magnetic field solution in the middle of the metal pad in T

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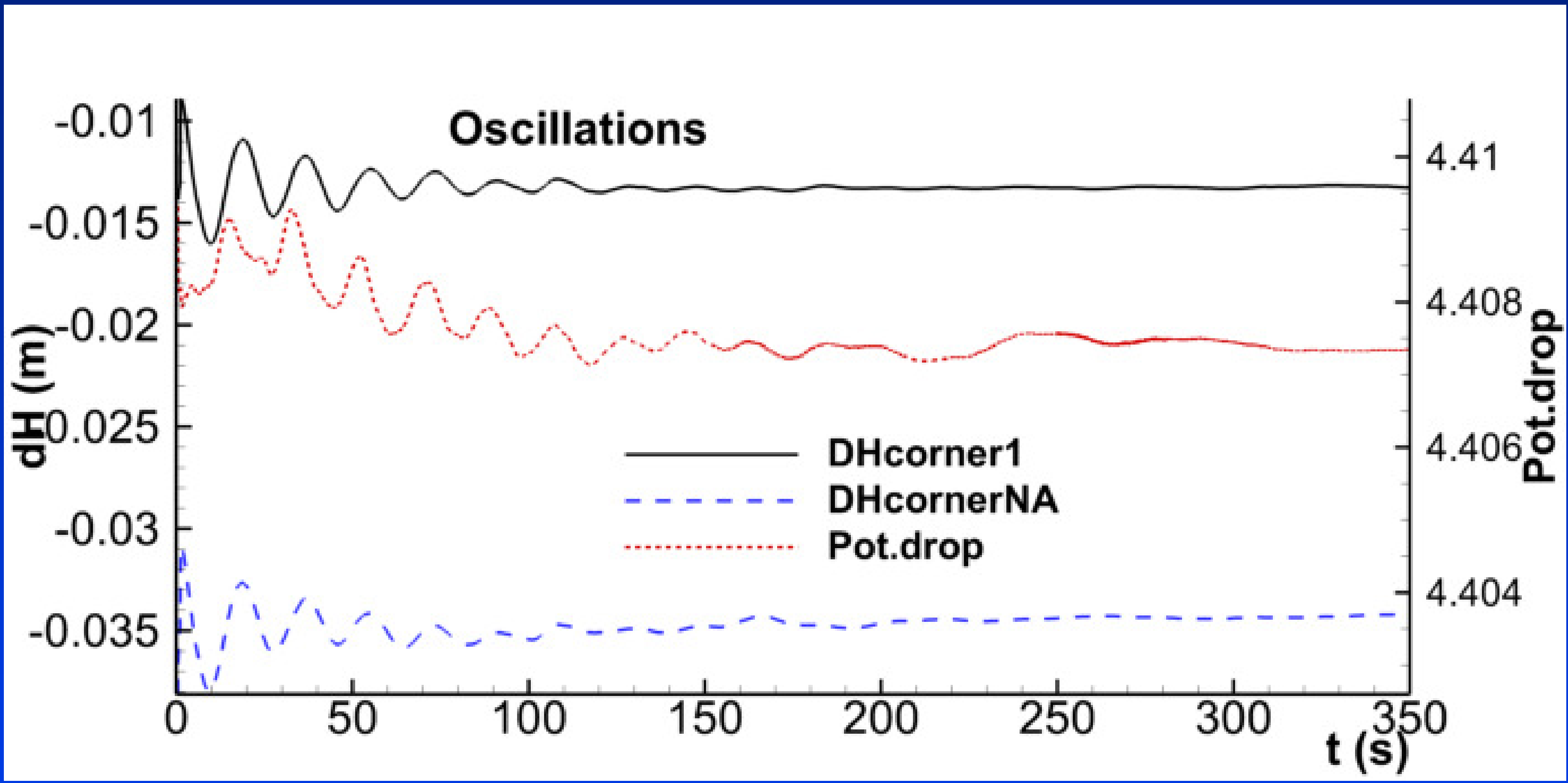
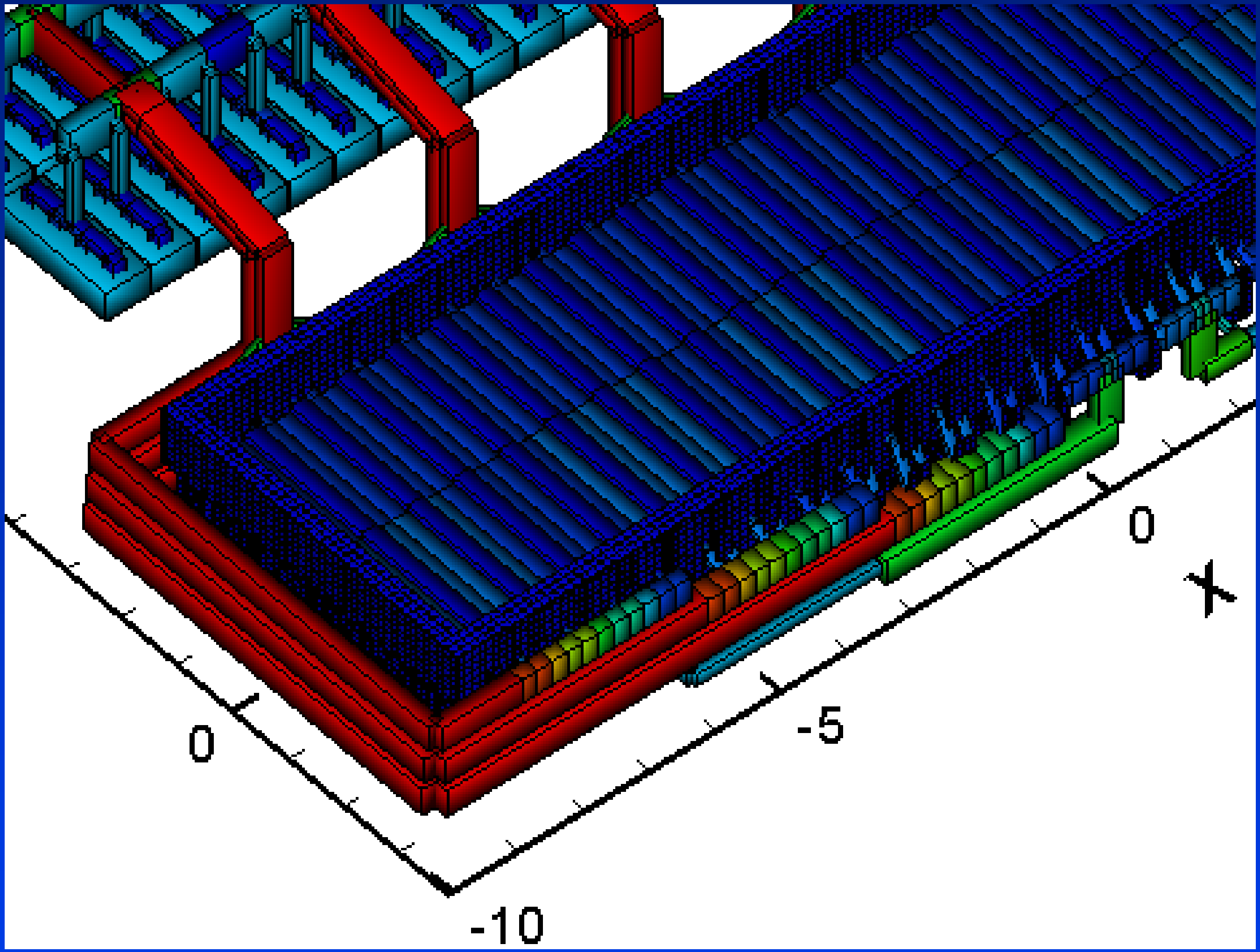


Evolution of the interface position (m)

Study of the Impact of Cathode Surface Geometry on the Cell Stability: 500 kA with Transversal Ridges Case Model



Geometry of the 500 kA with transversal ridges case model

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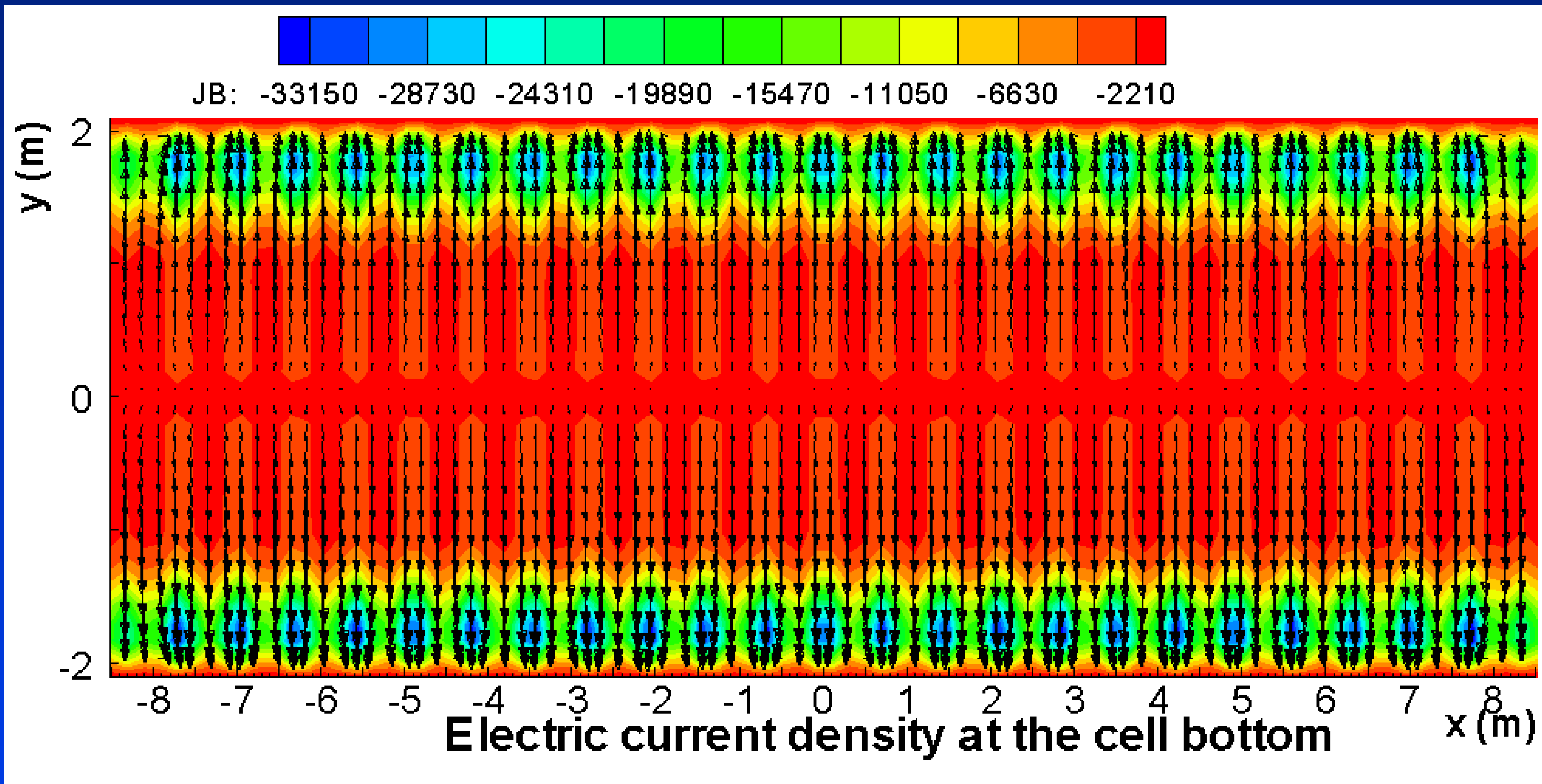

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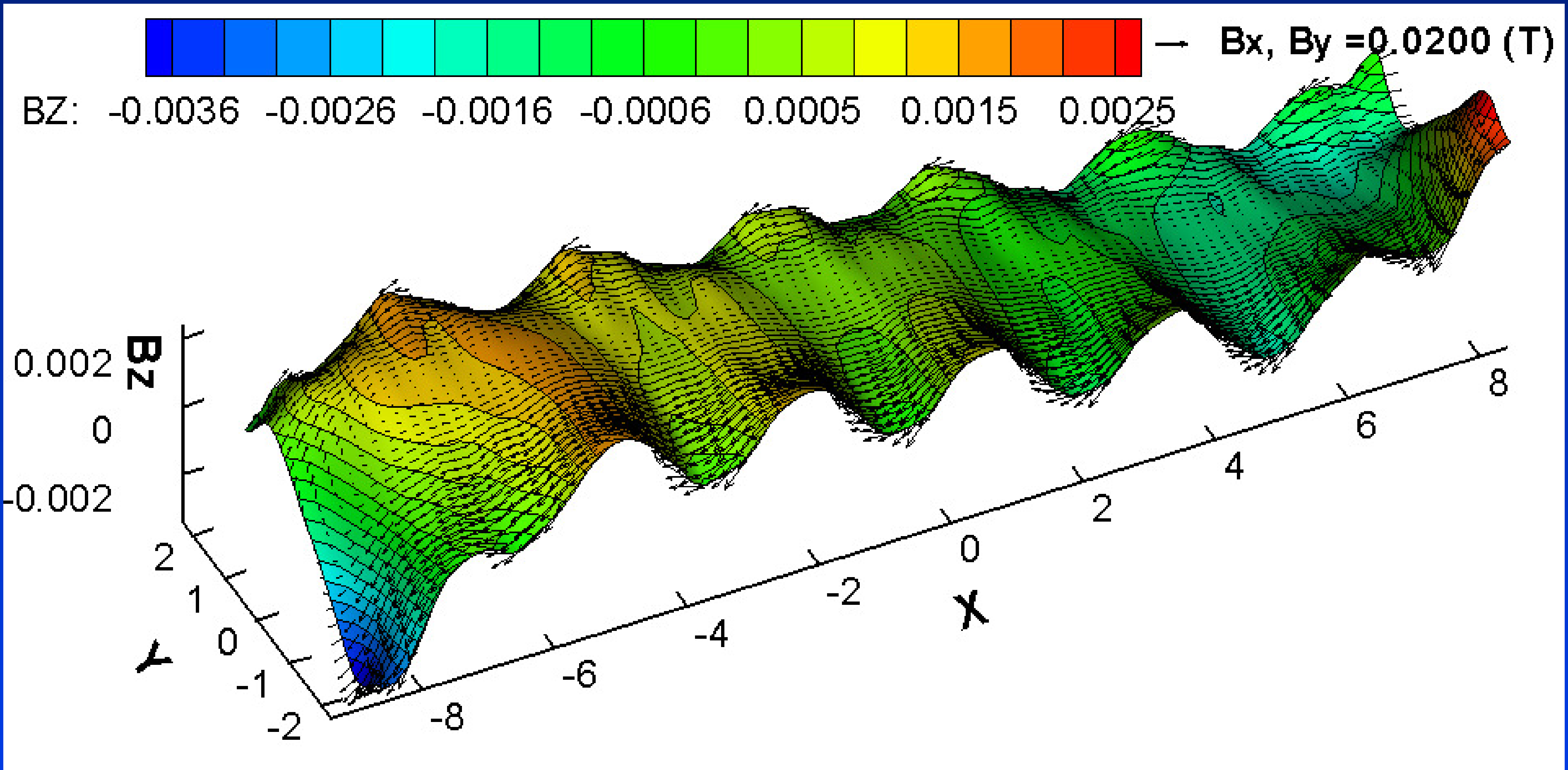

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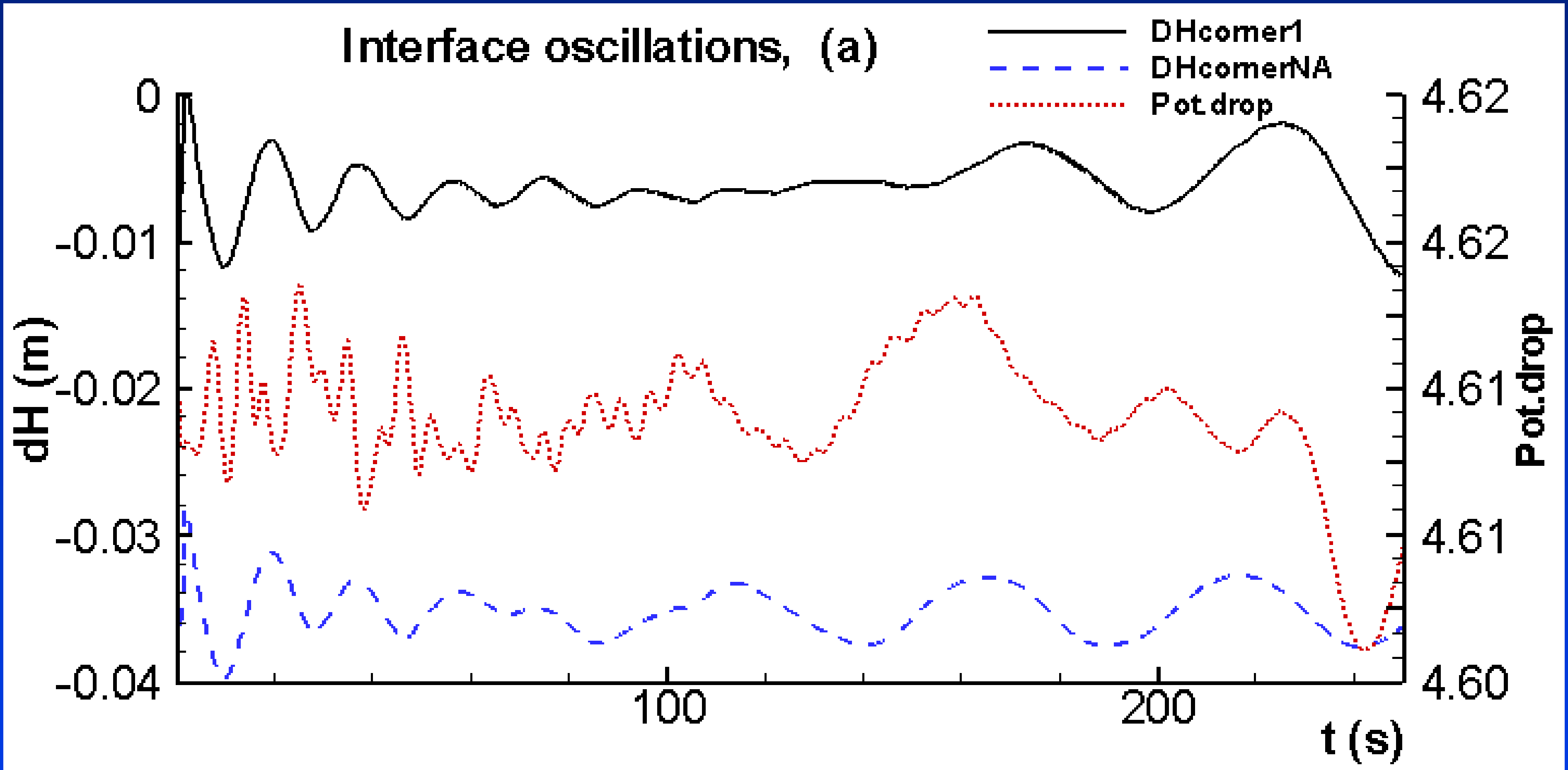

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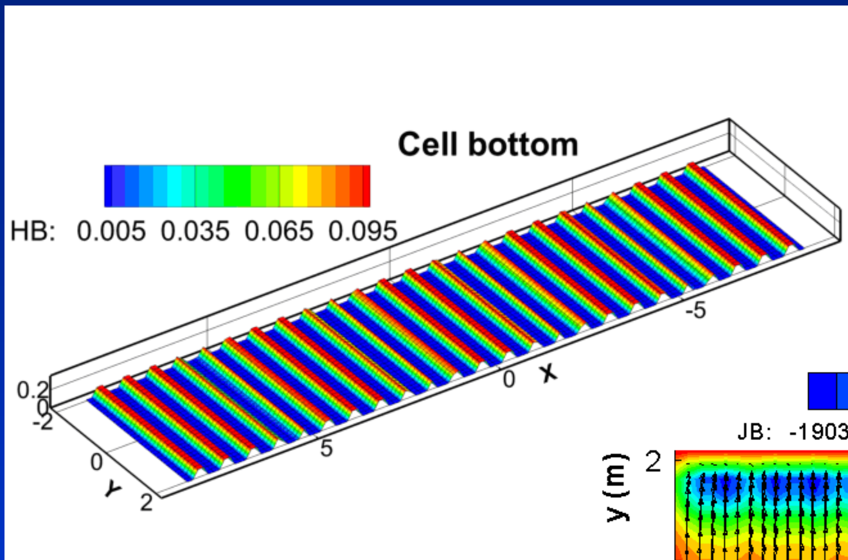
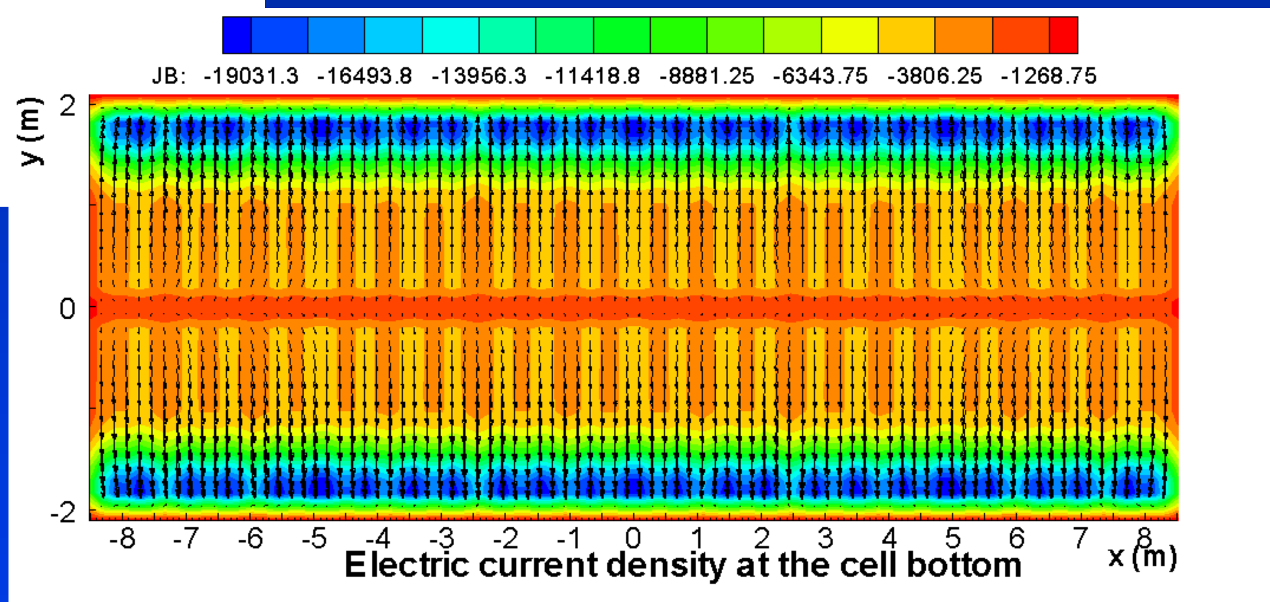


New Results Using the Updated MHD-Valdis Code Version (see ALUMINIUM article)



Current density solution on the top surface of the cathode in A/m^2

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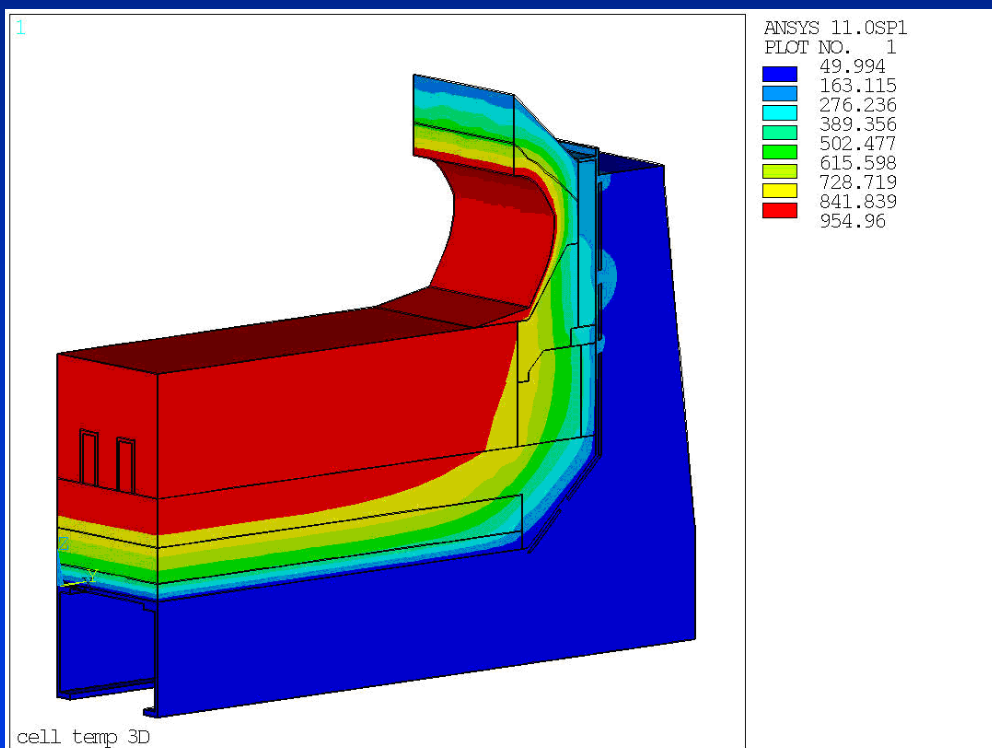
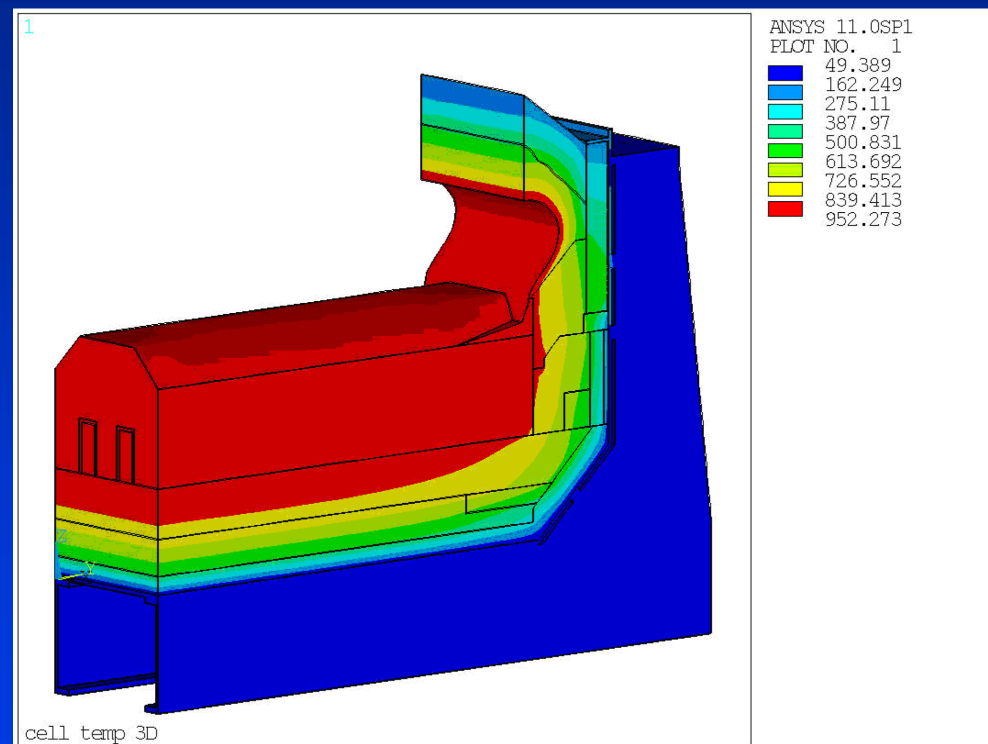
Study of the Impact of Cathode Surface Geometry on the Cell Stability: Base Case Model with Less Metal and More Ledge





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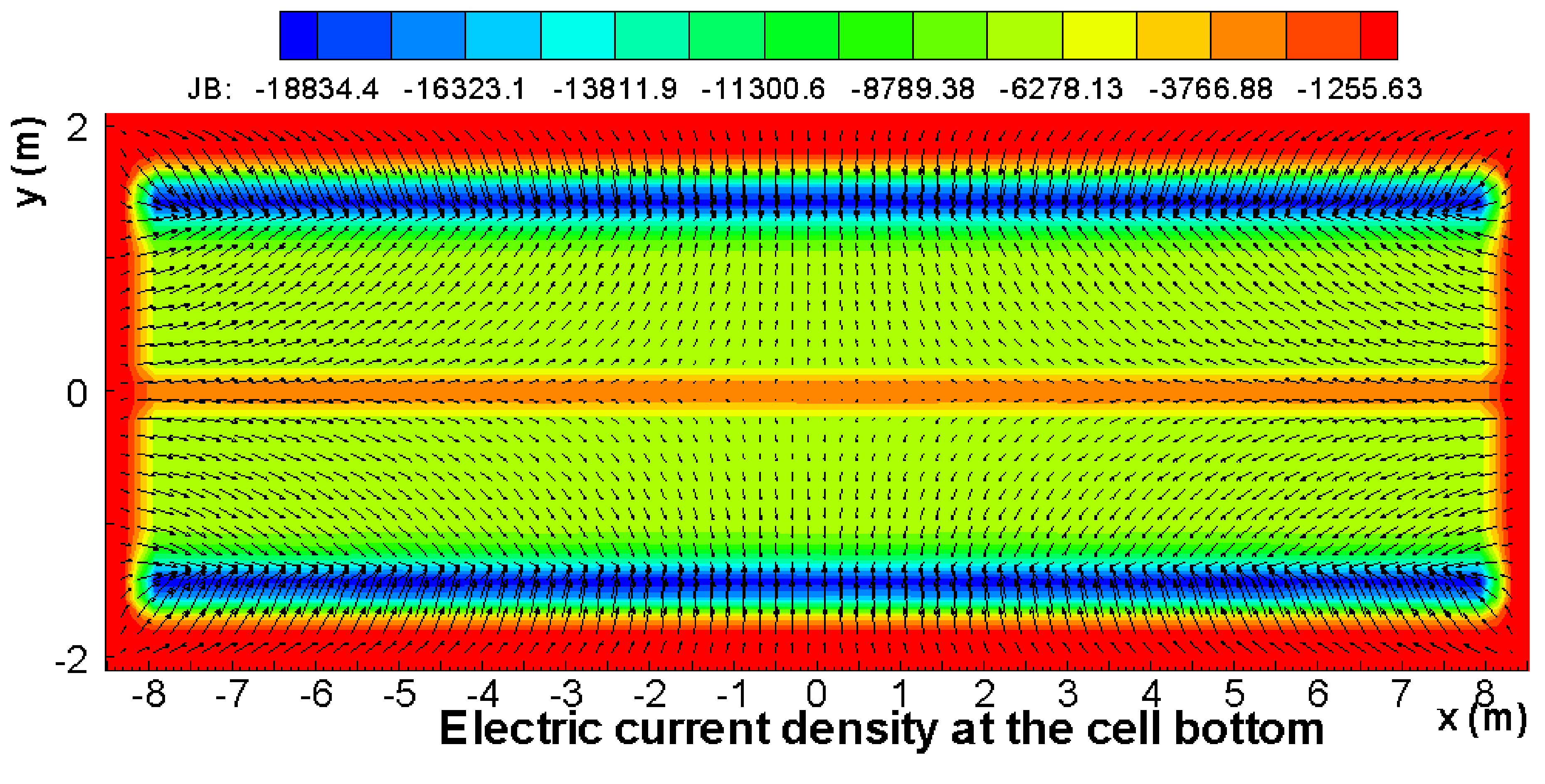

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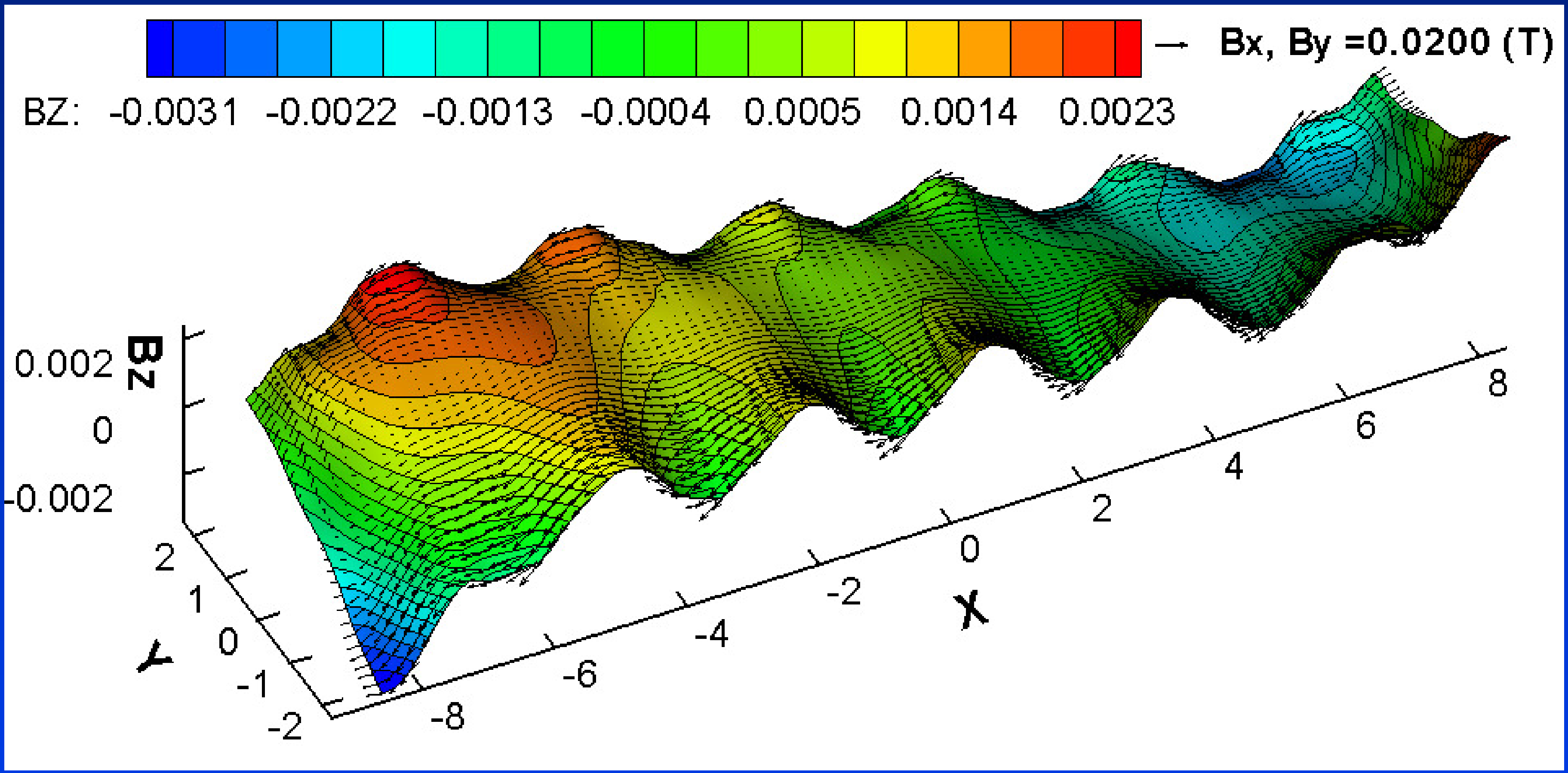

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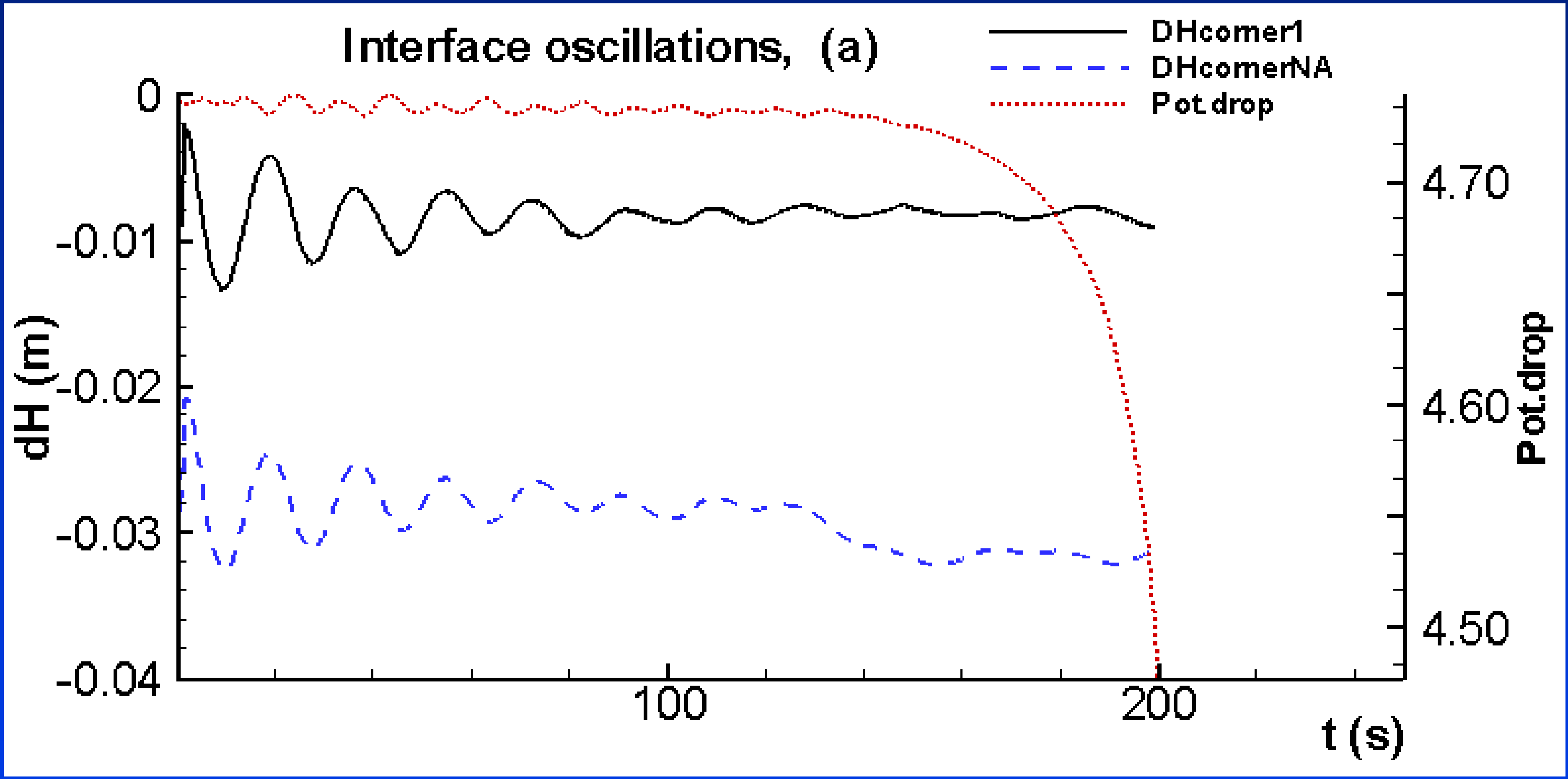

Evolution of the interface position (m)

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Conclusions

- In the first part of the paper, it was demonstrated that ridges on cathode surface affect the top cathode surface current density. This influences the metal pad current density in two ways, the first one by locally changing the depth of metal and the second way by affecting the top cathode surface current density.
- The cell stability analysis that was performed for a cell with transversal ridges on its cathode surface taking into account the two ways those ridges affect the metal pad current density. The conclusion of the study is that those ridges decrease the cell stability if the metal height is kept the same (less metal).
- Since the new results confirm the results of the previous study, the discrepancy between the cell stability analysis and the observations still needed to be explained.
- The last case studied addresses this by suggesting that it is the improvement of the ledge toe position that improved the observed cell stability not the impact of the ridges on the metal pad current density or the metal pad flow pattern.