

Retrofit of a 500 kA Cell Design into a 600 kA Cell Design

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GENISIM

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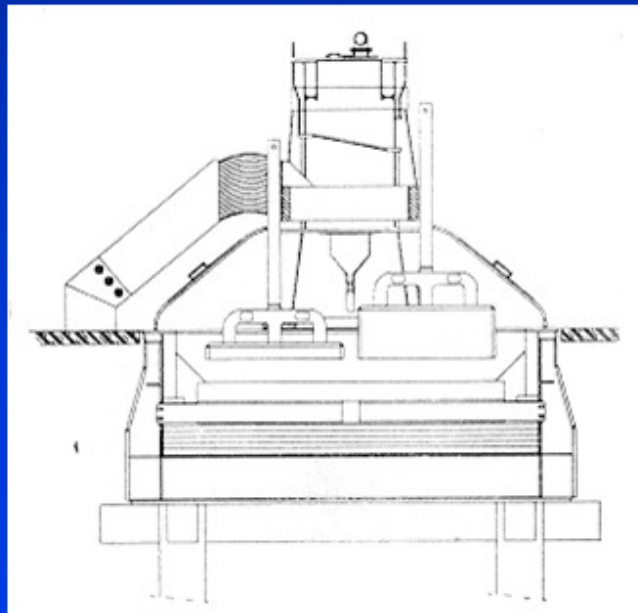
Plan of the Presentation

- **Introduction**
- **Review of the 500 kA Cell Busbar Designs**
- **New Anode Stub Hole TEM Model and Anode Design**
- **New Cathode Collector Bar Slot TEM Model and Cathode Design**
- **Full Cell Quarter Model Including the Liquid Zone**
- **Calculation of the Retrofitted Cell Amperage Using Dyna/Marc**
- **Verification of the Thermal Balance at 600 kA Using the ANSYS® based TE Models**
- **Verification of the MHD Stability at 600 kA Using MHD-Valdis**
- **Conclusions**

Introduction

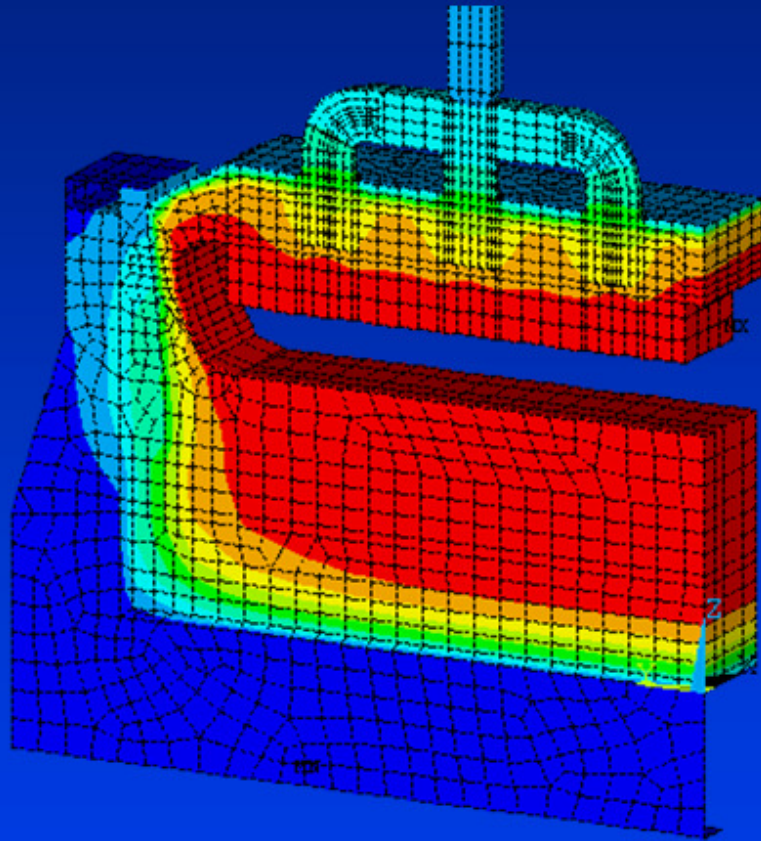
- In 2000, the first author has presented the retrofit of a 300 kA cell design into a 350 kA cell design and then by extending the length of the potshell, a new 400 ka cell thermo-electric design.
- Then in 2003, by further extending the length and this time by also slightly increasing the potshell width, the first author has presented a new 500 kA cell thermo-electric design.
- Later in 2005, still extending the length of the 500 kA cell potshell, the same author presented a new 740 kA cell thermo-electric design and claimed that there is no foreseeable limit to a cell size as far as the thermo-electric cell heat balance aspect of the cell design is concerned.
- Finally in 2005-2006, the authors have presented both the MHD and the potshell mechanical designs of the 500 and 740 kA cells claiming that there seems to be no foreseeable limit to the cell size as far as the MHD and potshell mechanical design aspects of the cell design are concerned.

Base Case 300 kA Cell Design



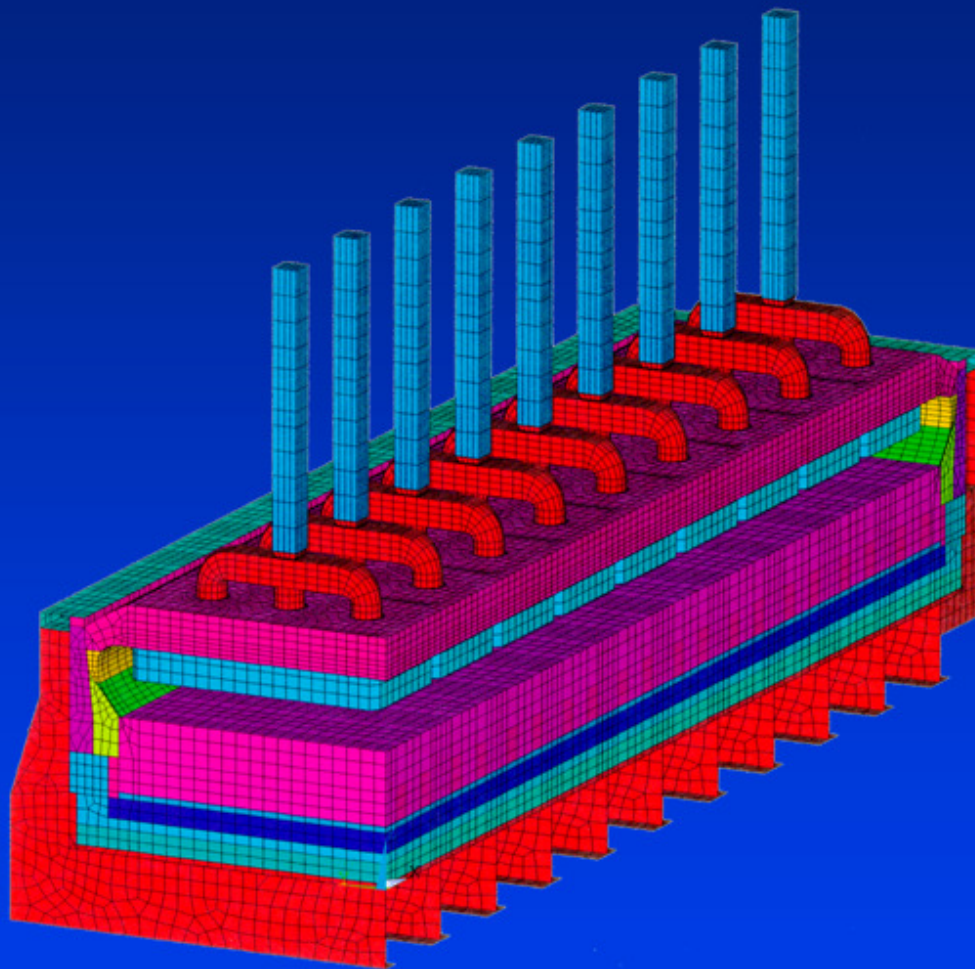
Amperage	300 kA
Nb. of anodes	32
Anode size	1.6 m X 0.8 m
Nb. of anode studs	3 per anode
Anode stud diameter	18 cm
Anode cover thickness	16 cm
Nb. of cathode blocks	18
Cathode block length	3.47 m
Type of cathode block	30 % graphitic
Type of side block	30 % graphitic
Side block thickness	15 cm +
ASD and AED	35 cm
Inside potshell size	14.4 m X 4.35 m
ACD	5 cm
Excess AlF_3	10.9 %
Operating temperature	973.3 °C
Liquidus superheat	6.8 °C
Current efficiency	94.0 %
Internal heat	628 kW
Energy consumption	13.75 kWh/kg

Retrofitted 350 kA Cell Design



Amperage	350 kA
Nb. of anodes	32
Anode size	1.7 m X 0.8 m
Nb. of anode studs	3 per anode
Anode stud diameter	19 cm
Anode cover thickness	10 cm
Nb. of cathode blocks	18
Cathode block length	3.67 m
Type of cathode block	100 % graphitized
Type of side block	Silicon carbide
Side block thickness	10 cm +
ASD	30 cm
Inside potshell size	14.4 m X 4.35 m
ACD	4 cm
Excess AlF_3	13.5 %
Operating temperature	960.4 °C
Liquidus superheat	6.7 °C
Current efficiency	96.1 %
Internal heat	713 kW
Energy consumption	13.4 kWh/kg

Greenfield 400 kA Cell Design



Amperage	400 kA
Nb. of anodes	36
Anode size	1.6 m X 0.8 m
Nb. of anode studs	3 per anode
Anode stud diameter	19 cm
Anode cover thickness	10 cm
Nb. of cathode blocks	20
Cathode block length	3.67 m
Type of cathode block	100 % graphitized
Type of side block	Silicon carbide
Side block thickness	10 cm +
ASD and AED	30 cm
Inside potshell size	16.1 m X 4.35 m
ACD	4 cm
Excess AlF_3	13.5 %
Operating temperature	962.4 °C
Liquidus superheat	8.7 °C
Current efficiency	96.0 %
Internal heat	834 kW
Energy consumption	13.6 kWh/kg

Greenfield 500 kA Cell Design

DYNA/MARC 1.7 - [VAWm16]

File Process Controller Operator Run List Windows Language Help

Demo example of a prebaked PBF cell inspired from VAW's JOM paper
 liquidus superheat, 4 cm ACD, 1.95m anode length, 13.5% AlF₃, 500 kA
 HC10 4.17m cathode block, top 10cm bottom 16.5 cm SiC side block
 10 cm cover over anodes, 17.5 cm stud diameter, 4 studs per anode
 40 anodes, 24 cathode blocks, 17.8 m X 4.85 m inside potshell

Date Created : 8/2/1999 Last Modified : 9/15/2002

Steady State Solution

Cell amperage	500.0 [kA]
Anode to cathode distance	4.00000 [cm]
Operating temperature	963.366 [C]
Ledge thickness, bath level	4.44079 [cm]
Ledge thickness, metal level	0.16550 [cm]
Anode beam position	0.0000 [cm]
Mass of metal	33763.7 [kg]
Mass of bath	11020.16 [kg]
Mass of dissolved alumina	275.504 [kg]
Mass of dispersed alumina	79.390 [kg]
Mass of alumina sludge	2.5966 [kg]
Mass of dissolved aluminum fluoride	1487.722 [kg]
Mass of dispersed aluminum fluoride	1.015 [kg]
Mass of aluminum fluoride sludge	0.0003 [kg]
Mass of calcium fluoride	330.605 [kg]
Mass of lithium fluoride	0.000 [kg]
Mass of magnesium fluoride	0.000 [kg]
Alumina feeding rate	310.010 [kg/hr]
Aluminum fluoride feeding rate	3.07019 [kg/hr]
Target cell resistance	5.31686 [micro-ohm]

Steady State derived Variables

Rate of change of:	
ACD	-0.02224 [cm/hr]
Operating temperature	0.0000 [C/hr]
Ledge thickness, bath level	0.000 [cm/hr]
Ledge thickness, metal level	0.000 [cm/hr]
Mass of dispersed Al ₂ O ₃	0.000 [kg/hr]

DYNA/MARC: What If

List of Design Variables

	Design Value	Set as Target
Anode to Cathode Distance	4 cm	<input type="radio"/>
Cell Amperage	500 kA	<input type="radio"/>
Conc. of Excess Aluminum Fluoride	13.5 %	<input type="radio"/>
Concentration of Dissolved Alumina	2.5 %	<input type="radio"/>
Concentration of Calcium Fluoride	3 %	<input type="radio"/>
Concentration of Lithium Fluoride	0 %	<input type="radio"/>
Conc. of Magnesium Fluoride	0 %	<input type="radio"/>
Bath Level	20 cm	<input type="radio"/>
Bath Ledge Heat Transfer Coef.	1425 W/m ² °C	<input type="radio"/>
Metal Ledge Heat Transfer Coef.	2052 W/m ² °C	<input type="radio"/>
Metal Level	20 cm	<input type="radio"/>
Anode Length	1.95 m	<input type="radio"/>
Cavity Length	17.48 m	<input type="radio"/>
Anode Panel Heat Loss	393.971849 kW	<input type="radio"/> Advanced
Cathode Bottom Heat Loss	237.657447 kW	<input type="radio"/> Advanced
Cell Operating Temperature	963.365699 °C	<input checked="" type="radio"/>
Anode Voltage Drop	319.513746 mV	<input type="radio"/> Advanced
Cathode Voltage Drop	311.865904 mV	<input type="radio"/> Advanced
Anode Width	0.8 m	<input type="radio"/>
Cavity Width	4.55 m	<input type="radio"/>

Run Exit

Press F1 for Help Demo example of a prebaked PBF cell inspired from VAW's JOM paper 10/3/2002 2:08 PM CAPS NUM INSERT

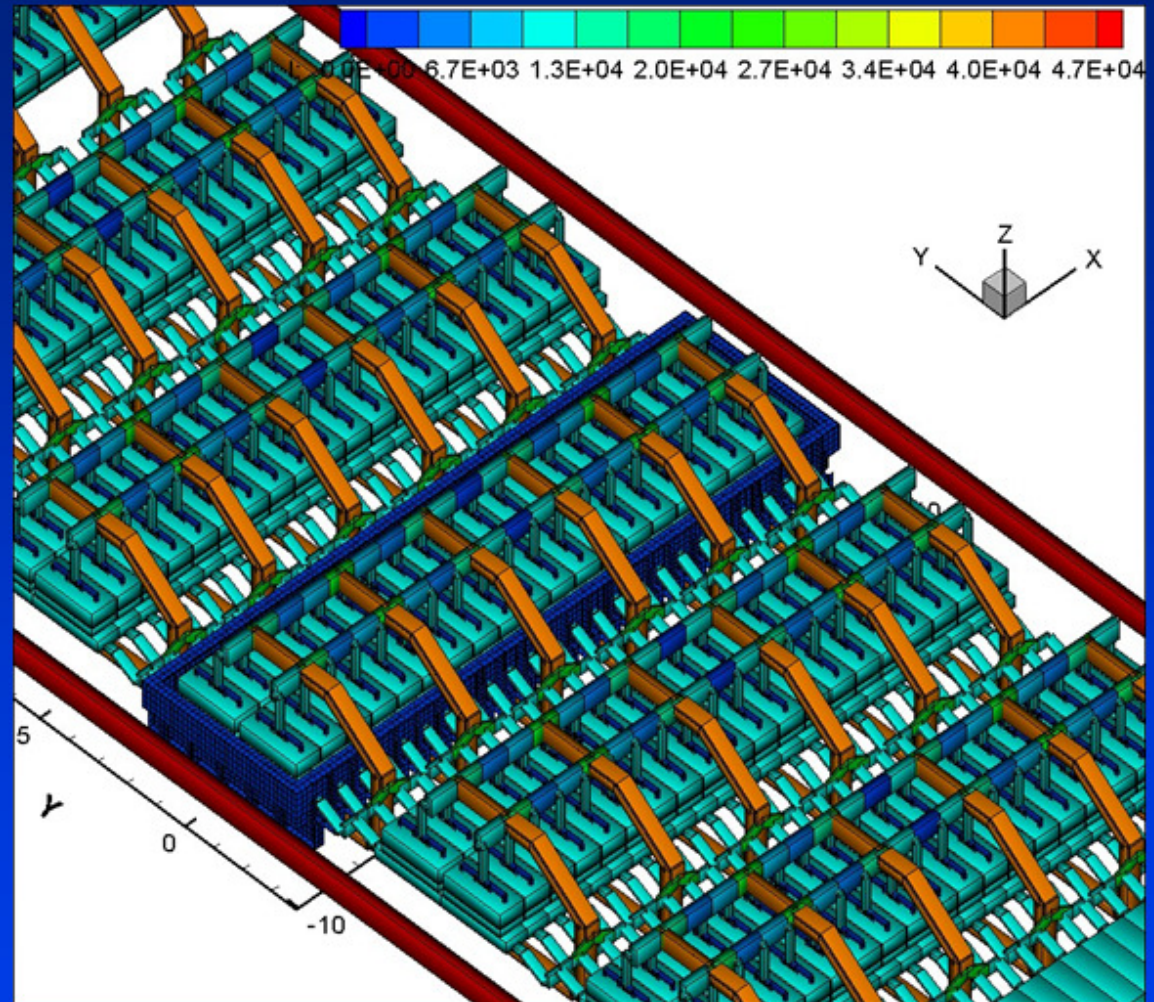
Amperage 500 kA
 Nb. of anodes 40
 Anode size 1.95 m X 0.8 m
 Nb. of anode studs 4 per anode
 Anode stud diameter 17.5 cm
 Anode cover thickness 10 cm
 Nb. of cathode blocks 24
 Cathode block length 4.17 m
 Type of cathode block HC10
 Type of side block SiC
 Side block thickness 10 cm +
 ASD 30 cm
 Inside potshell size 17.8 X 4.85 m
 ACD 4 cm
 Excess AlF₃ 13.5 %

Anode drop 320 mV
 Cathode drop 312 mV
 Anode panel heat loss 394 kW
 Cathode bottom heat loss 238 kW
 Operating temperature 963.4 °C
 Liquidus superheat 9.7 °C
 Bath ledge thickness 4.44 cm
 Metal ledge thickness 0.17 cm
 Current efficiency 95.9 %
 Internal heat 1019 kW
 Energy consumption 13.39 kWh/kg

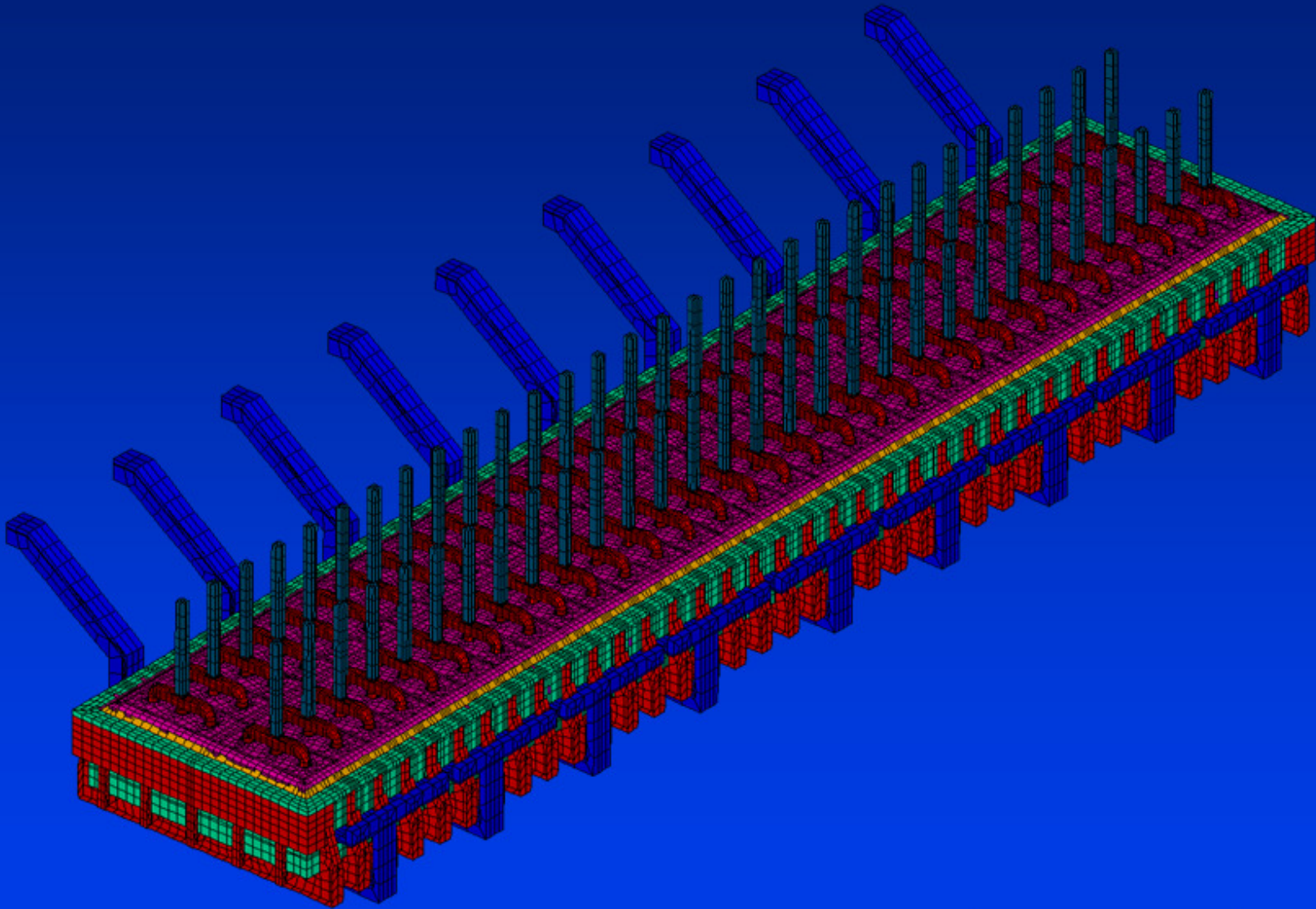
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Busbar Design of the 500 kA Cell

Busbar design
inspired from the
Pechiney 1987
busbar patent

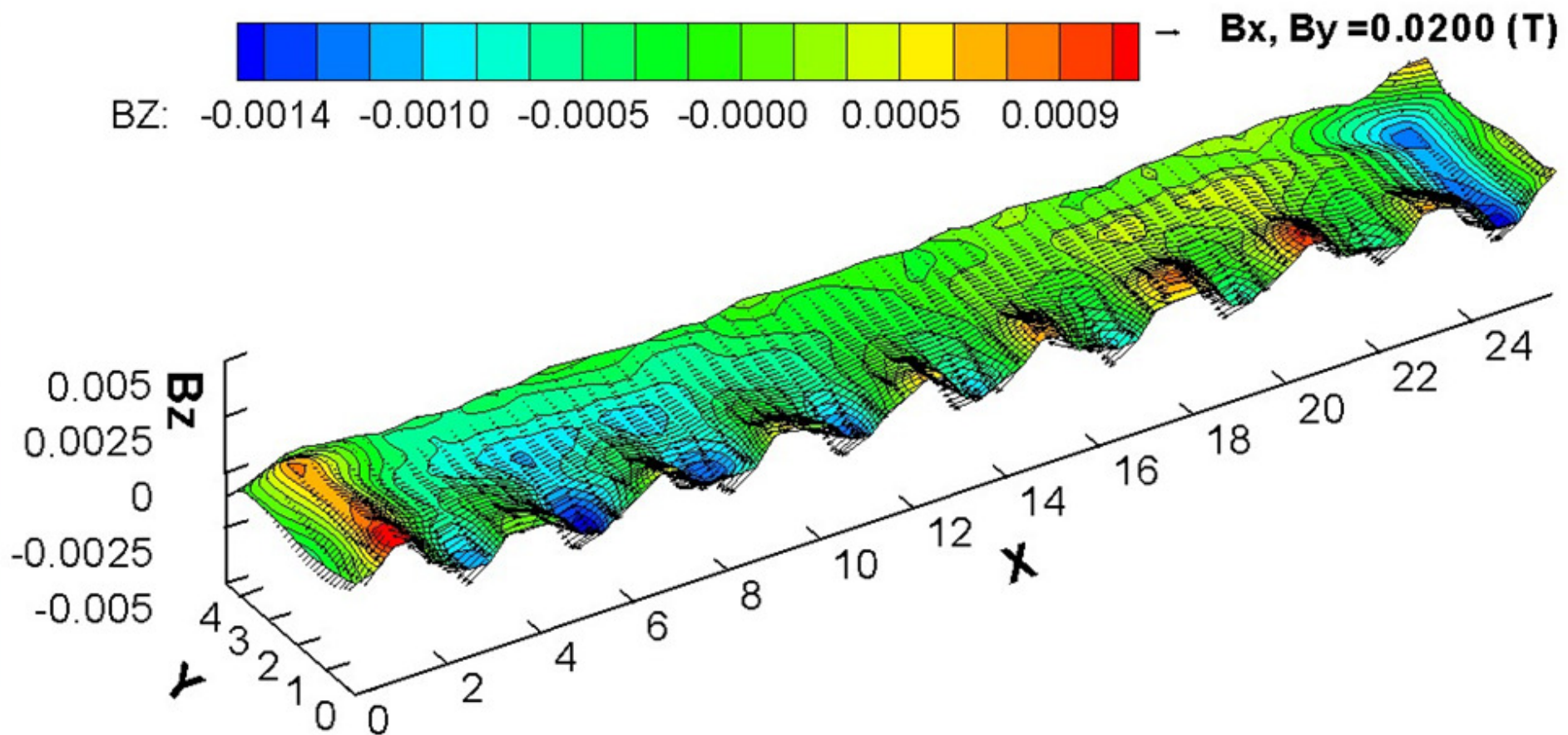


Greenfield 740 kA Cell Design



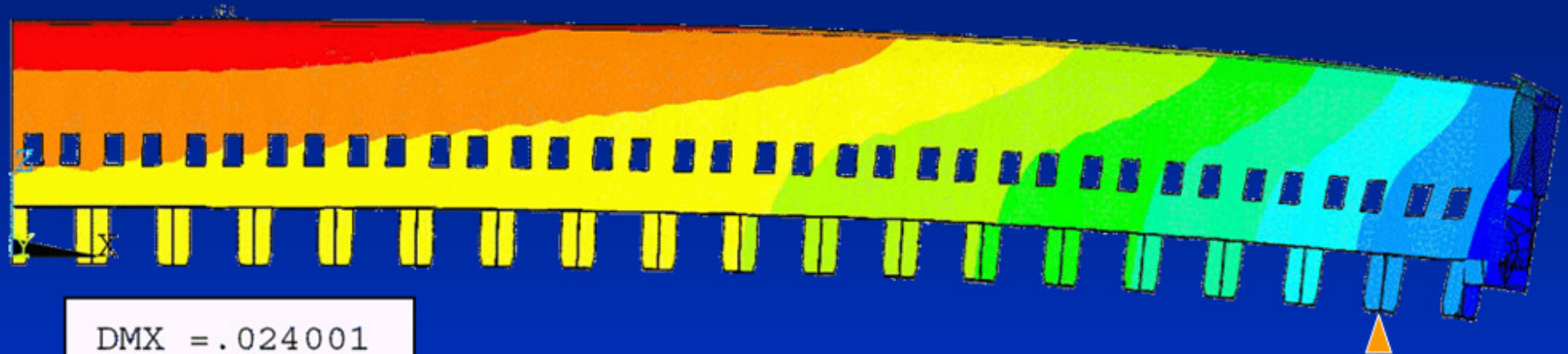
GENSIM











Greenfield 740 kA cell MHD Model Results



No global B_z longitudinal gradient, so no MHD instability wave

740 kA Cell Potshell Mechanical Model Results



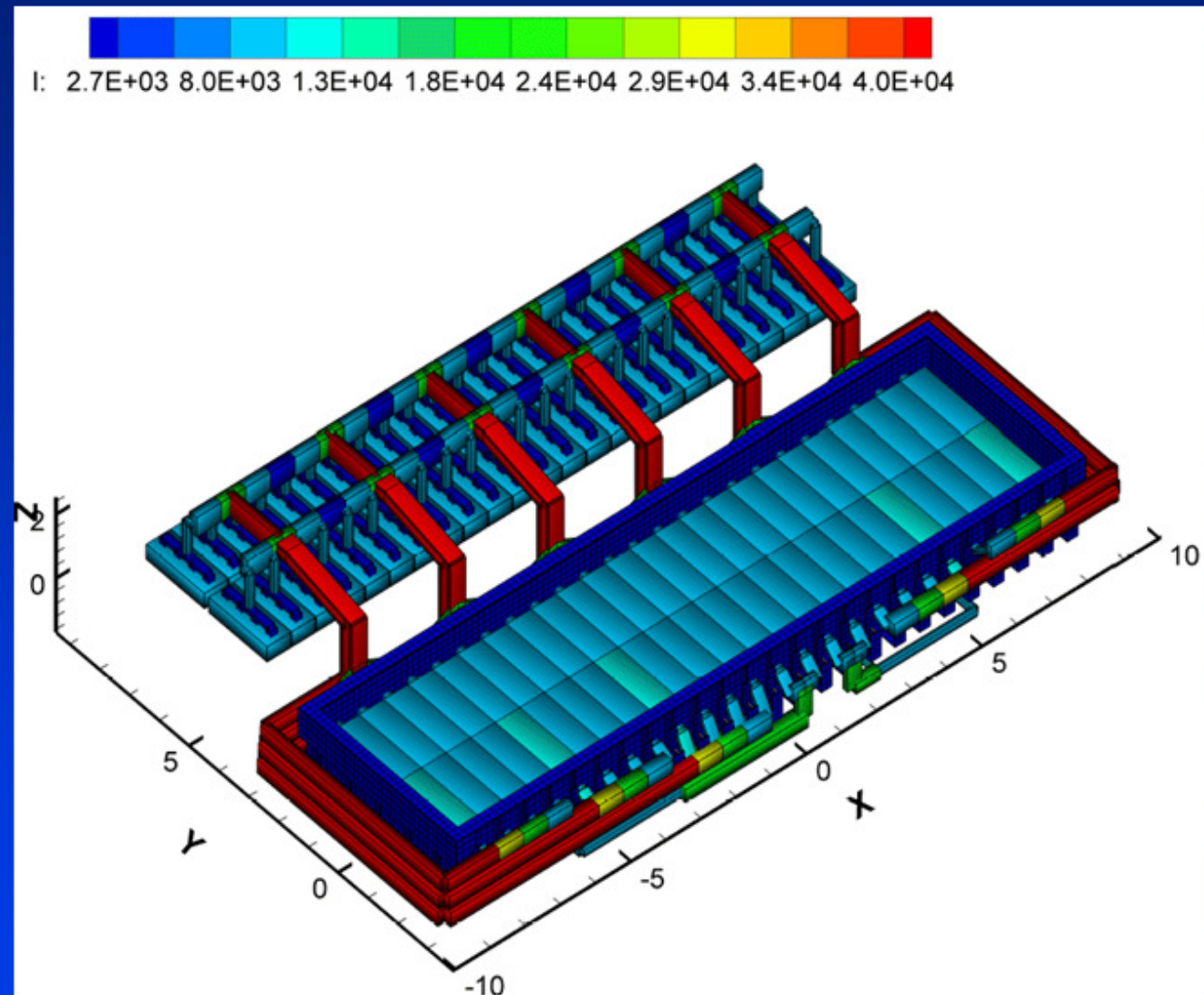
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SMN	= - .004463
SMX	= .022128
	- .004463
	- .001508
	.001447
	.004401
	.007356
	.01031
	.013265
	.016219
	.019174
	.022128

Relative Vertical Displacement for the Fine Mesh Model

Review of the 500 kA Cell Busbar Designs

Design no 1:

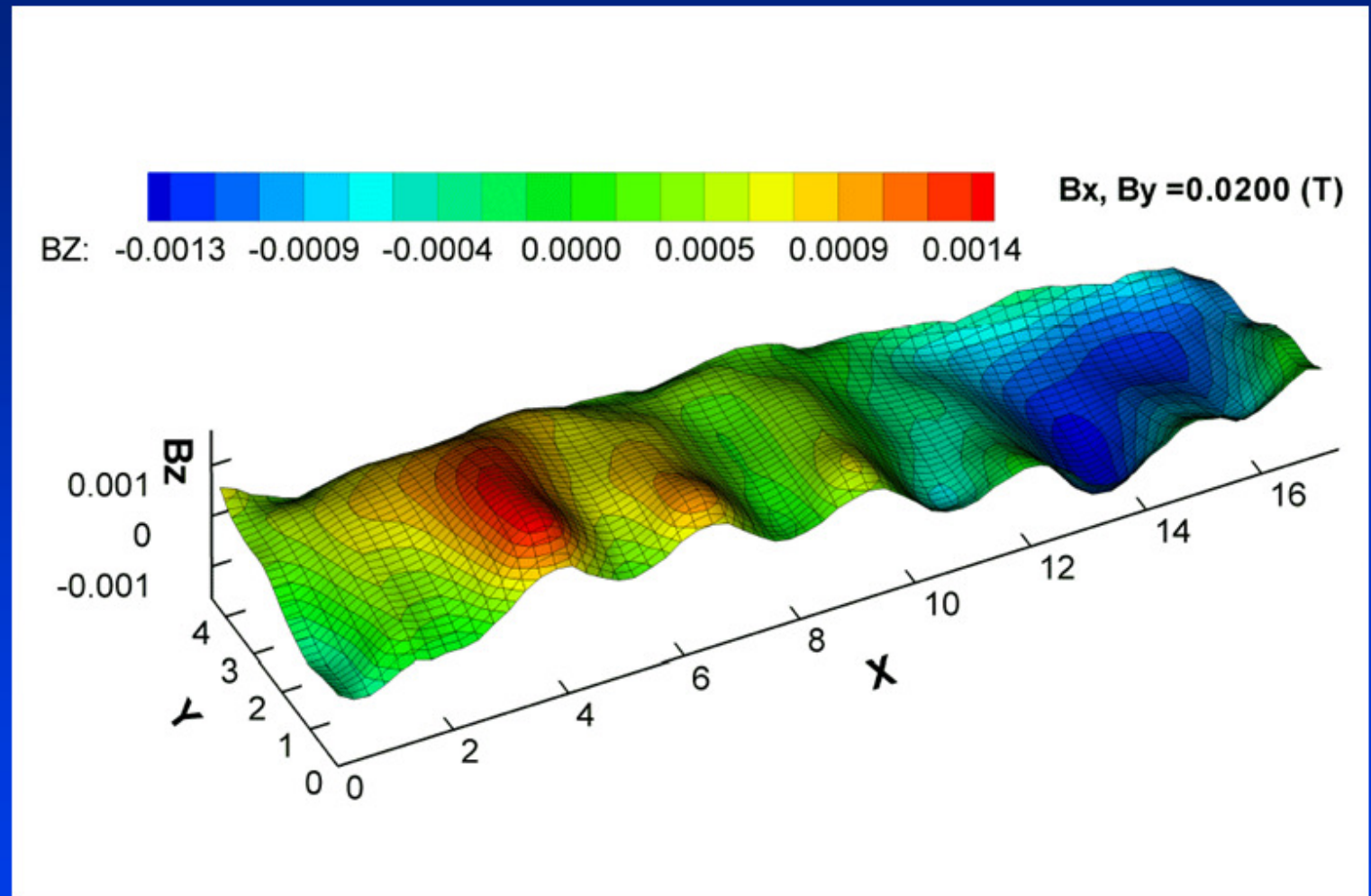
“classical”
asymmetric



Review of the 500 kA Cell Busbar Designs

Design no 1:

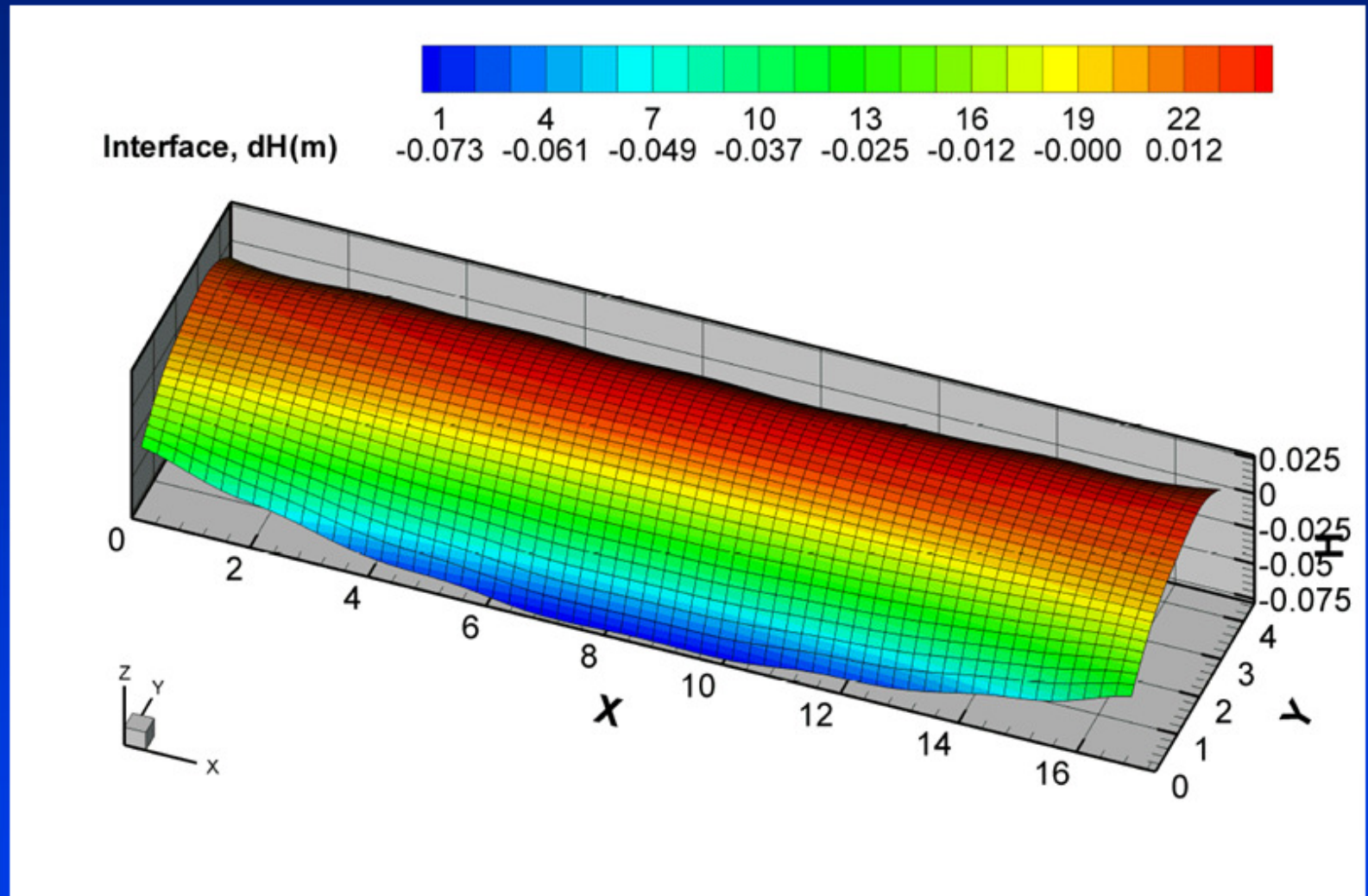
“classical”
asymmetric



Review of the 500 kA Cell Busbar Designs

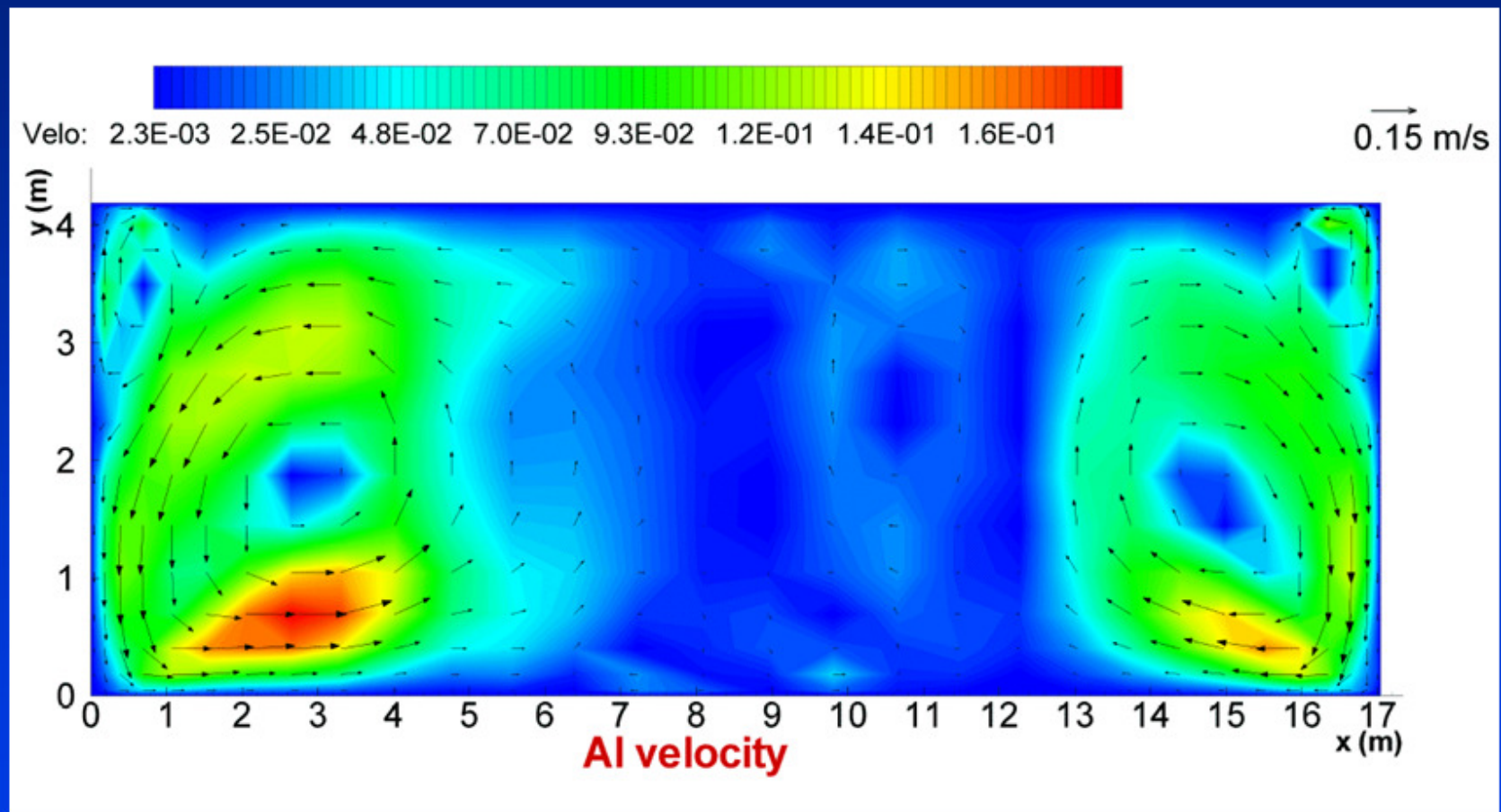
Design no 1:

“classical”
asymmetric



Review of the 500 kA Cell Busbar Designs

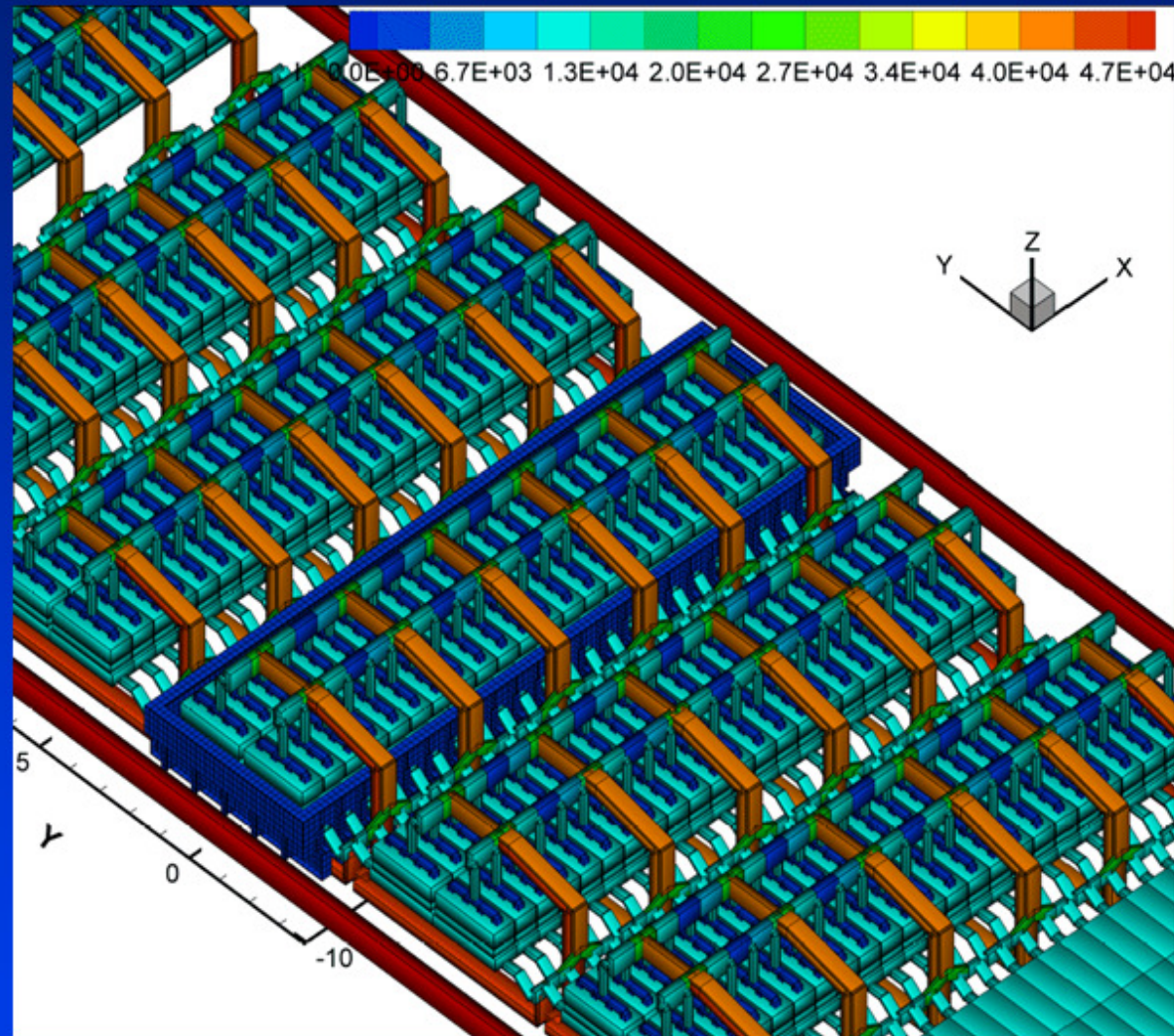
Design no 1:
“classical”
asymmetric



Review of the 500 kA Cell Busbar Designs

Design no 2:

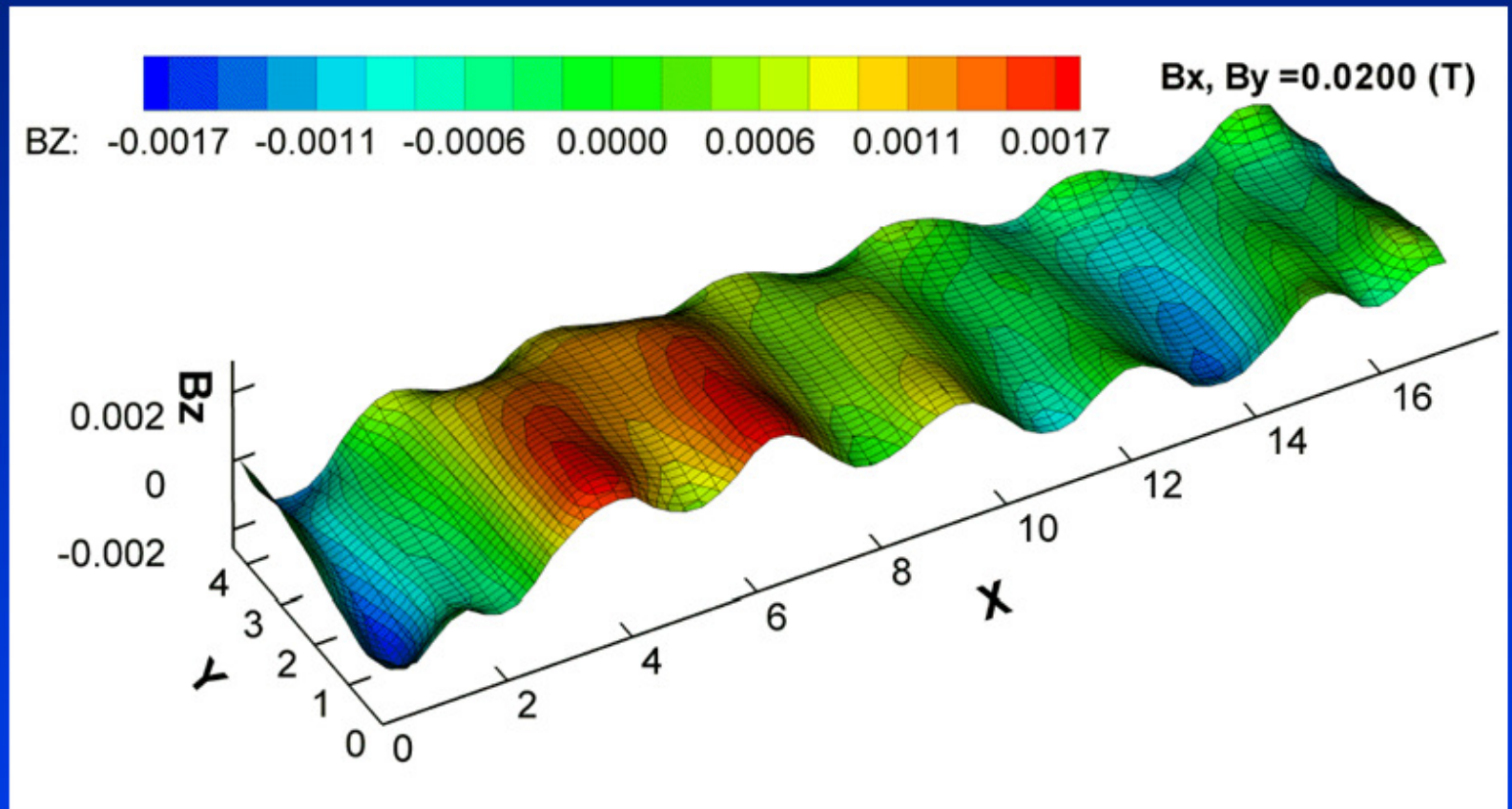
inspired
from the
Pechiney
1987 busbar
patent



Review of the 500 kA Cell Busbar Designs

Design no 2:

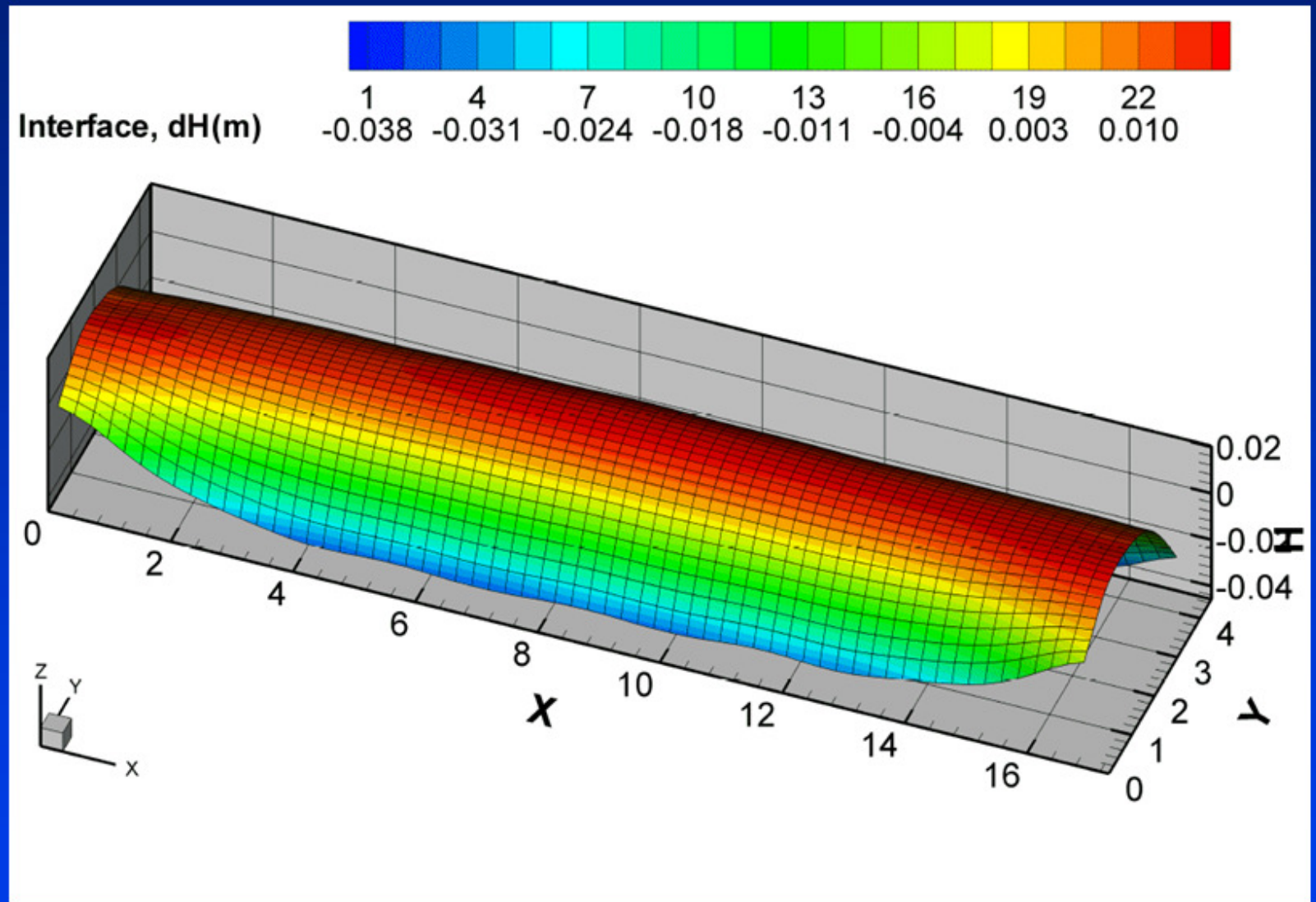
inspired
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Pechiney
1987 busbar
patent



Review of the 500 kA Cell Busbar Designs

Design no 2:

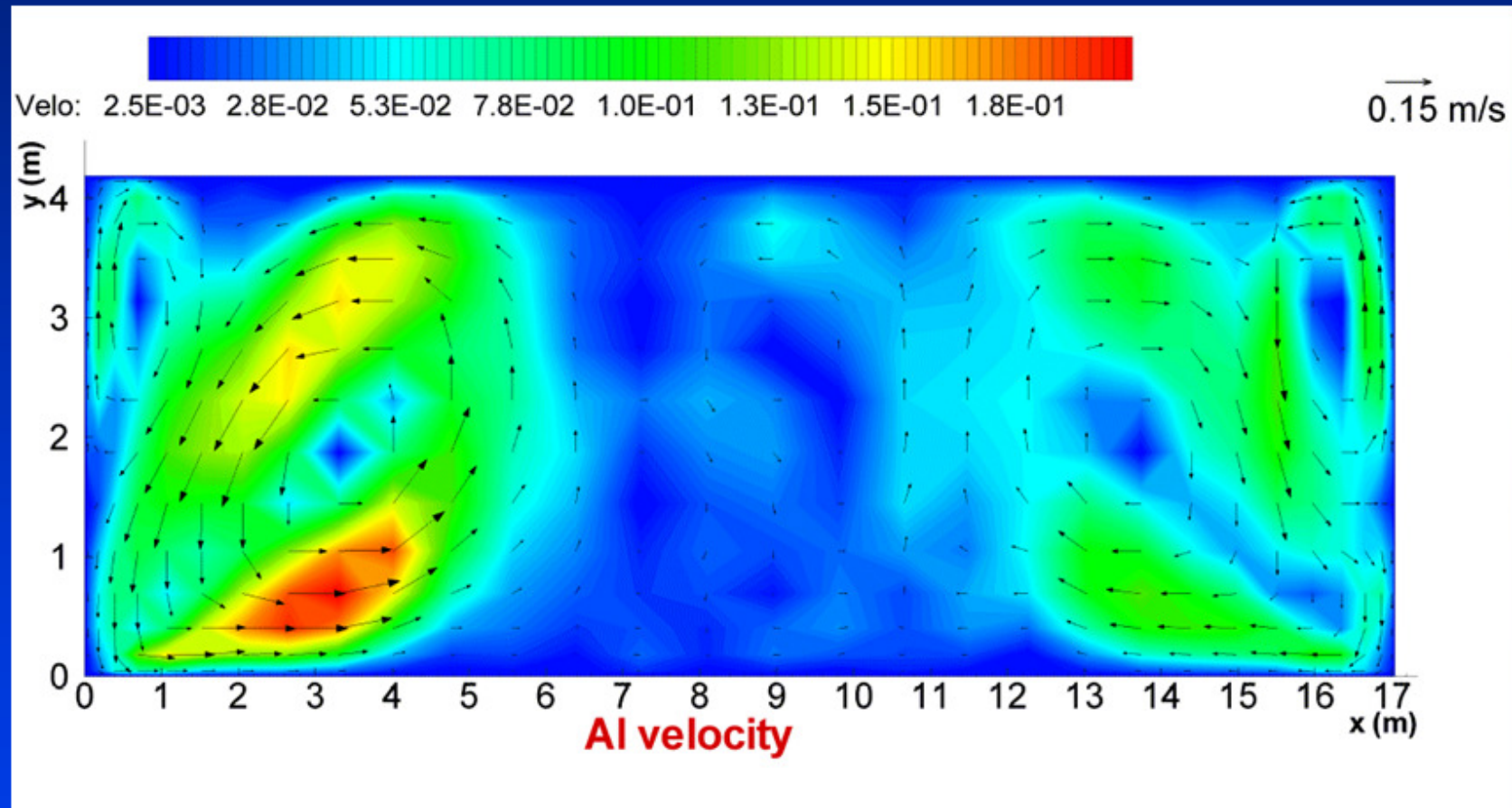
inspired
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Pechiney
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patent



Review of the 500 kA Cell Busbar Designs

Design no 2:

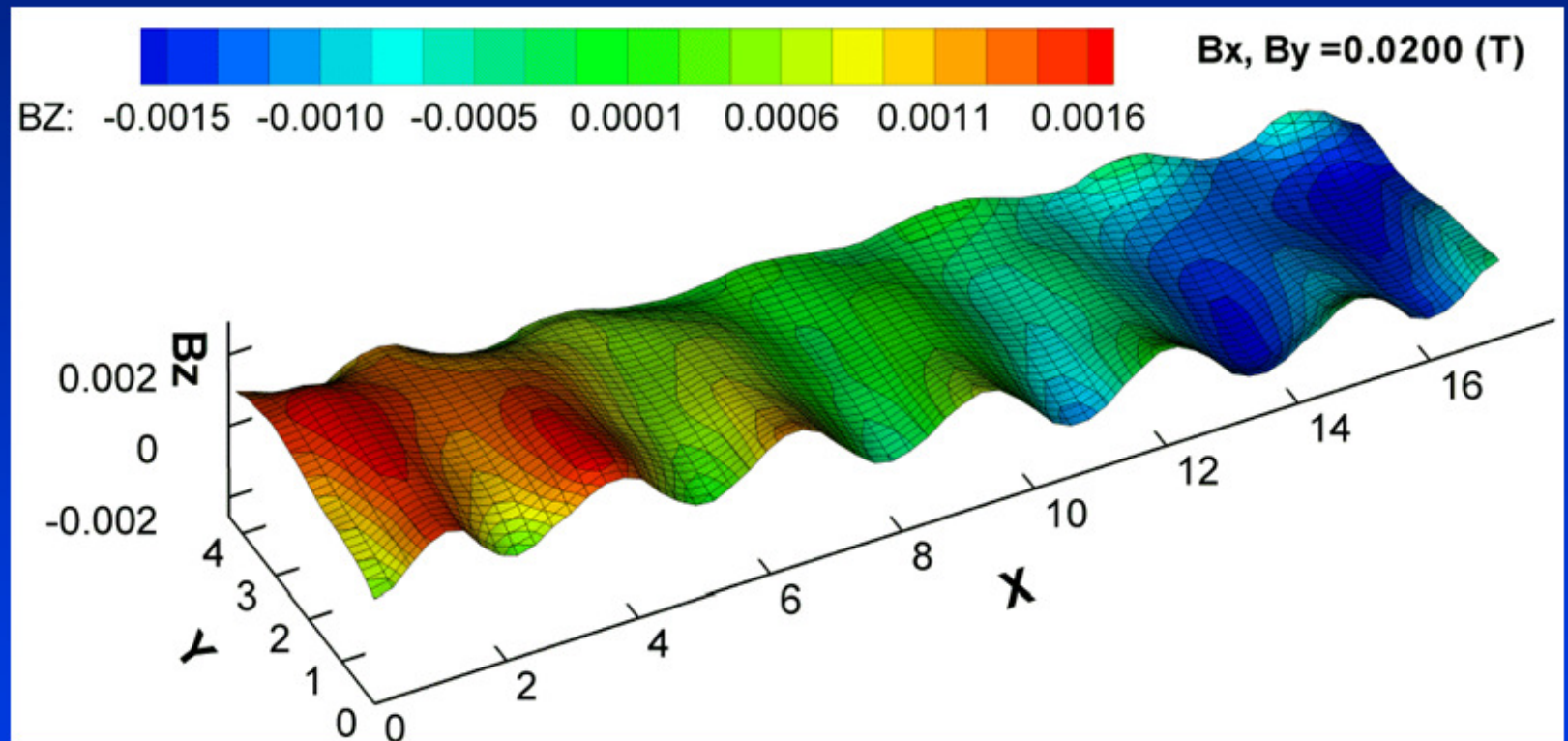
inspired
from the
Pechiney
1987 busbar
patent



Review of the 500 kA Cell Busbar Designs

Design no 3:

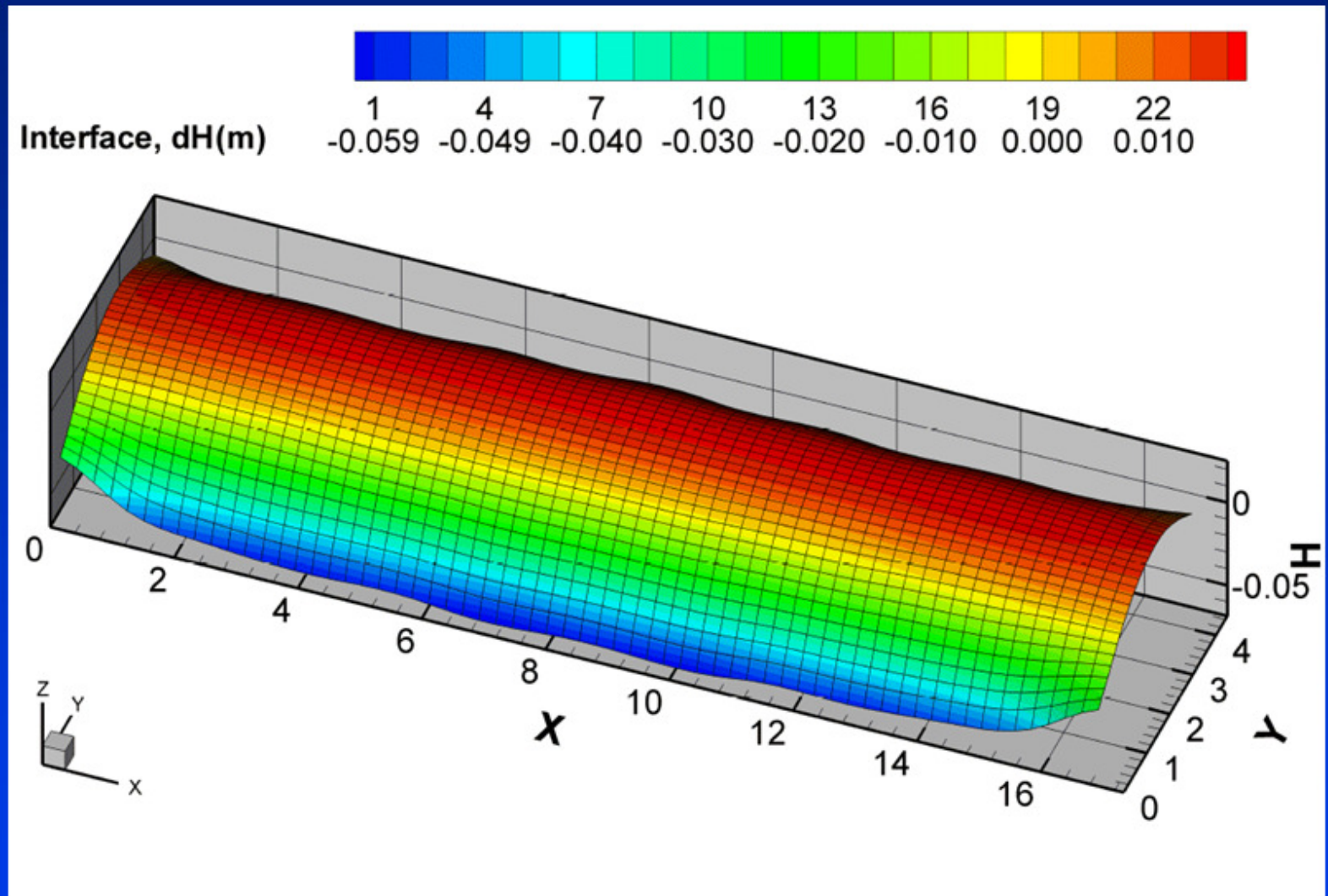
Alternative
compensation
busbar



Review of the 500 kA Cell Busbar Designs

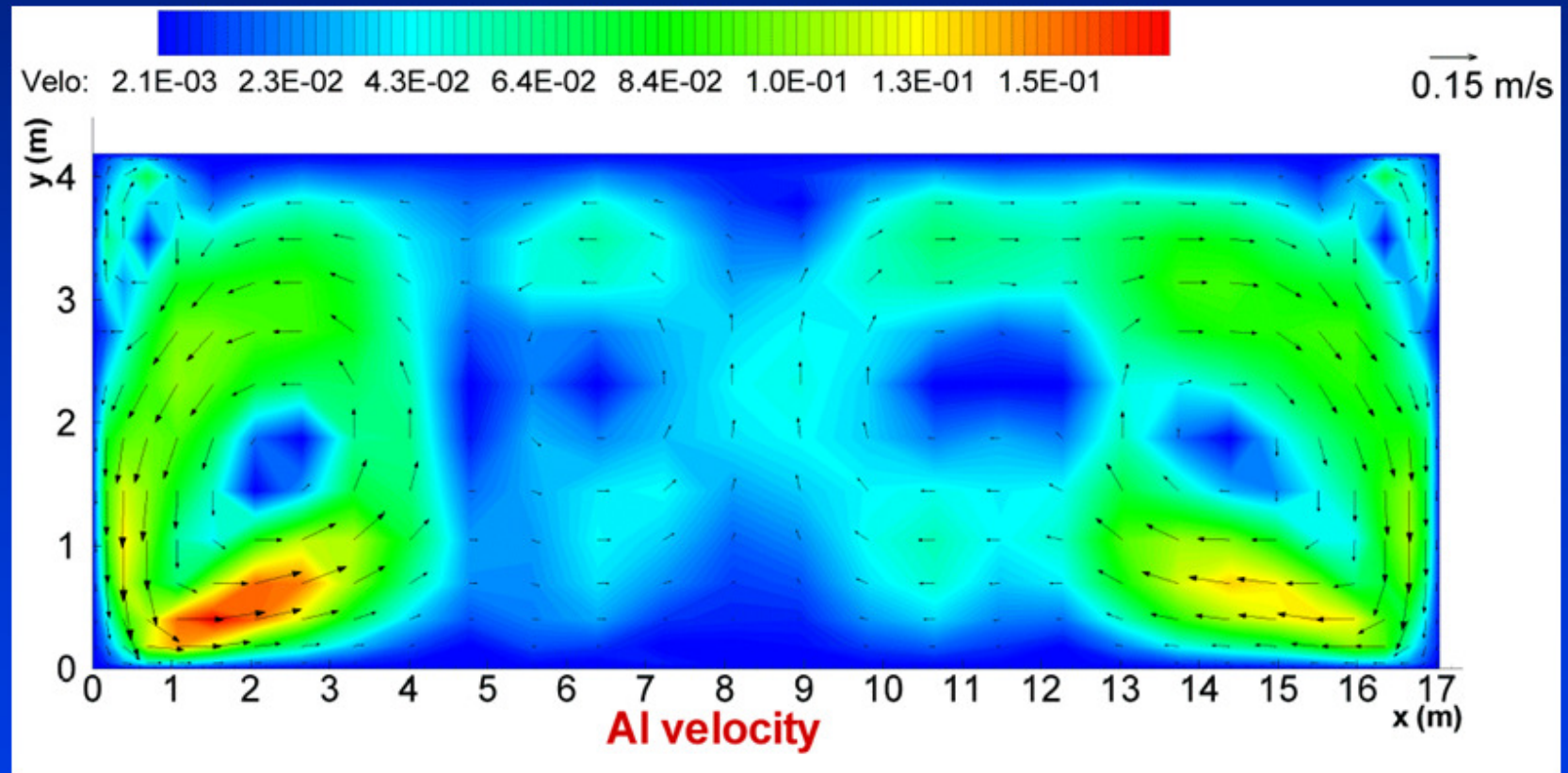
Design no 3:

Alternative
compensation
busbar



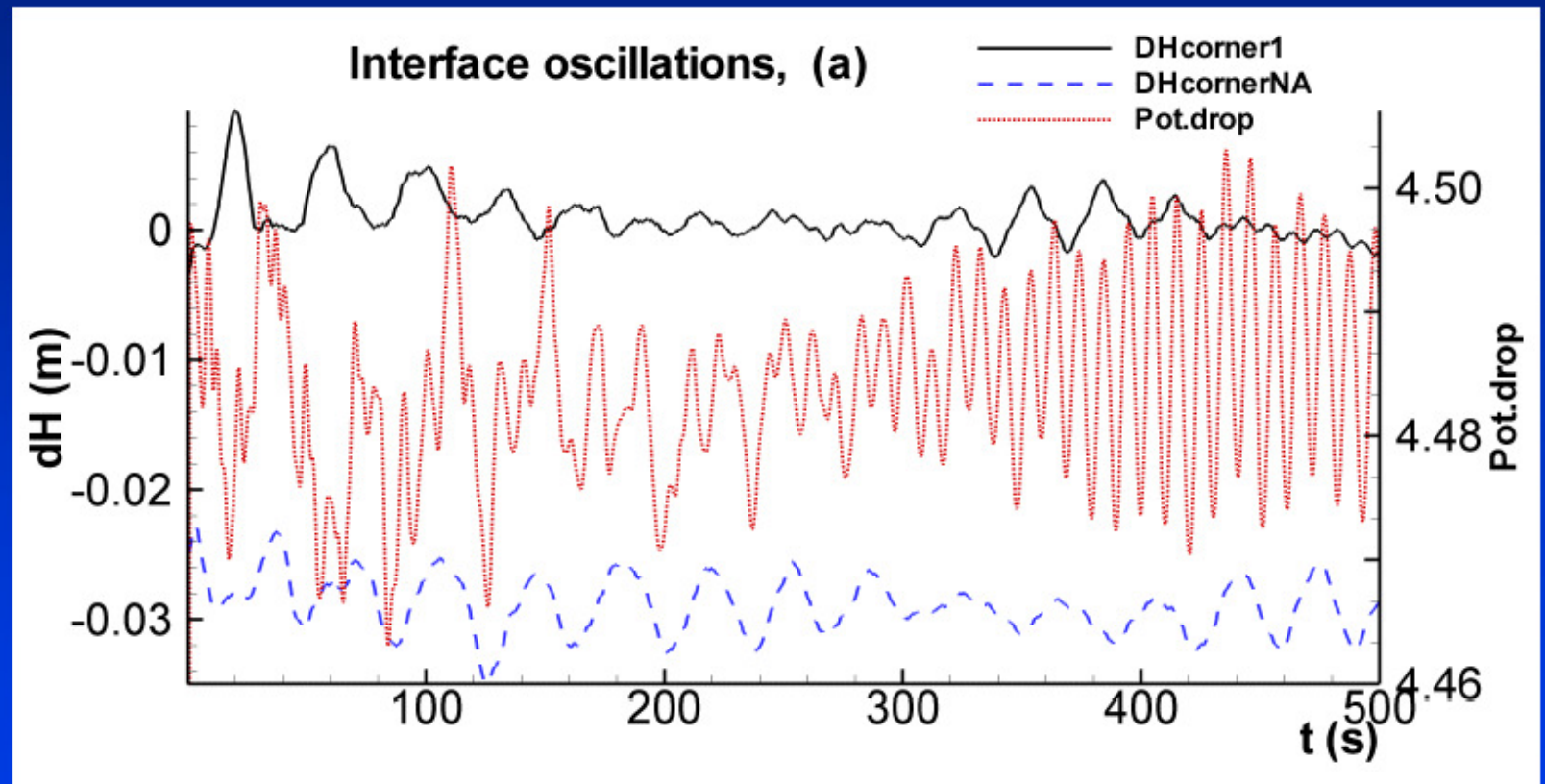
Review of the 500 kA Cell Busbar Designs

Design no 3:
Alternative
compensation
busbar

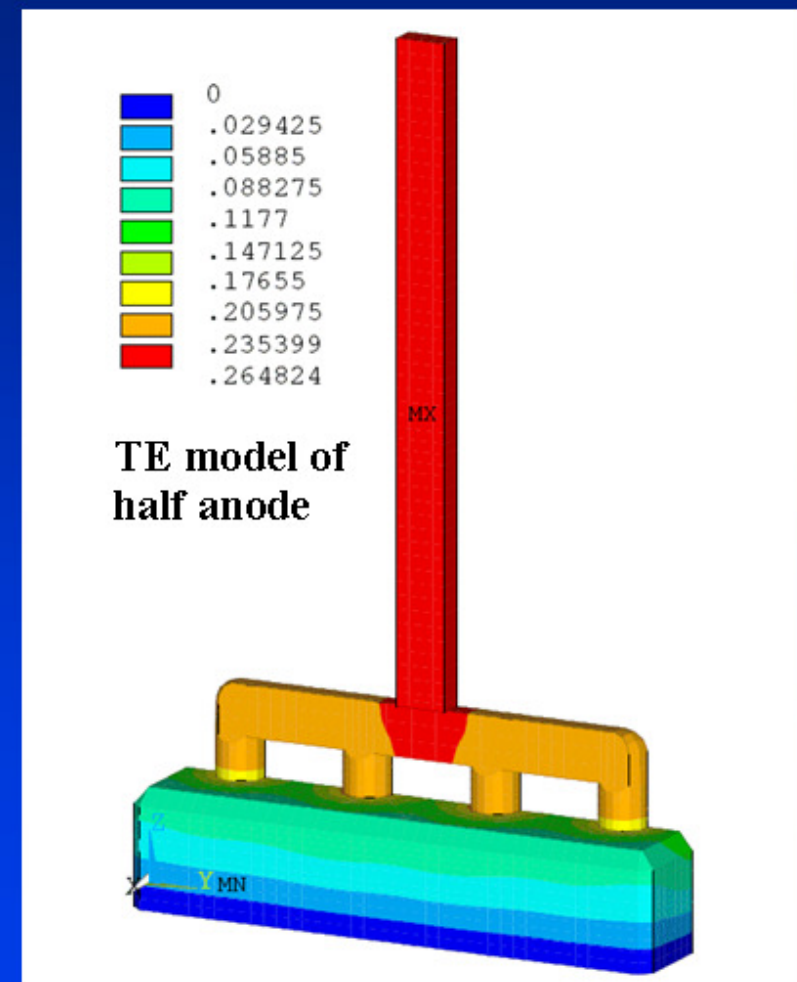
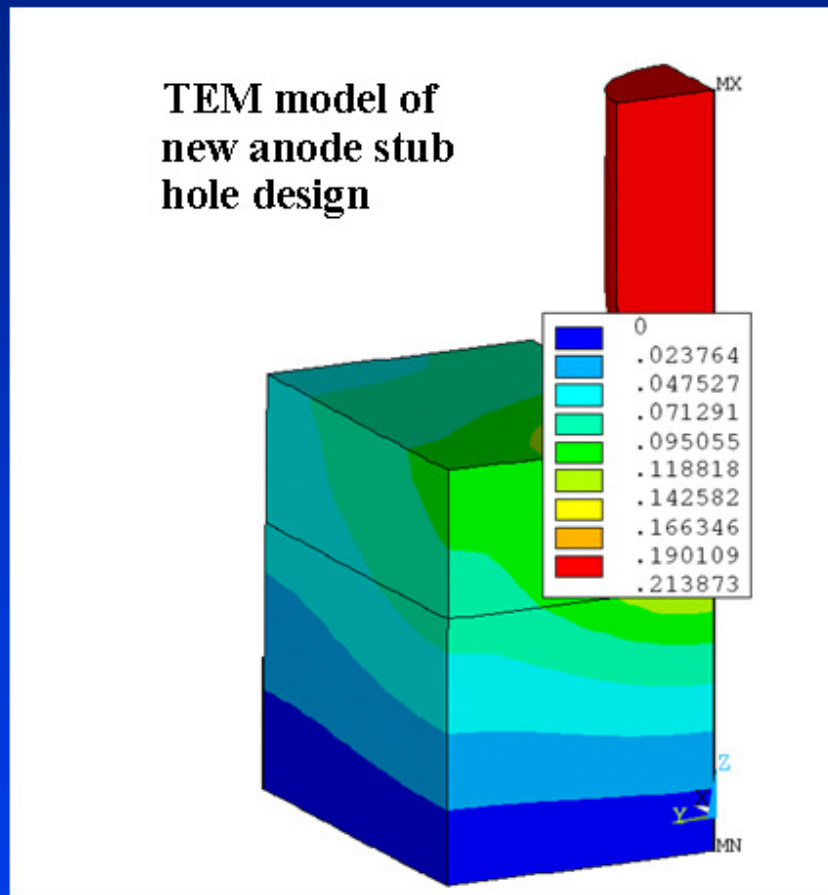


Review of the 500 kA Cell Busbar Designs

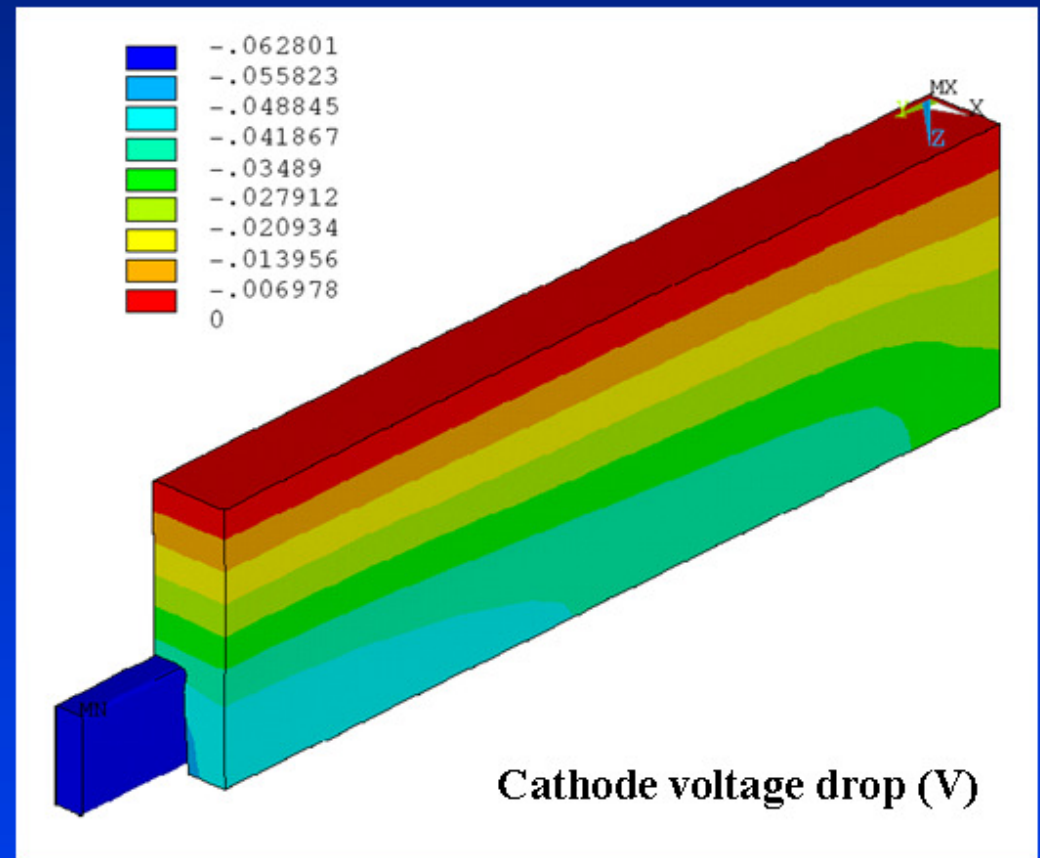
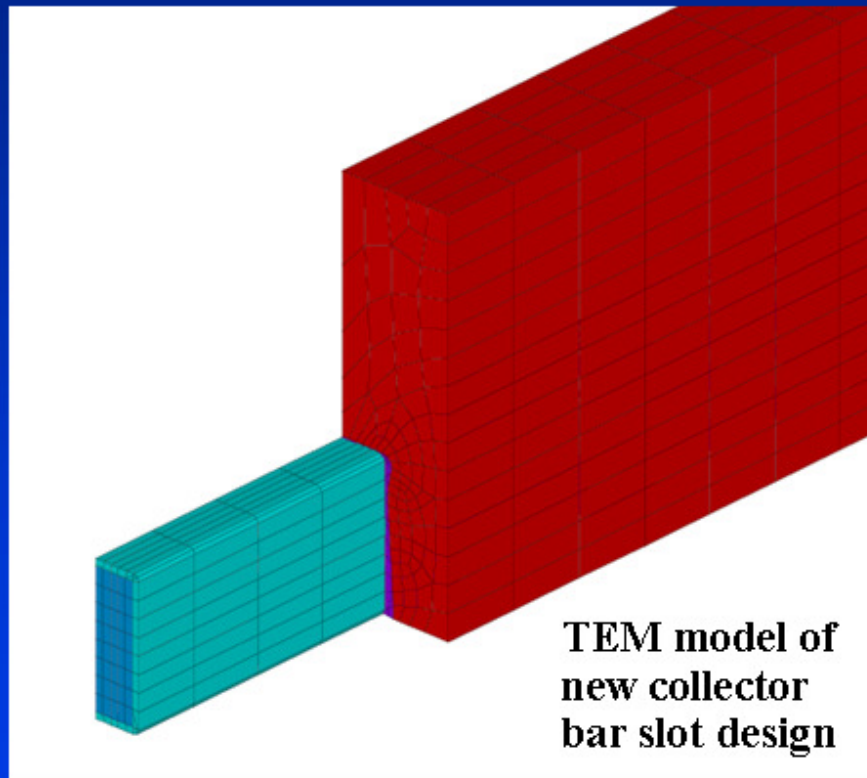
Design no 3:
Alternative
compensation
busbar



New Anode Stub Hole TEM Model and Anode Design

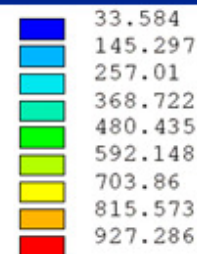
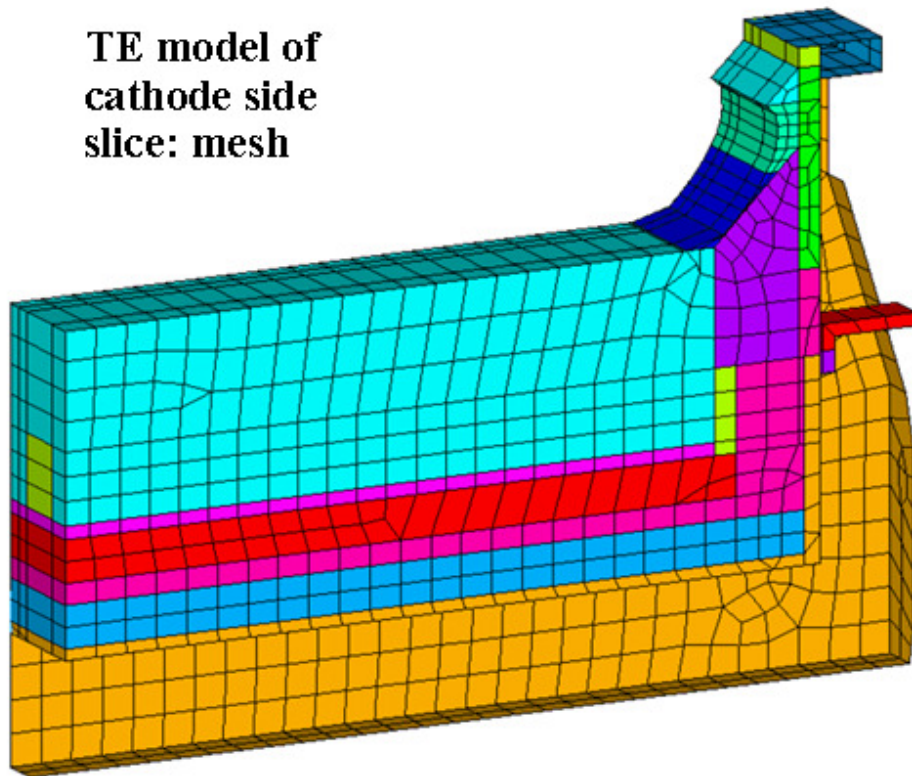


New Cathode Collector Bar Slot TEM Model and Cathode Design

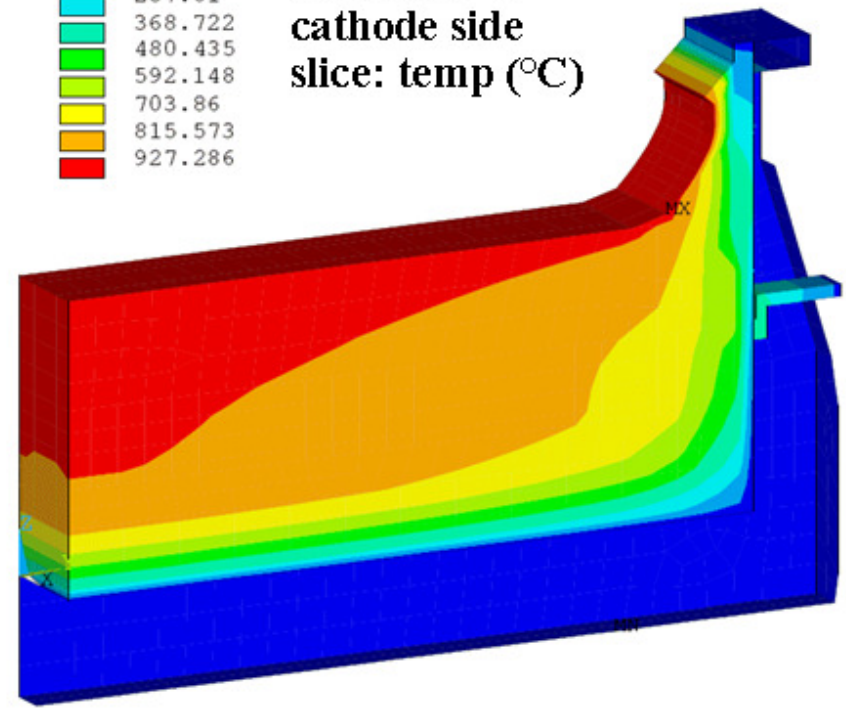


New Cathode Collector Bar Slot TEM Model and Cathode Design

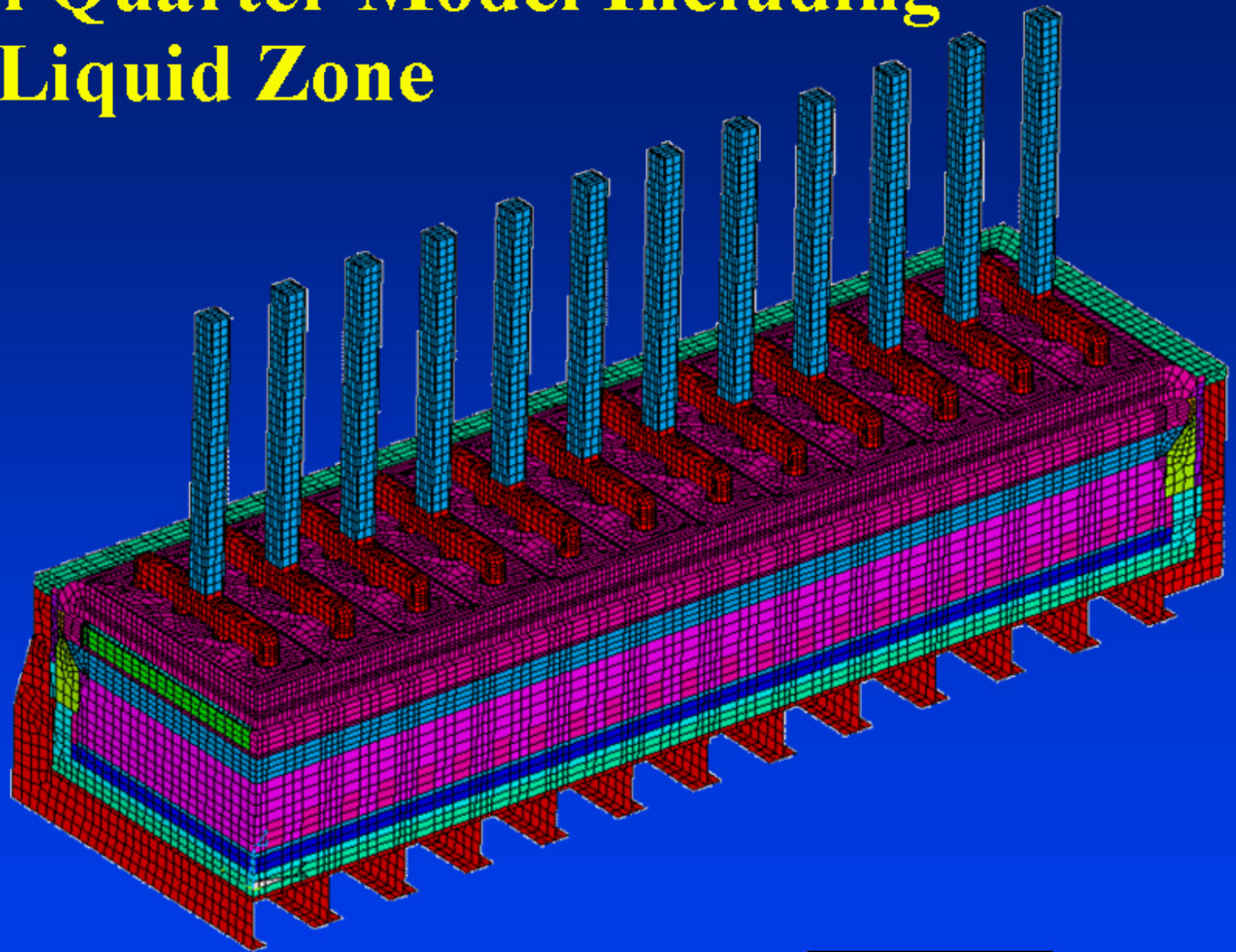
TE model of cathode side slice: mesh



TE model of cathode side slice: temp (°C)

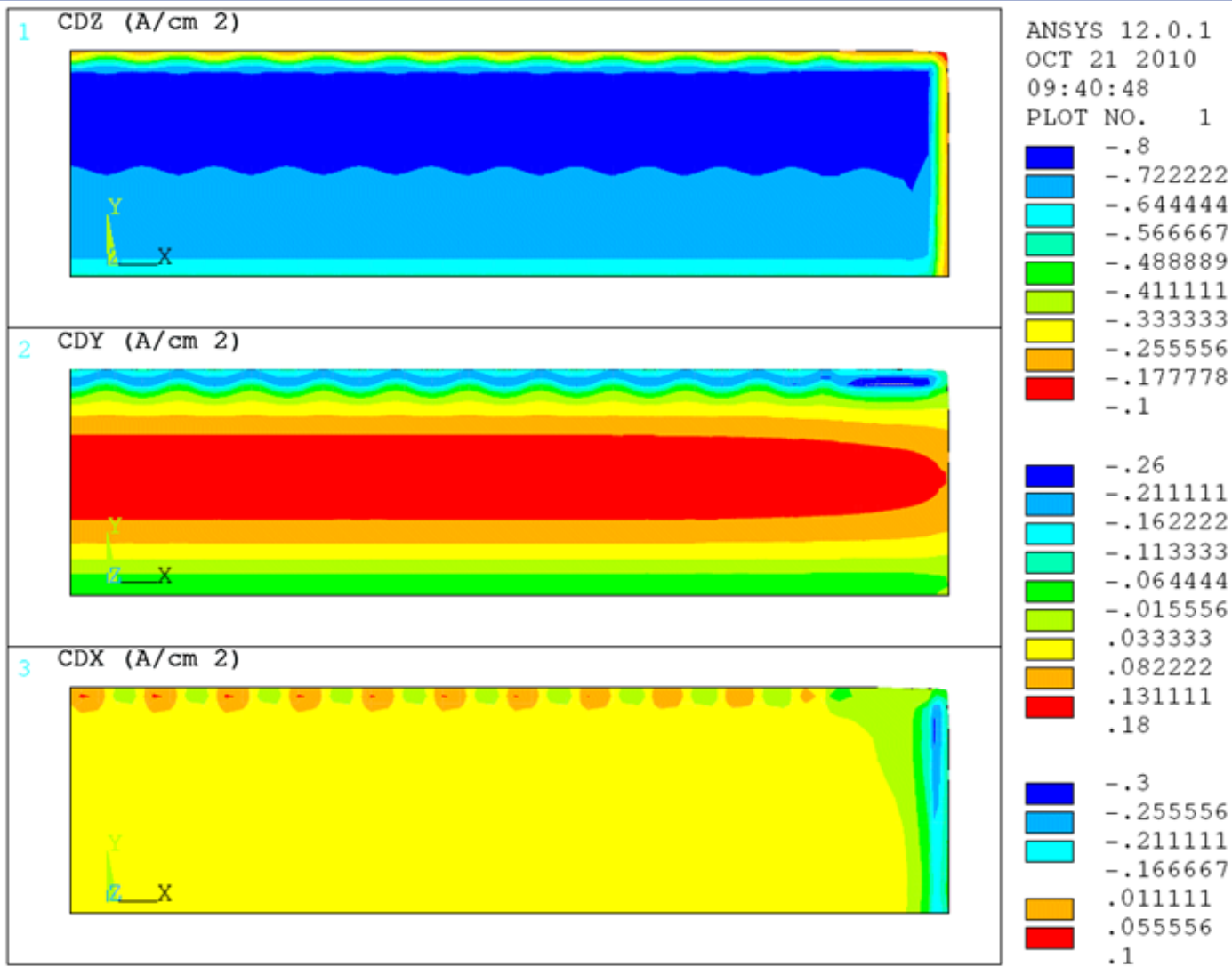


Full Cell Quarter Model Including the Liquid Zone



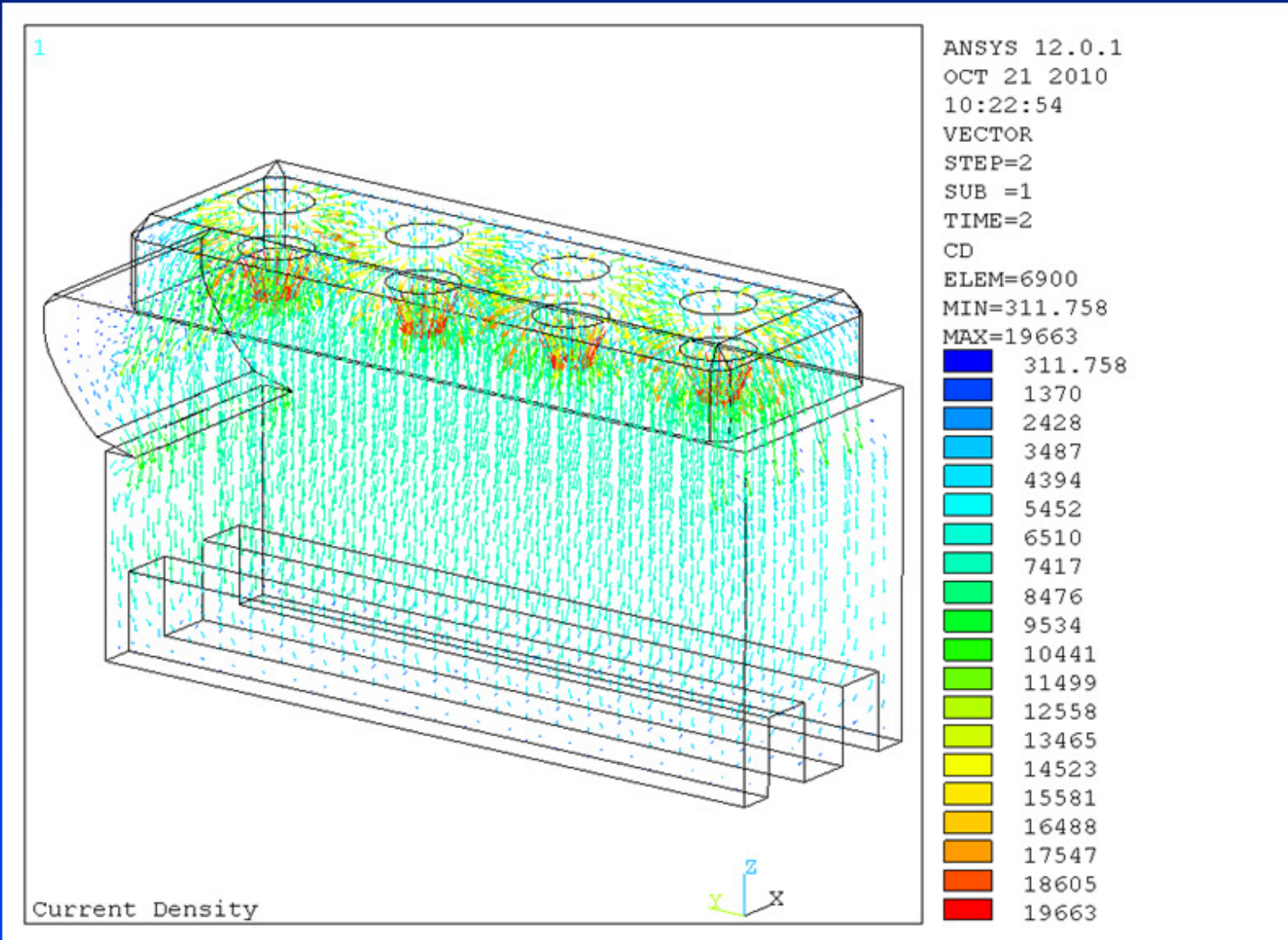
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Full Cell Quarter Model Including the Liquid Zone



MIDDLE OF METAL PAD

Full Cell Quarter Model Including the Liquid Zone



Retrofitted 600 kA Cell Design

DYNA/MARC 1.95 - [VAVm19]

File Process Formulas Operator Run List Windows Language Help

DYNA/MARC 1.95 - [VAVm19]

Demo example of a prebaked PBF cell inspired from VAW's JOM paper
 liquidus superheat, 3.5 cm ACD, 2 m anode length, 12.0% AlF₃, 600 kA
 HC10 4.17m cathode block, top 7 cm bottom 7 cm SiC side block
 10 cm cover over anodes, 17.5 cm stud diameter, 4 studs per anode
 48 anodes, 24 cathode blocks, 17.8 m X 4.85 m inside potshell size

Date Created : 8/2/99 Last Modified : 10/12/10

Steady State Solution

Cell amperage	600.0	[kA]
Anode to cathode distance	3.50000	[cm]
Operating temperature	963.899	[C]
Ledge thickness, bath level	5.37447	[cm]
Ledge thickness, metal level	1.68353	[cm]
Anode beam position	0.0000	[cm]
Mass of metal	33458.9	[kg]
Mass of bath	9739.88	[kg]
Mass of dissolved alumina	243.497	[kg]
Mass of dispersed alumina	110.829	[kg]
Mass of alumina sludge	4.1933	[kg]
Mass of dissolved aluminum fluoride	1168.785	[kg]
Mass of dispersed aluminum fluoride	1.081	[kg]
Mass of aluminum fluoride sludge	0.0003	[kg]
Mass of calcium fluoride	584.393	[kg]
Mass of lithium fluoride	0.000	[kg]
Mass of magnesium fluoride	0.000	[kg]
Alumina feeding rate	374.187	[kg/hr]
Aluminum fluoride feeding rate	2.46778	[kg/hr]
Target cell resistance	4.40157	[micro-ohm]

Steady State derived Variables

Rate of change of:	
ACD	-0.02987 [cm/hr]
Operating temperature	0.0000 [C/hr]
Ledge thickness, bath level	0.000 [cm/hr]
Ledge thickness, metal level	0.000 [cm/hr]
Mass of dispersed Al ₂ O ₃	0.000 [kg/hr]
Mass of Al ₂ O ₃ sludge	0.00000 [kg/hr]
Mass of dissolved Al ₂ O ₃	0.0000 [kg/hr]

DYNA/MARC: What If

List of Design Variables

	Design Value	Set as Target
Anode to Cathode Distance	3.5 cm	<input type="radio"/>
Cell Amperage	600 kA	<input type="radio"/>
Conc. of Excess Aluminum Fluoride	12 %	<input type="radio"/>
Concentration of Dissolved Alumina	2.5 %	<input type="radio"/>
Concentration of Calcium Fluoride	6 %	<input type="radio"/>
Concentration of Lithium Fluoride	0 %	<input type="radio"/>
Conc. of Magnesium Fluoride	0 %	<input type="radio"/>
Bath Level	20 cm	<input type="radio"/>
Bath Ledge Heat Transfer Coef.	1425 W/m ² °C	<input type="radio"/>
Metal Ledge Heat Transfer Coef.	2052 W/m ² °C	<input type="radio"/>
Metal Level	20 cm	<input type="radio"/>
Anode Length	2 m	<input type="radio"/>
Cavity Length	17.48 m	<input type="radio"/>
Anode Panel Heat Loss	423 kW	<input type="radio"/>
Cathode Bottom Heat Loss	240 kW	<input type="radio"/>
Cell Operating Temperature	963 °C	<input type="radio"/>
Anode Voltage Drop	318 mV	<input type="radio"/>
Cathode Voltage Drop	104.4 mV	<input type="radio"/>
Anode Width	0.665 m	<input type="radio"/>
Cavity Width	4.55 m	<input type="radio"/>

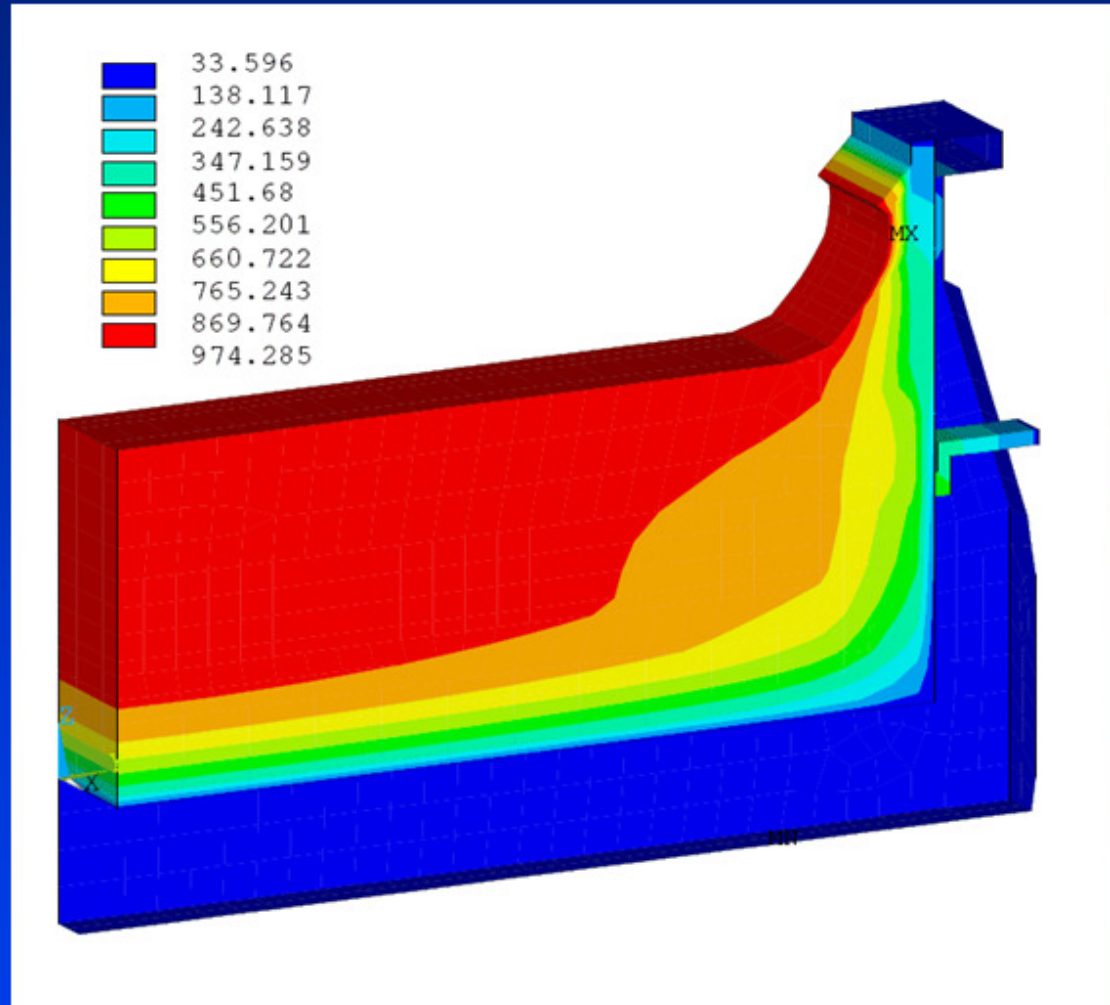
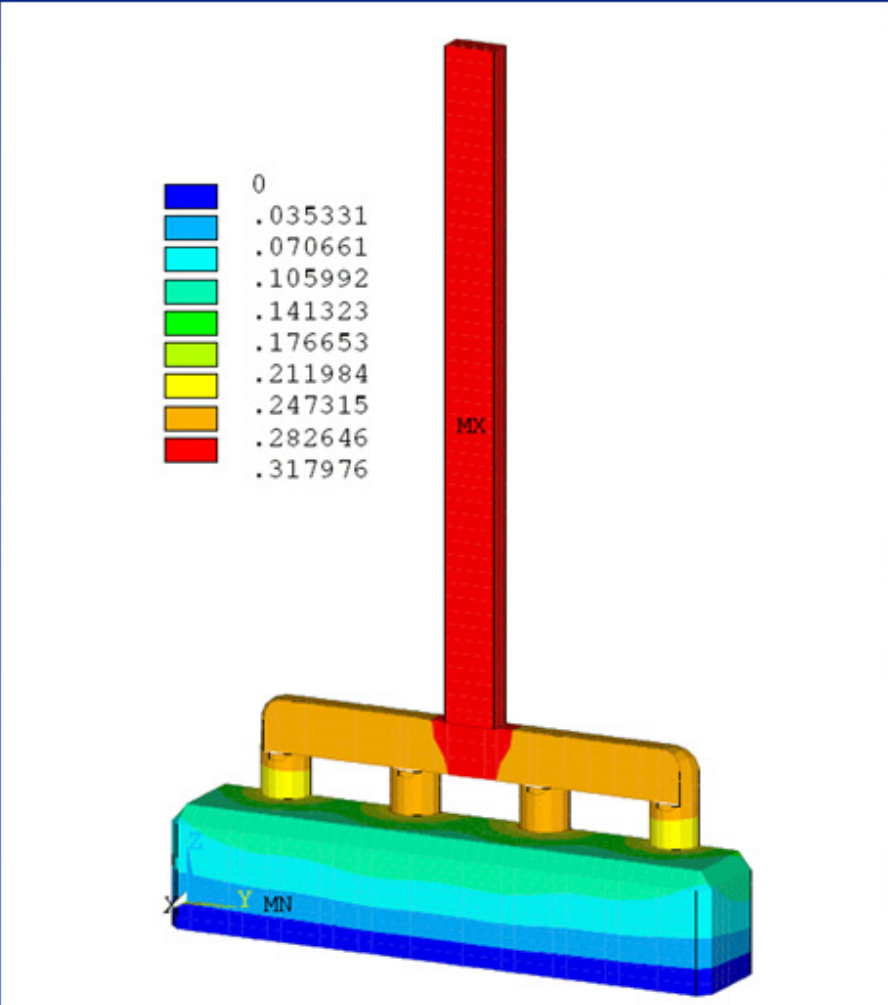
Run Exit

Press F1 for Help Demo example of a prebaked PBF cell inspired from VAW's JOM paper 10/21/10 12:10 PM CAPS NUM INSER

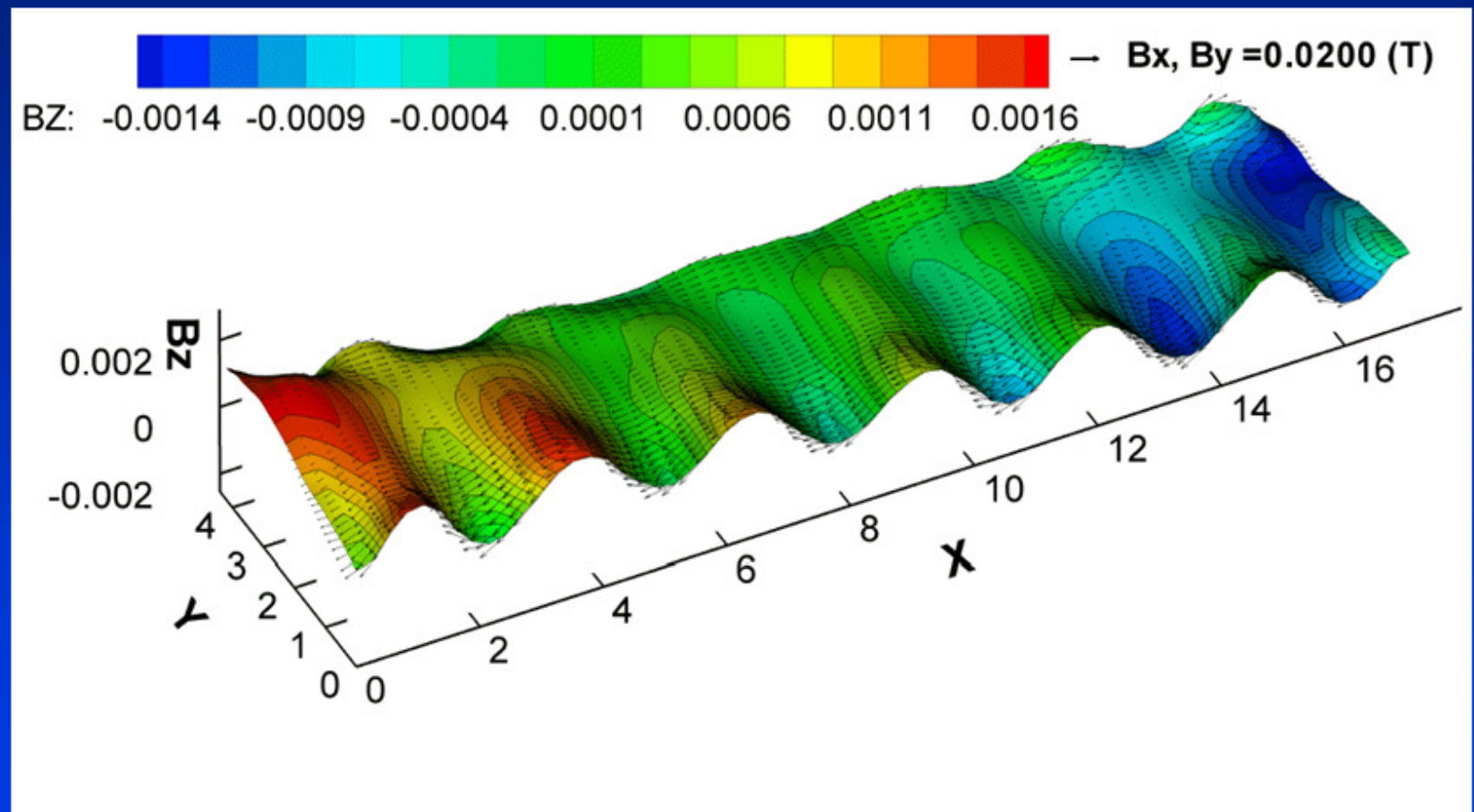
Amperage	600 kA
Nb. of anodes	48
Anode size	2.00 m X 0.665 m
Nb. of anode studs	4 per anode
Anode stud diameter	17.5 cm
Anode cover thickness	10 cm
Nb. of cathode blocks	24
Cathode block length	4.17 m
Type of cathode block	HC10
Type of side block	SiC
Side block thickness	7 cm
ASD	28 cm
Inside potshell size	17.8 X 4.85 m
ACD	3.5 cm
Excess AlF ₃	12.0 %
Anode drop	318 mV
Cathode drop	104 mV
Anode panel heat loss	423 kW
Cathode bottom heat loss	240 kW
Operating temperature	963.9 °C
Liquidus superheat	11.8 °C
Bath ledge thickness	5.37 cm
Metal ledge thickness	1.68 cm
Current efficiency	96.4 %
Internal heat	1141 kW
Energy consumption	13.26 kWh/kg

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Verification of the Thermal Balance at 600 kA Using the ANSYS® based TE Models



Verification of the MHD Stability at 600 kA



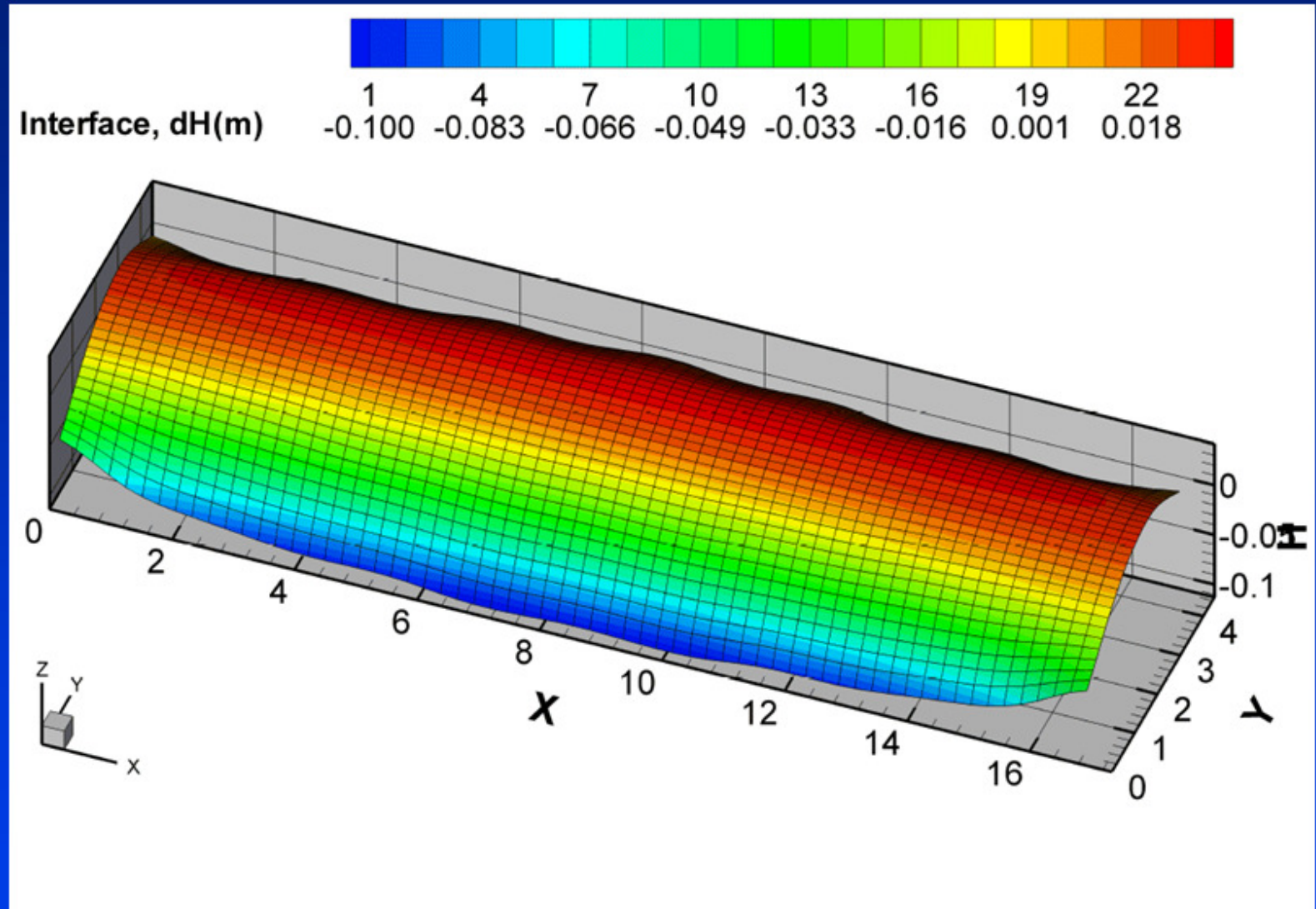
Design no 3:

Alternative
compensation
busbar

Verification of the MHD Stability at 600 kA

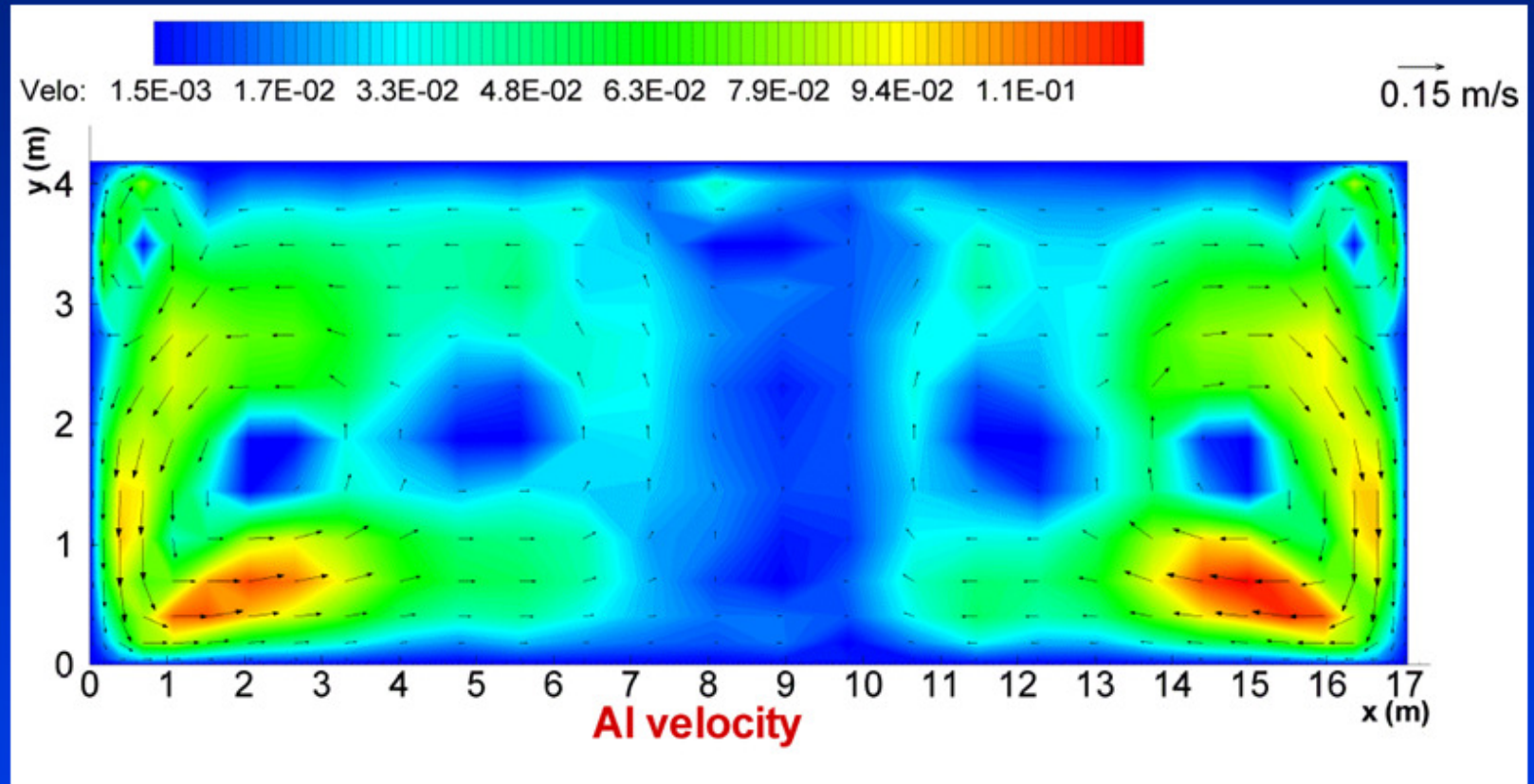
Design no 3:

Alternative
compensation
busbar



Verification of the MHD Stability at 600 kA

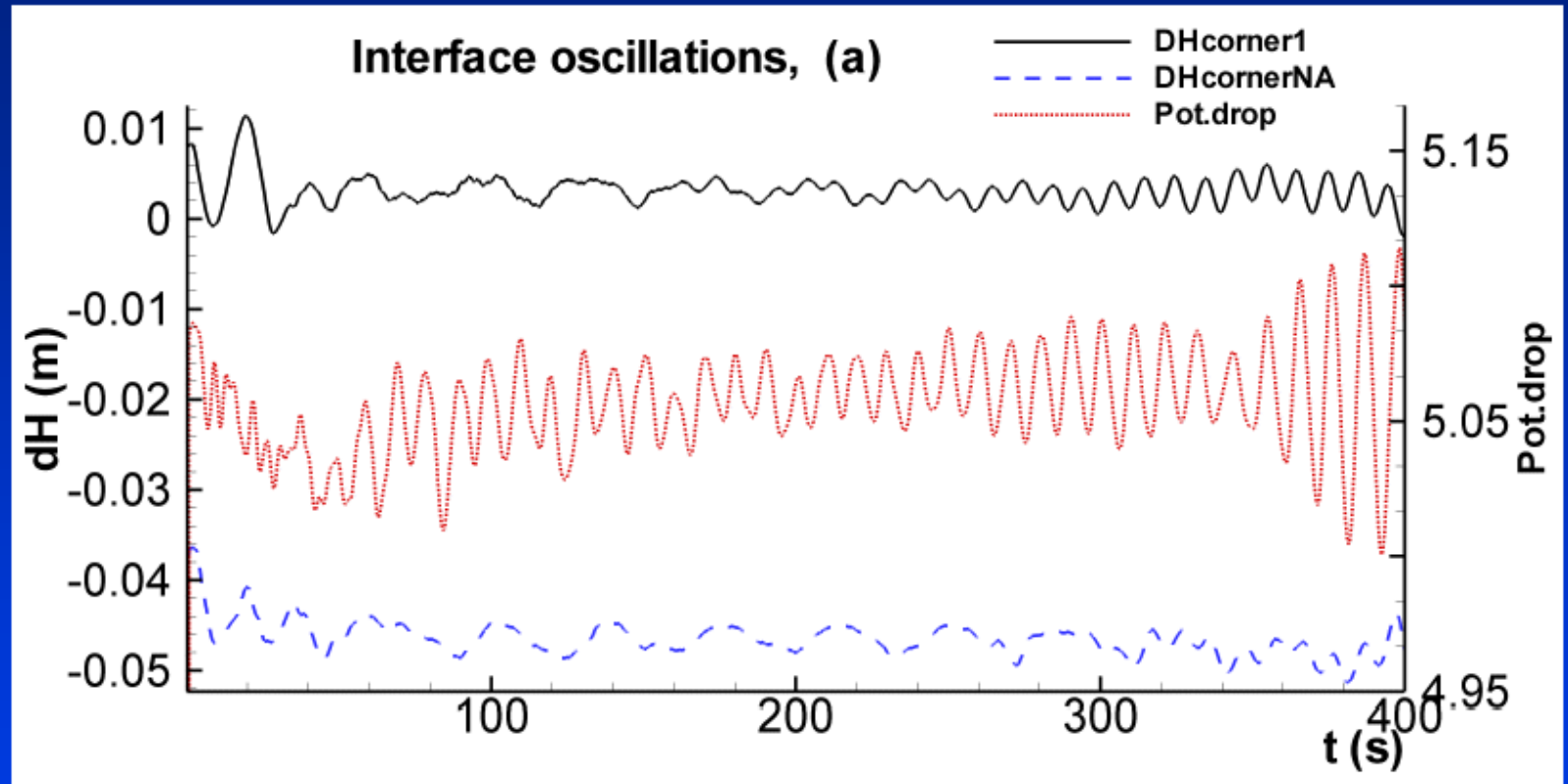
Design no 3:
Alternative
compensation
busbar



Verification of the MHD Stability at 600 kA

Design no 3:

Alternative
compensation
busbar



Conclusions

- **This demonstration retrofit study of a 10 years old “past prime if not obsolete” 500 kA cell technology into an up-to-date “innovative” 600 kA cell technology highlights the huge capacity creep potential that is present in even fairly recent cell designs.**
- **The authors also hope that this demonstration study highlights the value of using mature state of the art mathematical models to carry-up such studies.**
- **Those models, used by the majority of the groups actively developing high amperage cell technology today, are available to the whole aluminium industry through GeniSim Inc.**

GENISIM

3D ANSYS® T/E models

Clients list:

Alcan
Alumax
Reynolds
Hoogovens
Alcoa
Noranda
Indal
Nalco
SAMI
Comalco
NEUI
Dubal
GAMI

MHD-Valdis

SAMI
NEUI
Dubal
GAMI
Rusal

Dyna/Marc cell simulator

Alcan
Alusuisse
VAW
Alumax
Reynolds
Hoogovens
Hydro Aluminium

GENISIM

GENISIM

Dr. Marc Dupuis Experience Building T/E Models

**With Alcan
1984-1994:**

Alcan prototypes: A275, A265-H, A310
Alcan prebaked: A70, A140, A165
Alcan HSS
Alcoa P155
Pechiney AP18

**With GeniSim
1995-2011:**

Pechiney AP18, AP30
Alcoa: P155, A697
Reynolds prebaked: P-19, P-20S, P-23S
Kaiser P69
SAMI 300 kA
NEUI 300 kA
GAMI 300 kA, 420 kA
Dubal DX, D20
VAW 240 kA
Comalco B32
Reynolds HSS
Pechiney HSS
Alcan VSS



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