Development and Application of an ANSYS® based Thermo-Electro-Mechanical Collector Bar Slot Design Tool

Marc Dupuis

GENISIM

Plan of the Presentation

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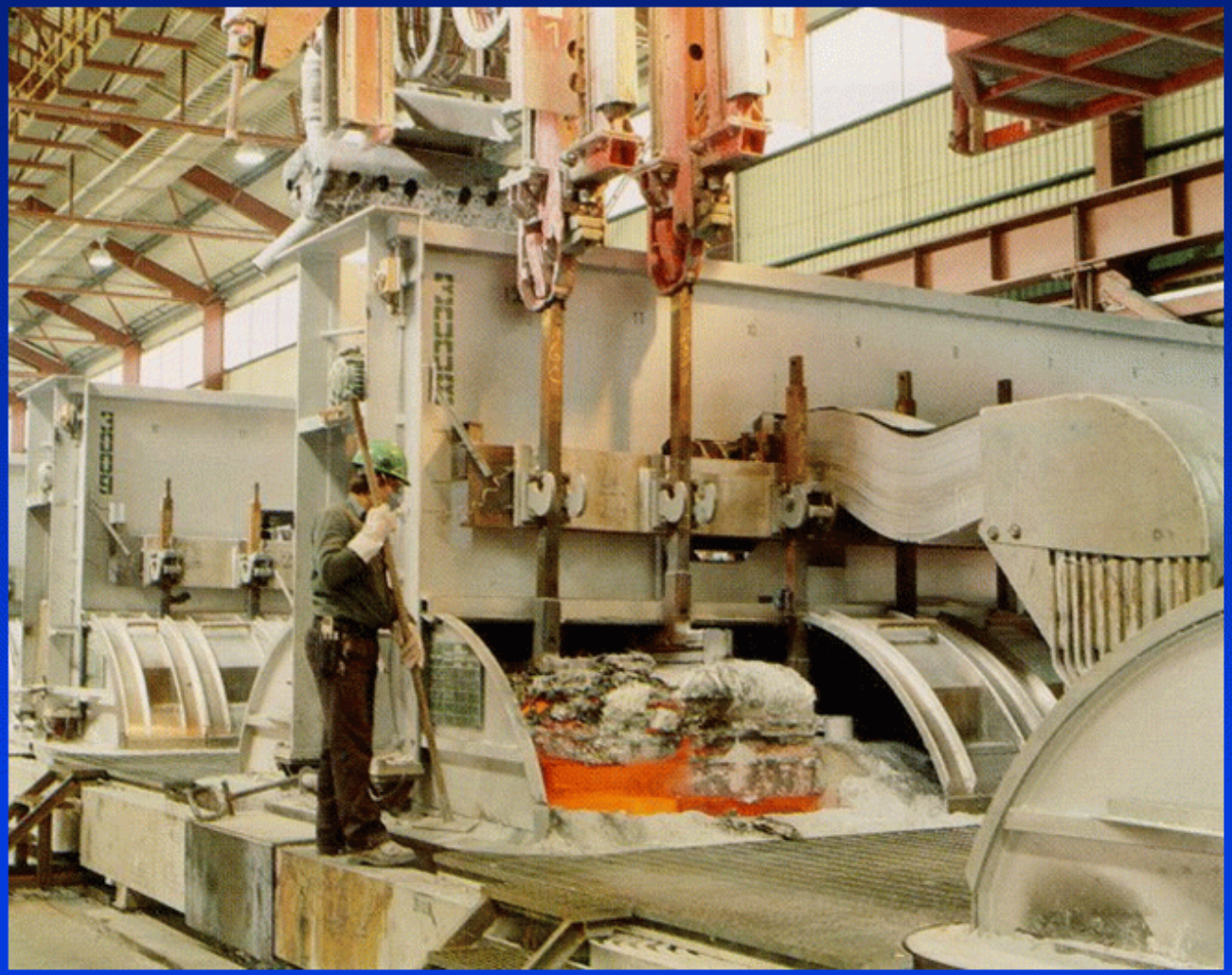
- ANSYS® version 12.0 based Thermo-Electro-Mechanical (TEM) Cathode Collector Bar Slot Model Development
- Base Case Model
- Base Case Model, Finer Mesh
- Same Slot, Higher Collector Bar
- Same Slot, Higher and Wider Collector Bar
- New Slot Design, Higher and Wider Collector Bar
- New Collector Bar Aspect Ratio
- Two Collector Bar Slots per Block
- Conclusions

The Aluminum Reduction Cell



Aluminum reduction cells are very complex to model because it is a truly multi-physics modeling application involving, to be rigorous, a fusion of thermo-electro-mechanic and magneto-hydro-dynamic modeling capabilities in a complex 3D geometry

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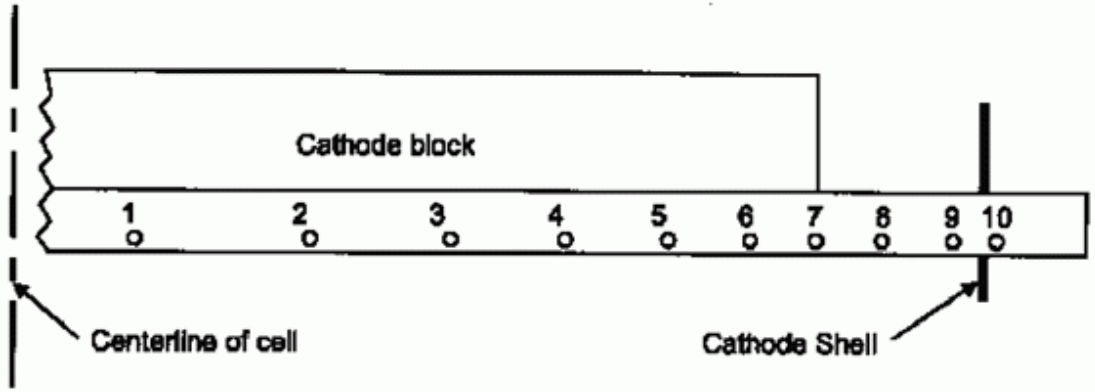
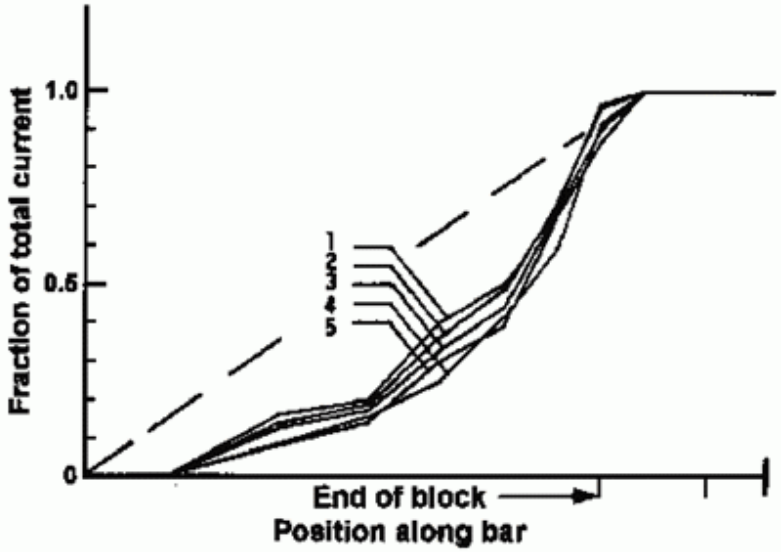
1985, Instrumented Collector Bar Setup



Position of thermocouples and voltage probes along the bar



Current pick-up along collector bar after 1, 2, 3, 4 and 5 months of operation

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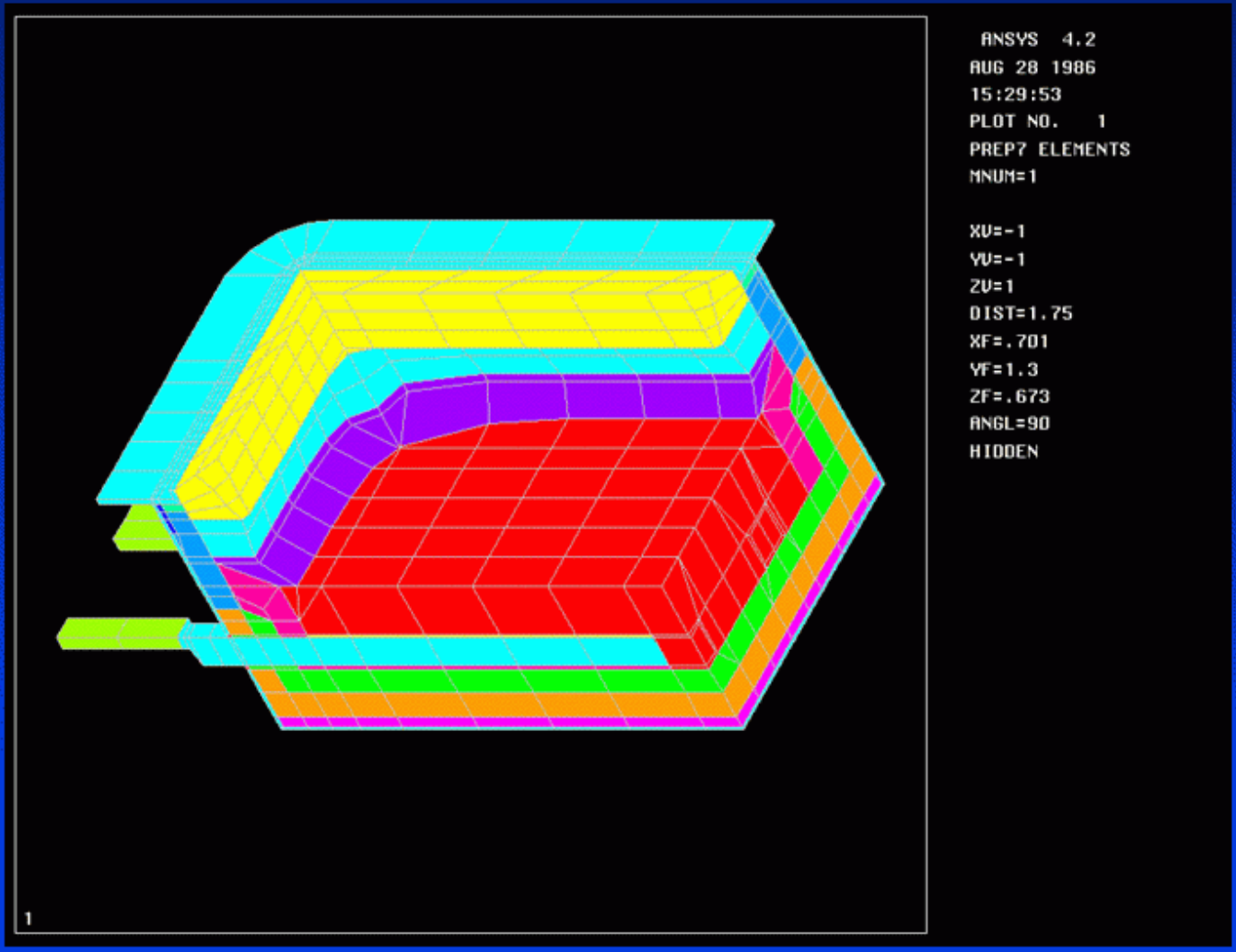
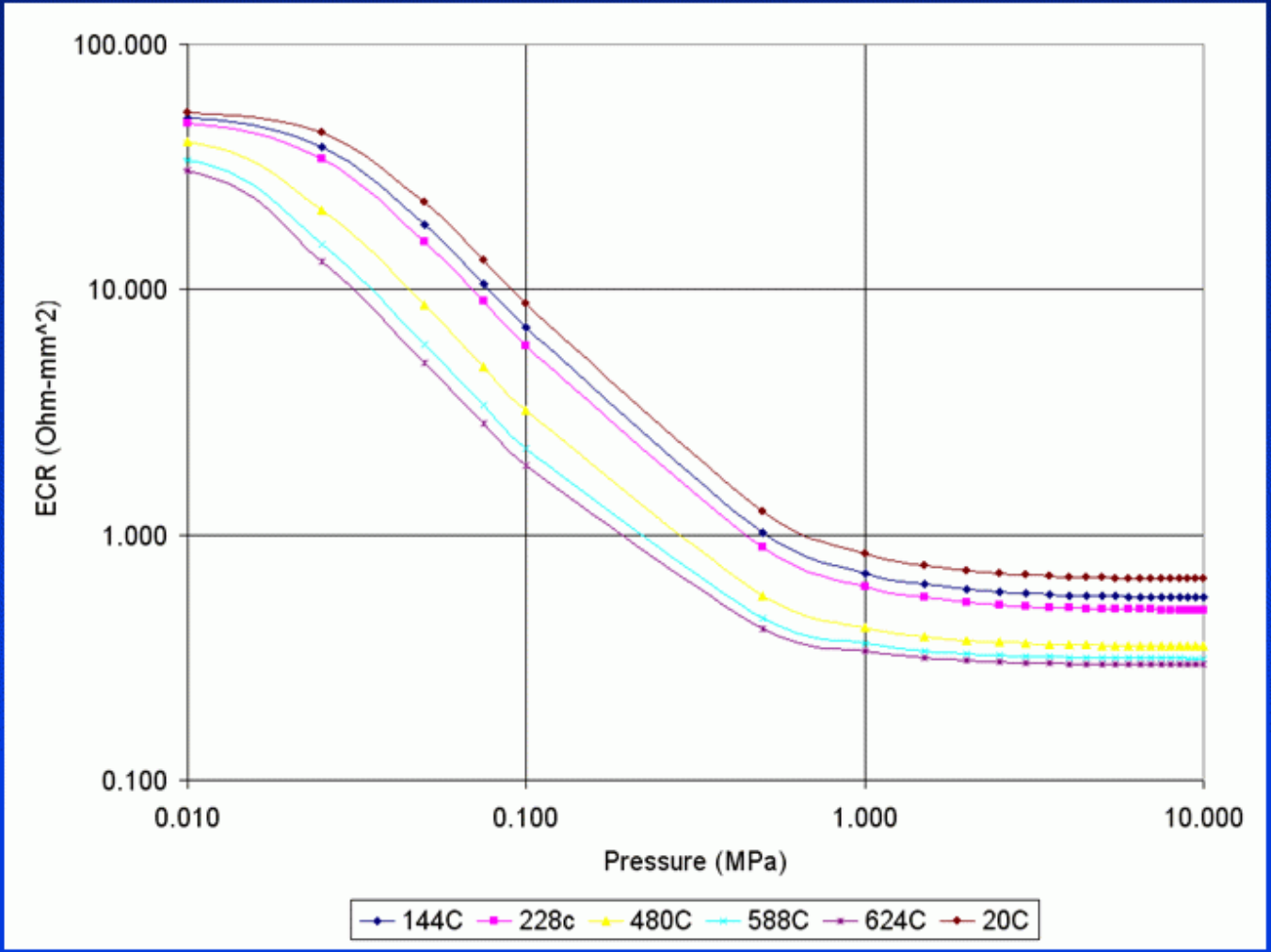
1986, 3D Thermo-electric Cathode Side Slice and Cathode Corner Model



The next step was the development of a 3D cathode side slice thermo-electric model that included the calculation of the thickness of the solid electrolyte phase on the cell side wall .

Despite the very serious limitations on the size of the mesh, a full cathode corner was built next .

Historical Background



It was measured that the contact resistance is strongly dependent on the applied pressure at the contact interface.

Richard conveniently fitted the raw data into a 12 parameter equation that is function of both pressure and temperature.

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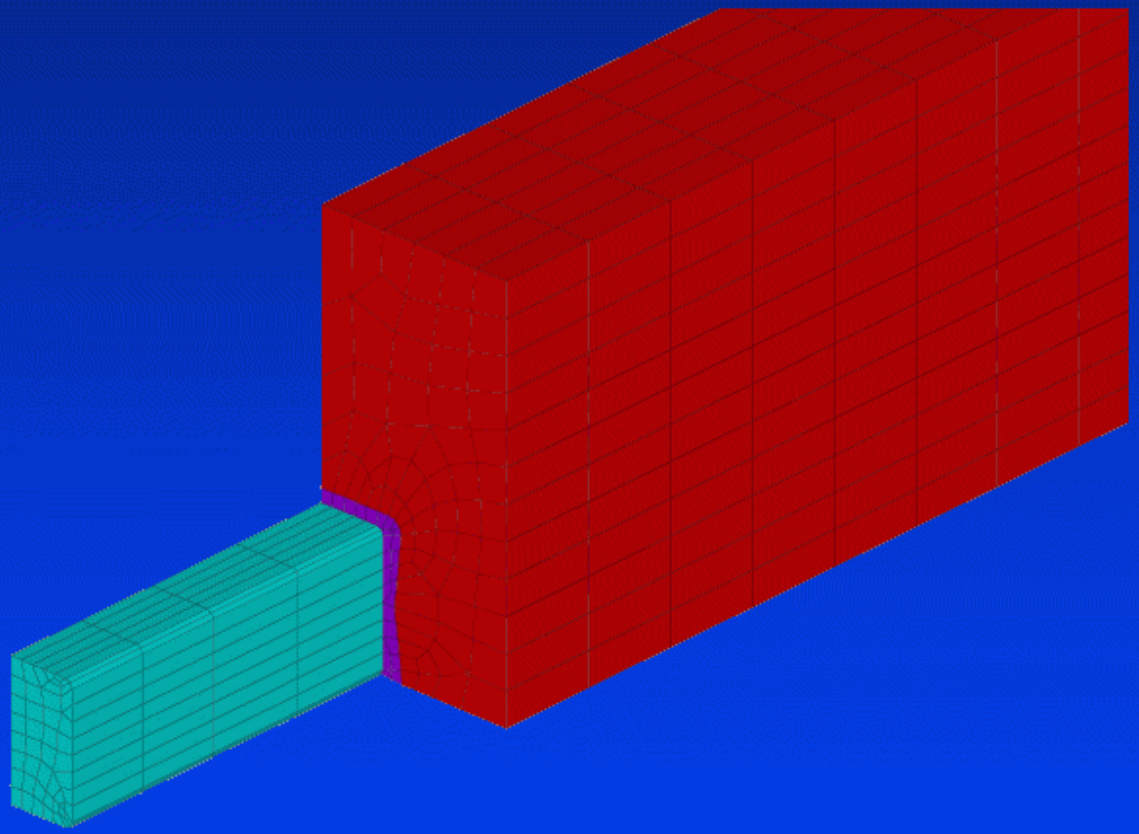
ANSYS® version 12.0 based Thermo-Electro-Mechanical (TEM) Cathode Collector Bar Slot Model Development



An ANSYS® version 12.0 based fully coupled TEM cathode collector bar slot design tool based on the usage of SOLID226 3D thermo-electro-mechanical second order element together with CONTA174 and TARGE170 thermo-electro-mechanical contact pair elements have now been developed.

CONTA174 element supports the setup of a pressure and temperature TCC (thermal contact conductance) and ECC (electrical contact conductance) values through the %table% option.

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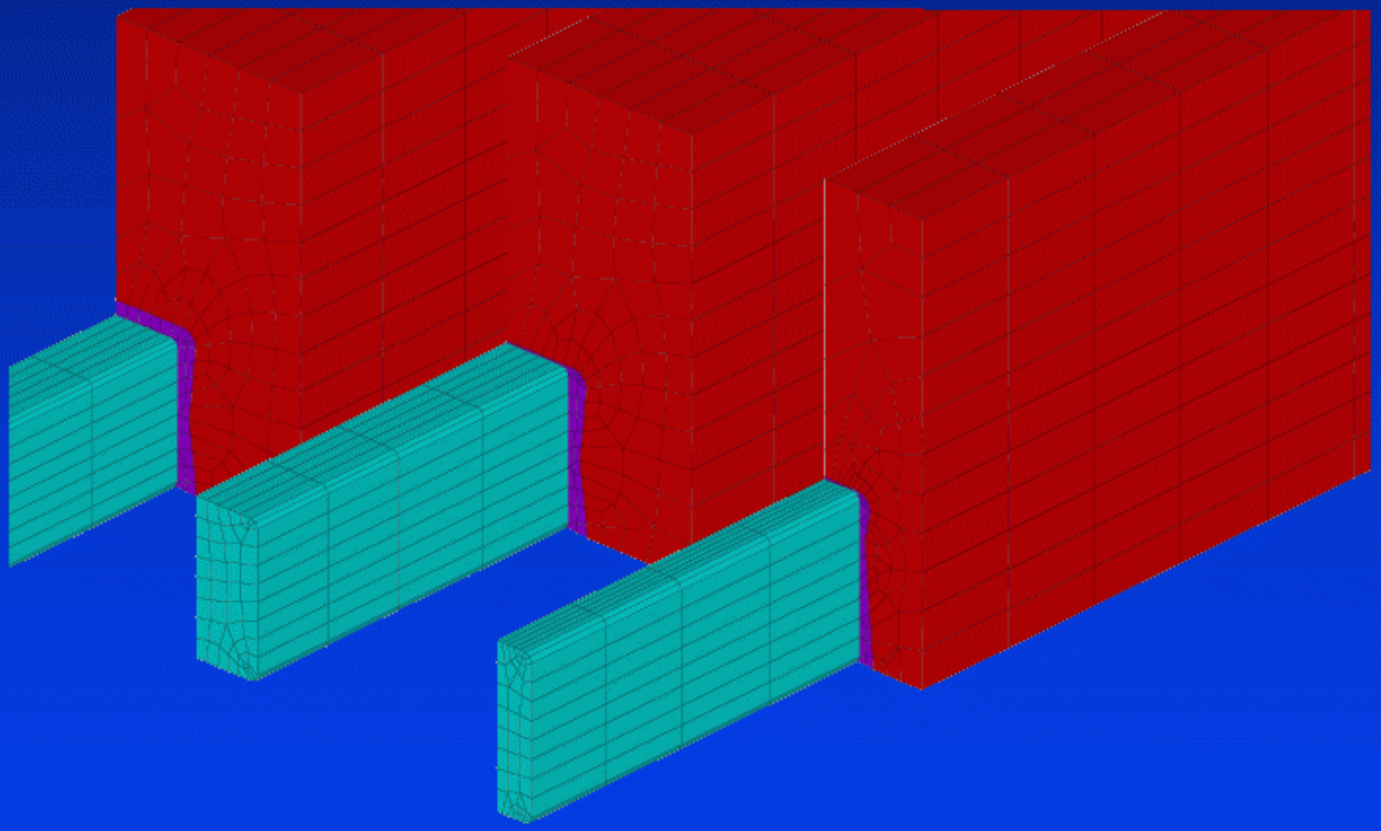
ANSYS® version 12.0 based Thermo-Electro-Mechanical (TEM) Cathode Collector Bar Slot Model Development



Having all the required components to model the complex collector bar cast iron/anode carbon contact resistance complex physics in ANSYS® version 12.0, it was quite straightforward to take advantage of the classic ANSYS® parametric design language (APDL) to develop demonstration cathode collector bar slot models and to use them as efficient collector bar slot design tools.

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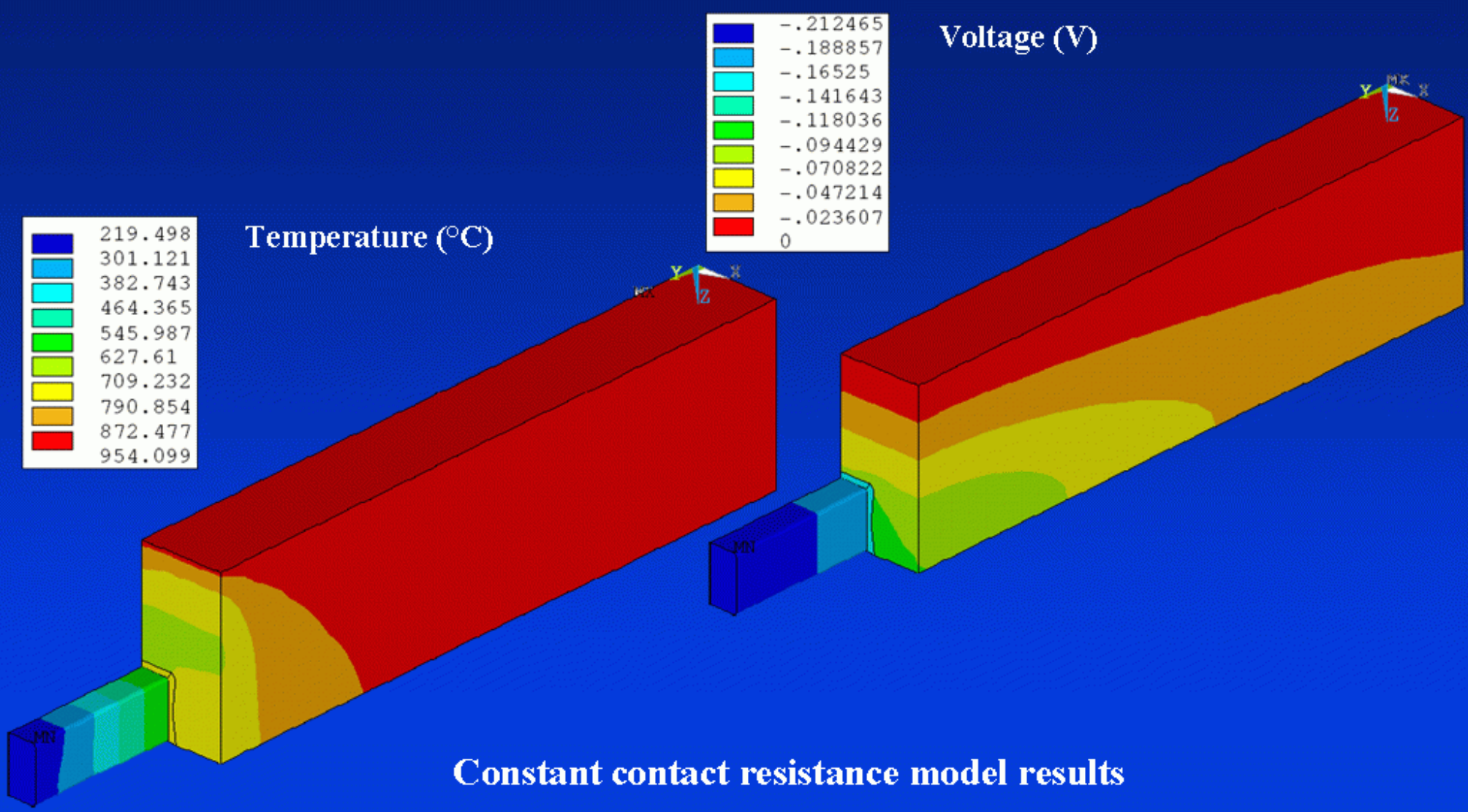
Base Case



Constant contact resistance model results

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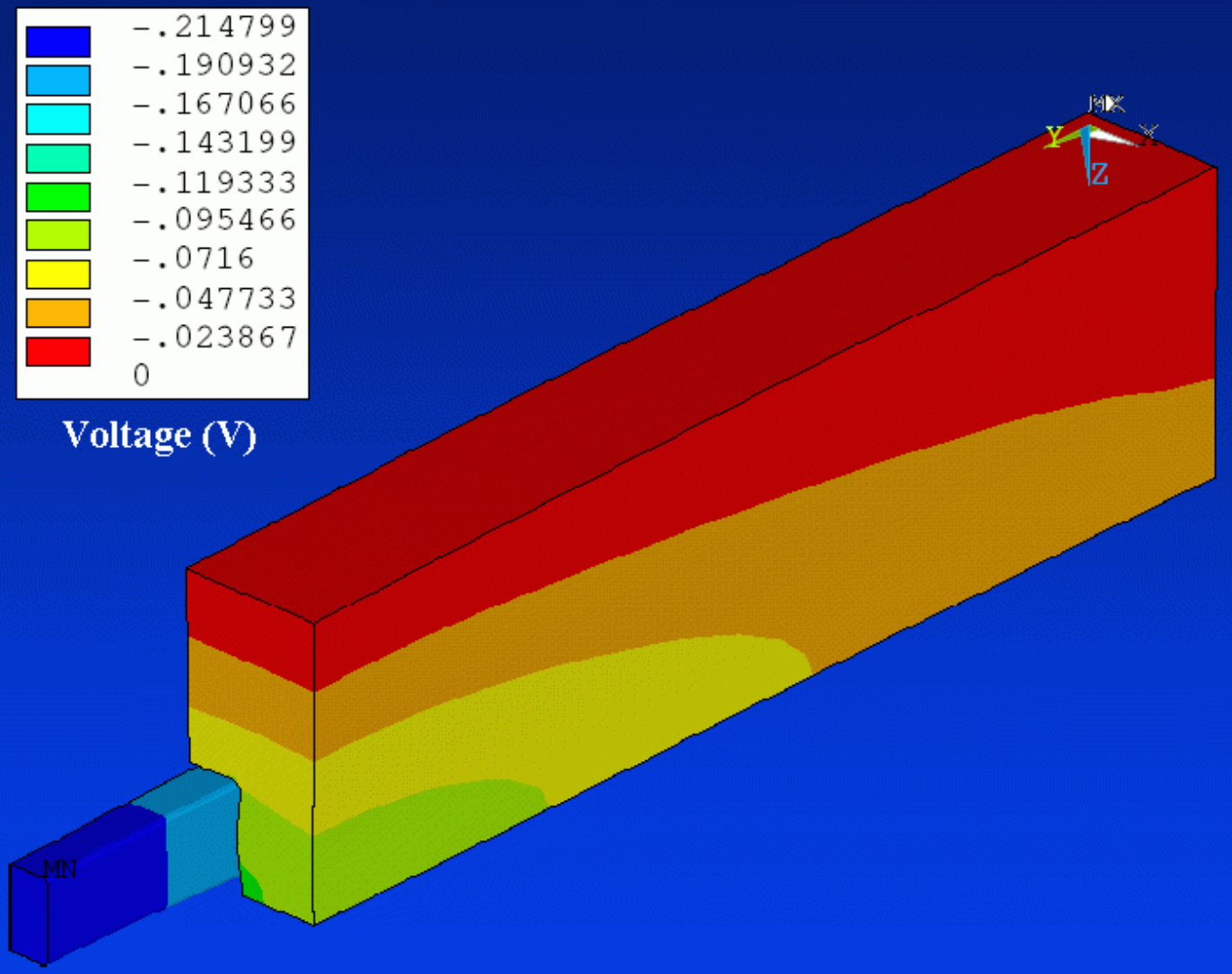
Base Case



Pressure and temperature dependent contact resistance model results

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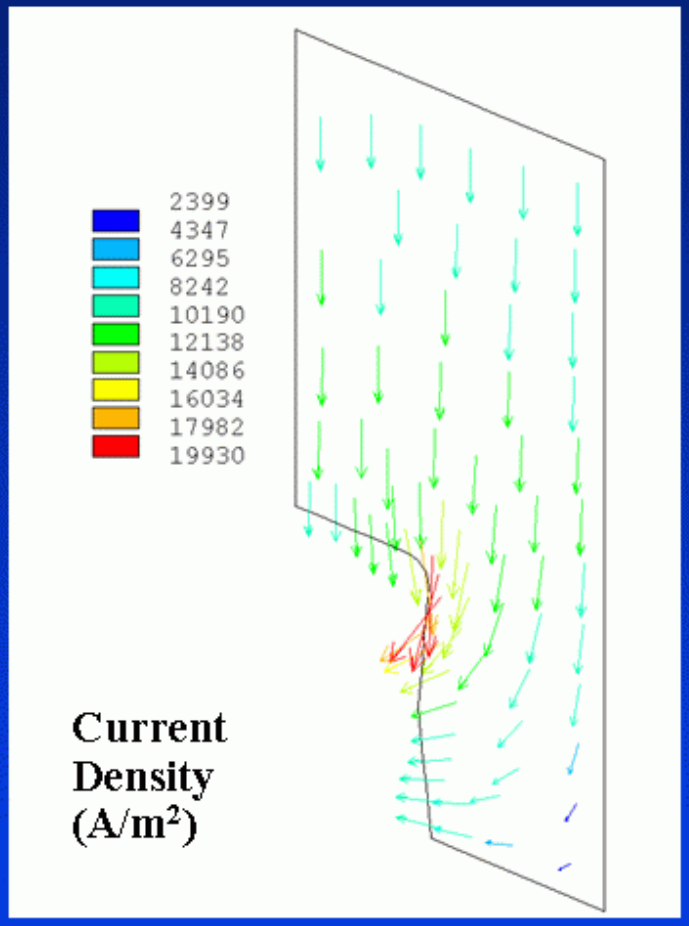
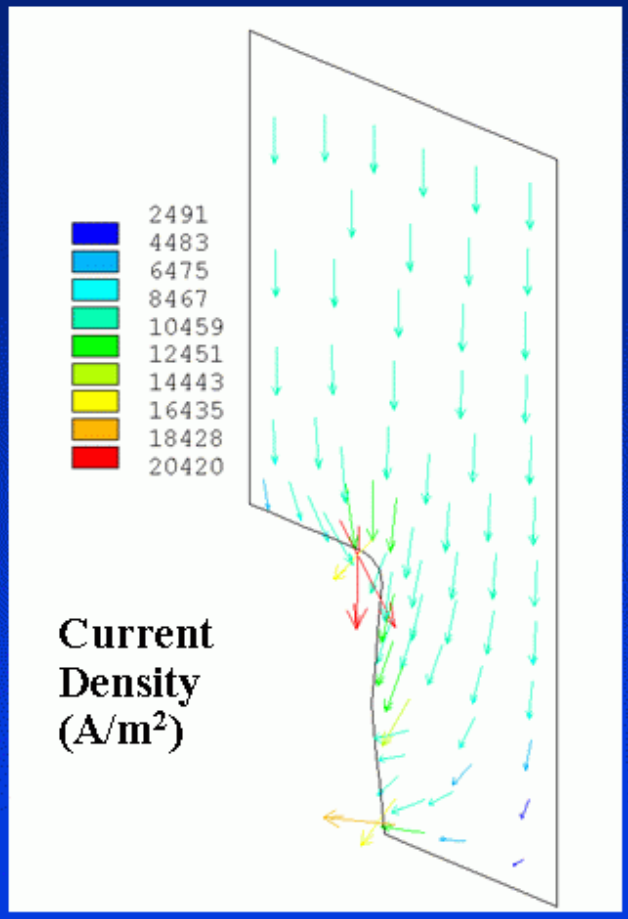
Base Case



Constant contact resistance model results



Pressure and temperature dependent contact resistance model results

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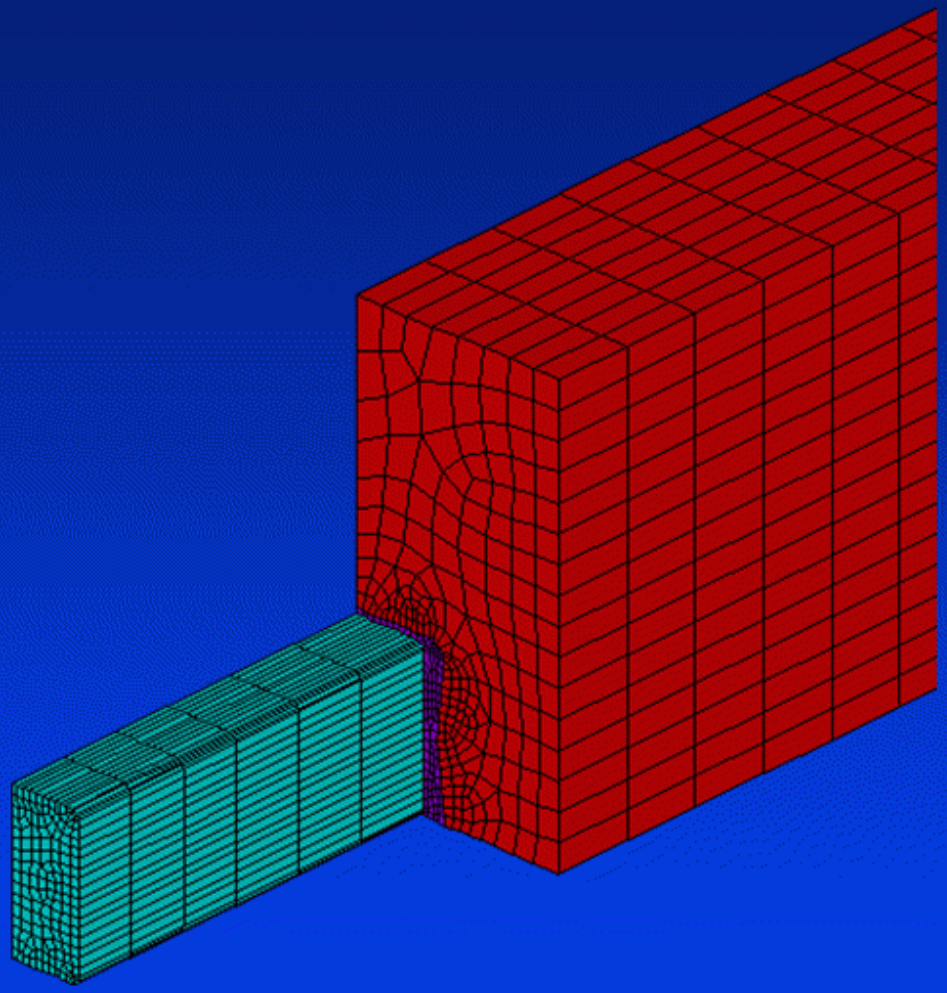
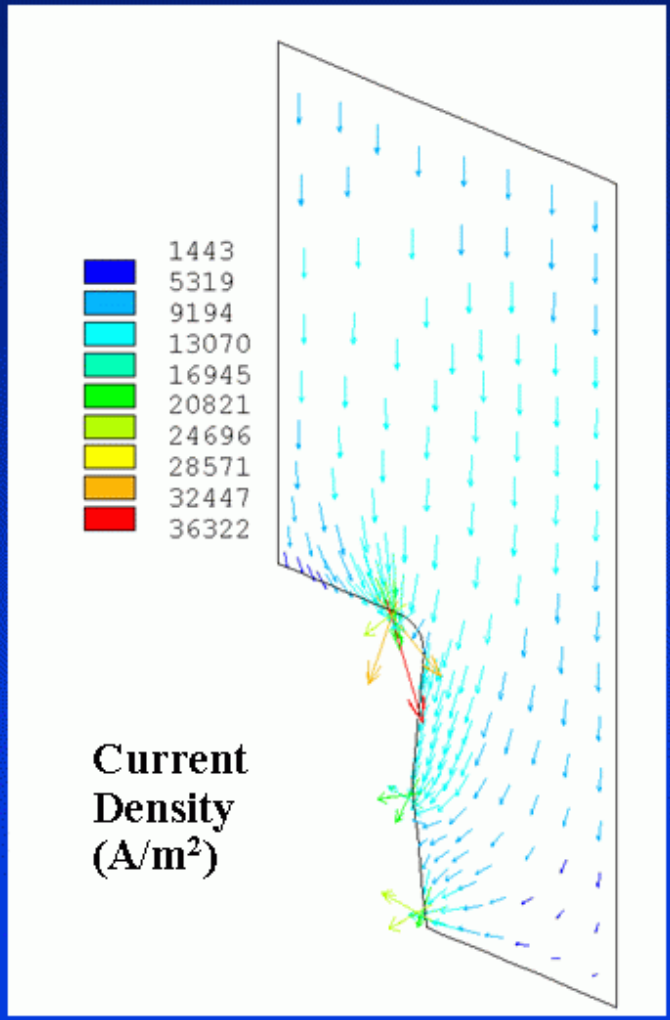
Base Case, Finer Mesh





Pressure and temperature dependent contact resistance model results

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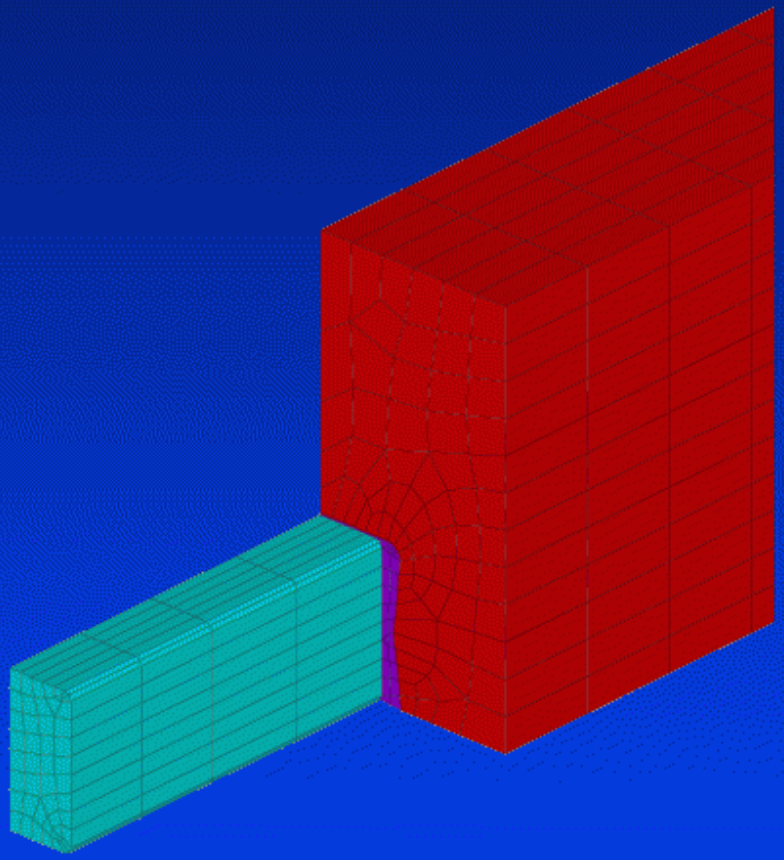
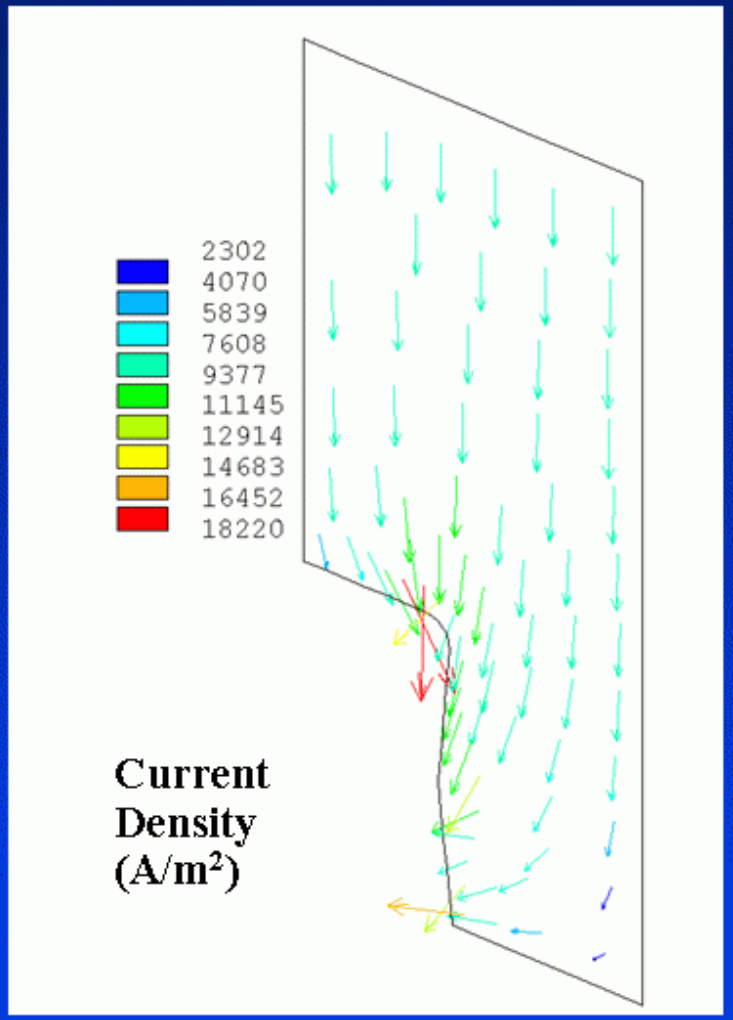
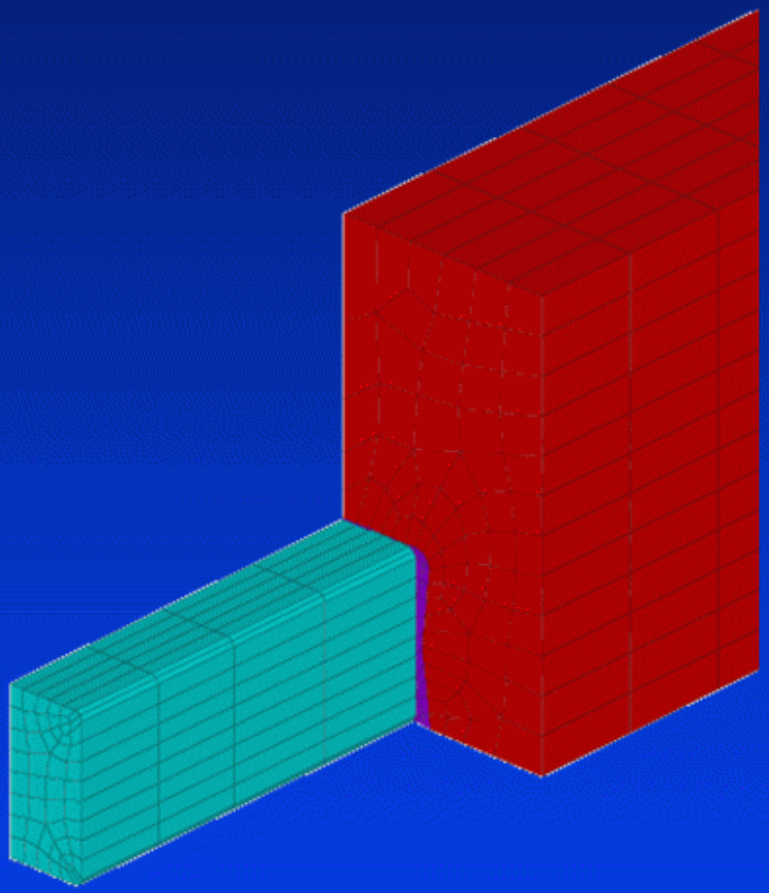
Same Slot, Higher Collector Bar

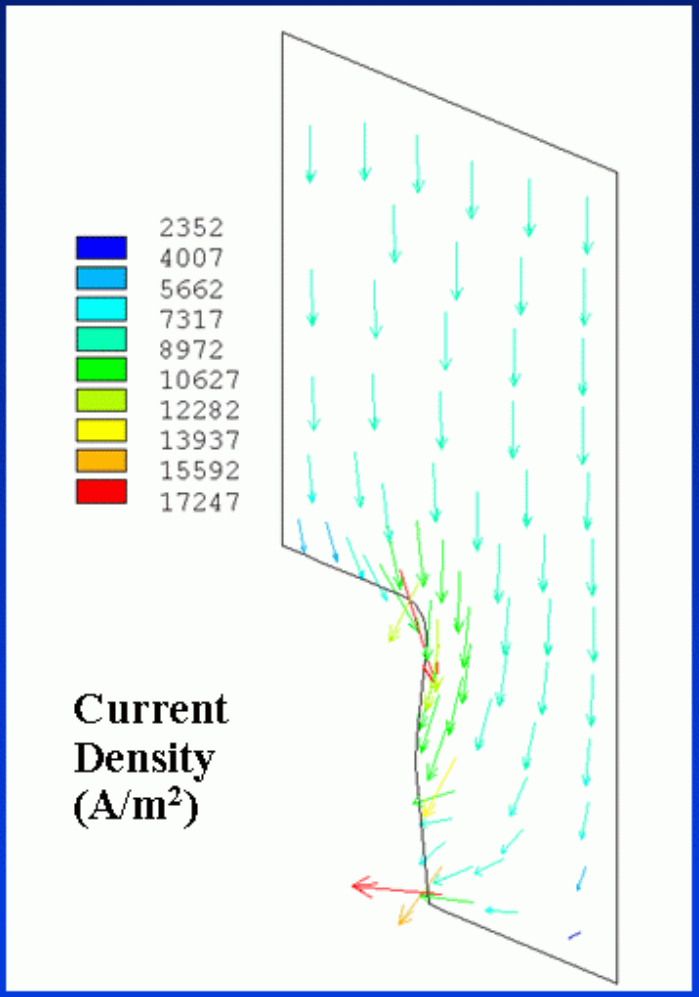




Pressure and temperature dependent contact resistance model results: 197 mV

Same Slot, Higher and Wider Collector Bar





Pressure and temperature dependent contact resistance model results: 195 mV

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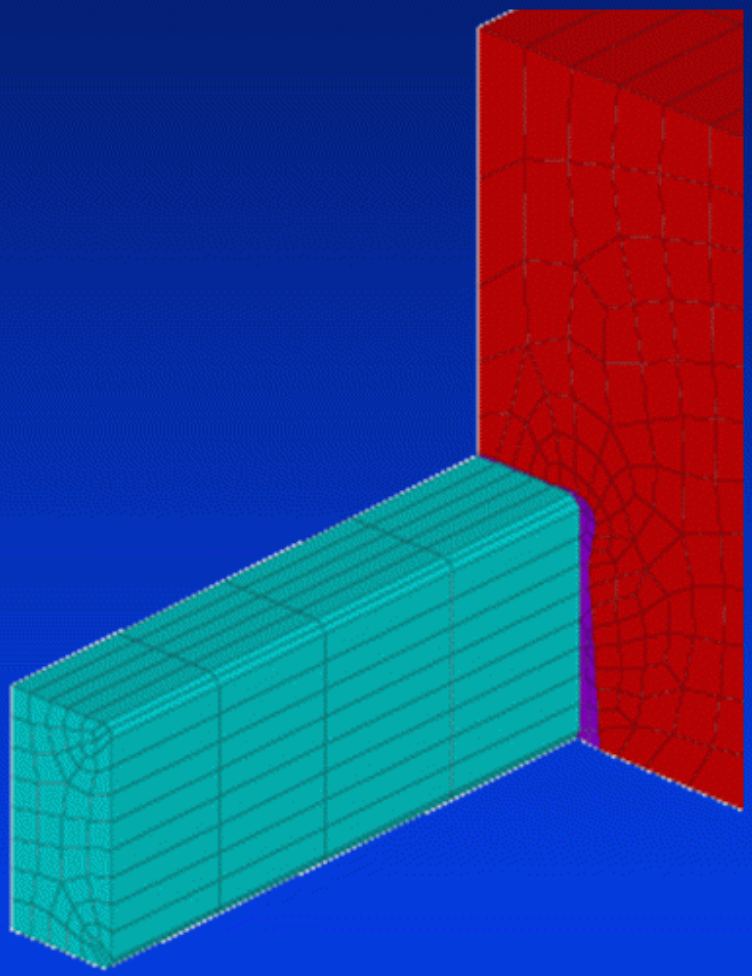
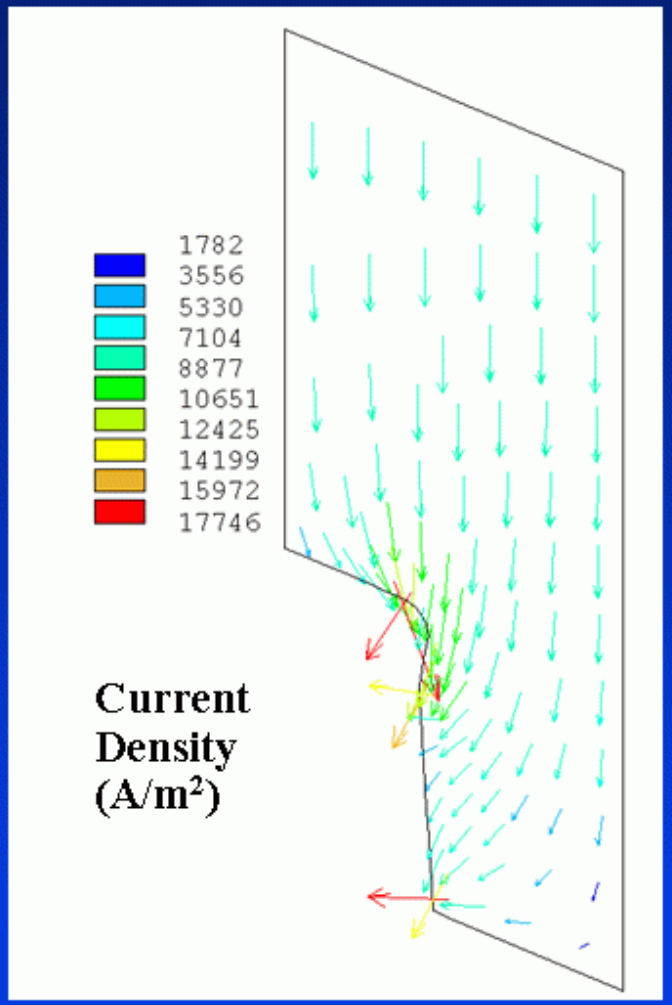
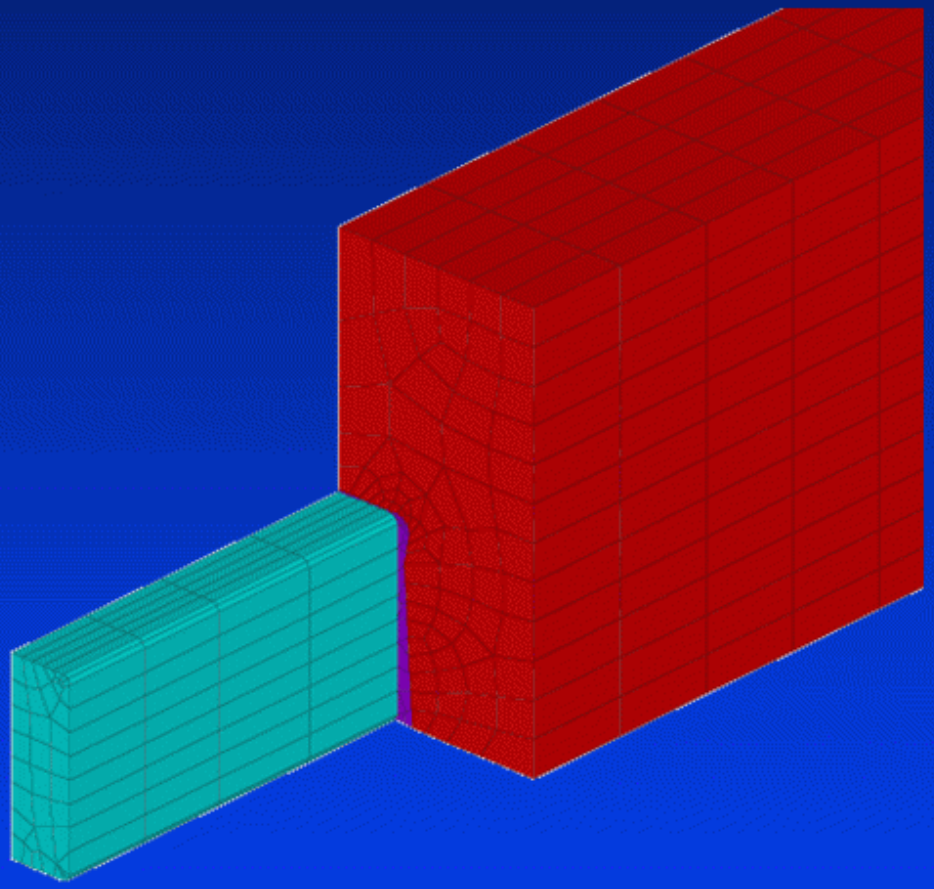
New Slot Design, Higher and Wider Collector Bar

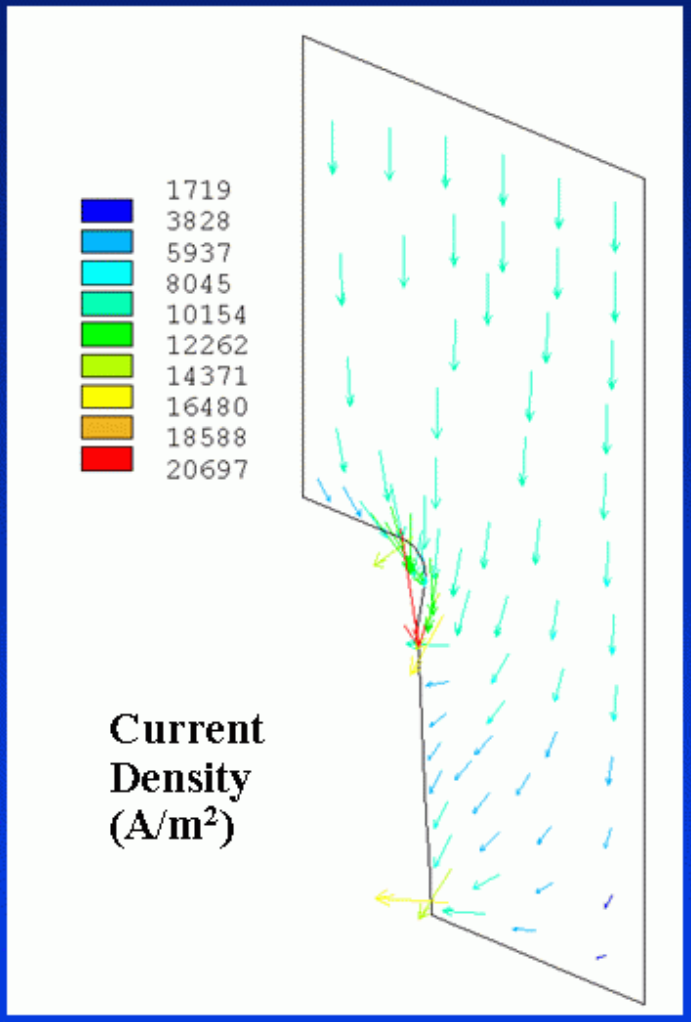




Pressure and temperature dependent contact resistance model results: 192 mV

New Collector Bar Aspect Ratio





Pressure and temperature dependent contact resistance model results: 187 mV

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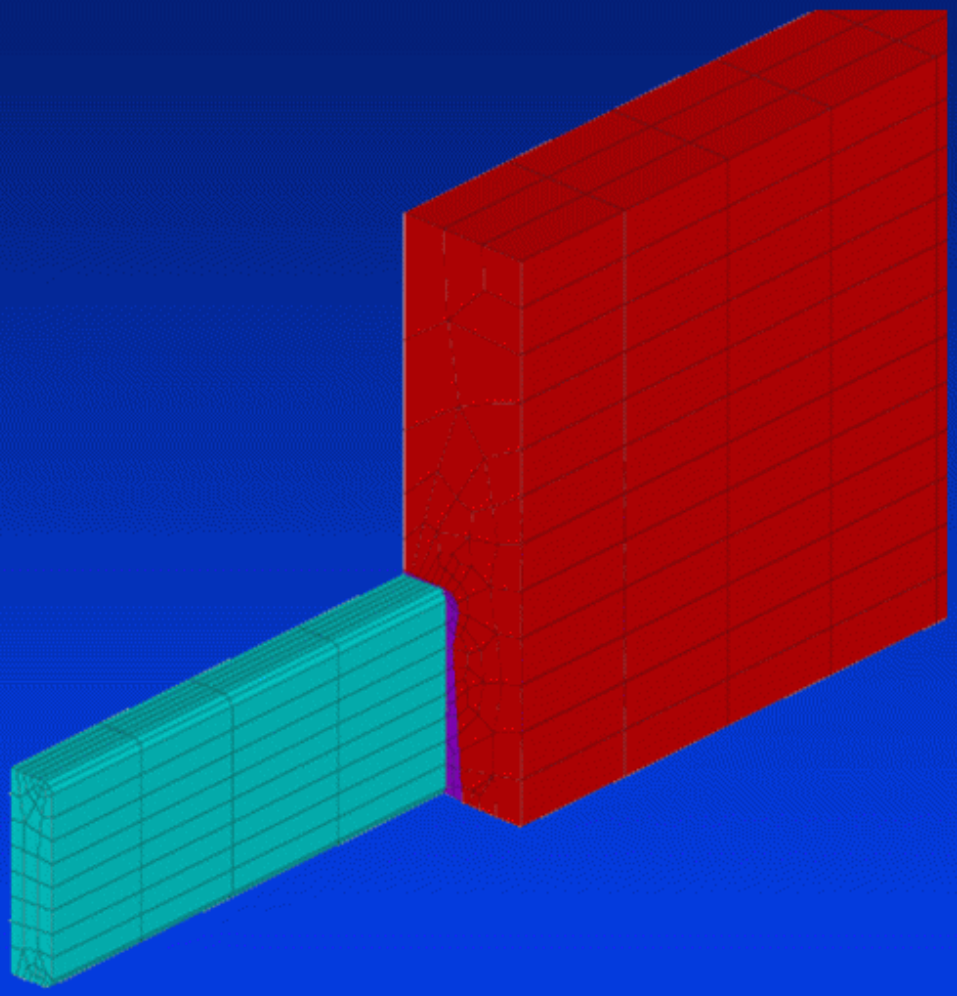
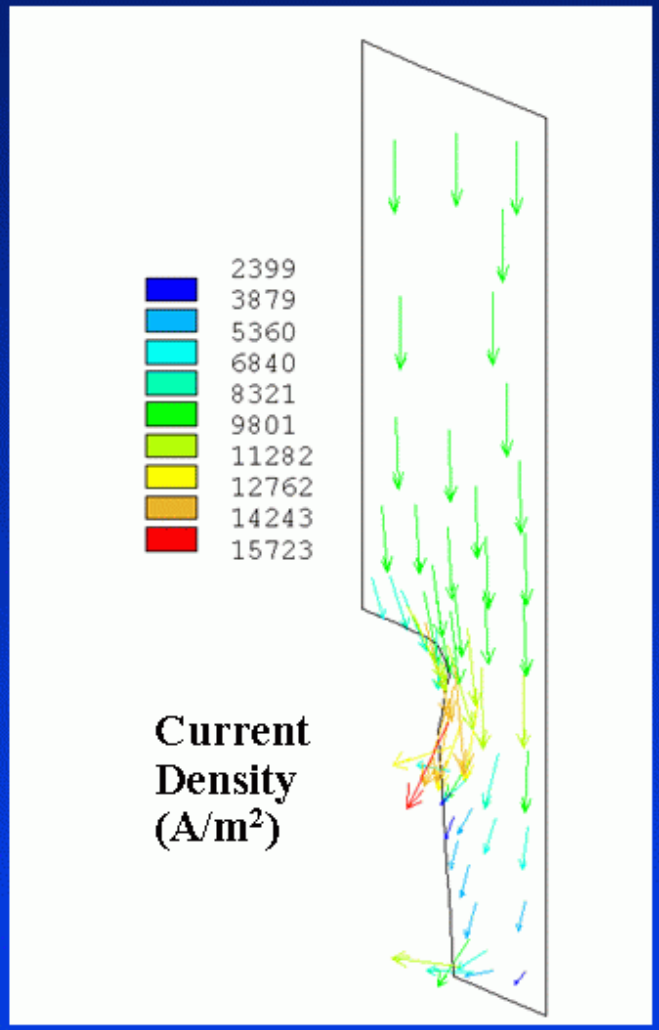
Two Collector Bar Slots per Block





Pressure and temperature dependent contact resistance model results: 172 mV

Conclusions

- An ANSYS® version 12.0 based fully coupled TEM collector bar slot design tool has been successfully developed and is now available to the whole aluminium industry through GeniSim Inc.
- The ANSYS® based APDL model is parametric, which means that for a given model topology, it is possible almost instantaneously to edit the APDL model input file to change the model geometry and submit another run.
- The finer mesh quarter block model presented here solves in only around 5200 CPU seconds on a 64 bits dual core Intel Centrino T 9300 Cell Precision M6300 portable computer running ANSYS® 12.0 version. So this parametric ANSYS® based TEM collector bar slot model is a very efficient tool to study alternative collector bar and collector bar slot design.
- A very quick design optimization study has revealed that it is possible to reduce the cathode lining drop of a typical single collector bar slot per block design having a square collector bar section of 160 mm x 160 mm by 40 mV or about 19%. This is done by keeping the same amount of carbon above the collector bar by shifting to a double collector bar slots per block design.