Calculation No: NSTXU-11-11-00 **Revision No: 0**

Electromagnetic Load Calculation for CSA tiles Row 5 and Row 6

Purpose of Calculation:

To determine the electromagnetic loads on CSA tiles Row 5 and Row 6 due to interaction with plasma and background magnetic field.

Codes and versions:
Internal PPPL guidelines and acceptance criteria were used. See NSTXU-CALC-11-08-00 for details.

References:
1. NSTXU-CALC-11-08-00
2. NSTX-U-RQMT-RD-003-00_Disruptions

Assumptions:

1) The value of peak background fields and peak dBdts were taken from NSTXU-CALC-11-08-00. All assumptions described in the fields and dBdts document are valid for this analysis.

2) As described in the disruptions requirements document NSTX-U-RQMT-RD-003-00_Disruptions, halo currents are assumed to strike in a toroidal band of 20 cm poloidal width. The halo current incident on each tile was factored based on poloidal width of the tile.

3) Current is assumed to flow thru the conducting support structure into the casing. The casing face was grounded (zero volts) to represent this current flow.

Calculation:

This report documents the calculation for Halo Loads and Eddy Moments for CSA tiles Row 5 and Row 6 due to plasma strike and background magnetic field.

Conclusion:
EM loads have been calculated. There is no specific requirement for load values but the loads may be imported into a structural model to determine the stresses resulting from these loads.

Cognizant Individual (or designee) printed name, signature, and date:

Michael Jaworski

Preparer's printed name, signature and date:

Wassee Syed Wassee Syed Digitally signed by Wassee Syed Date: 2018.09.27 15:27:34 -04'00'

I have reviewed this calculation and, to my professional satisfaction, it is properly performed and correct.

Jiarong Fang Jiarong Fang Digitally signed by Jiarong Fang Date: 2018.09.27 15:38:25 -04'00'

National Spherical Torus eXperiment - Upgrade

NSTX-U

Electromagnetic Load Calculation for CSA Tiles Row 5 and Row 6

NSTXU-CALC-11-11-0

Sep 24, 2018

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Approved By – Responsible Engineer
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NSTX-U CALCULATION

Record of Changes

Rev.	Date	Description of Changes	Revised by
0	9/24/18	Initial Release	

Table of Contents

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1 Executive Summary

This report documents the methodology and results of the electromagnetic Finite Element Analysis performed on PFCs (Plasma Facing Components) – CSA Tiles row 5 and row 6. The EM load reactions presented in this report may be imported into a Multiphysics model as inputs to determine the overall response of the PFCs when exposed to structural, thermal, and EM loading

2 Introduction

PFCs experience Lorentz forces induced by plasma disruptions. Fluctuations in electric and magnetic fields due to plasma disruptions induce eddy currents in the PFCs and the conductive support structures. Additionally, plasma contact with the PFCs may also generate halo currents. The halo currents strike the structure at one poloidal and toroidal location, flow thru the conductive structures and exit at another location.

The magnitudes and directions of the induced Lorentz loads depend on a number of factors including plasma shapes, movement, current decay, structure material properties, and geometry. Several assumptions must be made in order to determine “worst case” values for the Lorentz loads.

3 Method of Analysis

ANSYS electric and APDL were utilized for this analysis. The mesh was generated within ANSYS electric module, and the mesh file was then imported to APDL. Load application, solution and post processing were performed via ANSYS APDL.

3.1 Geometry and Materials

Figure 1 shows the labelled geometry, Coordinate System and material specifications. The material properties were taken from standard PPPL material database.

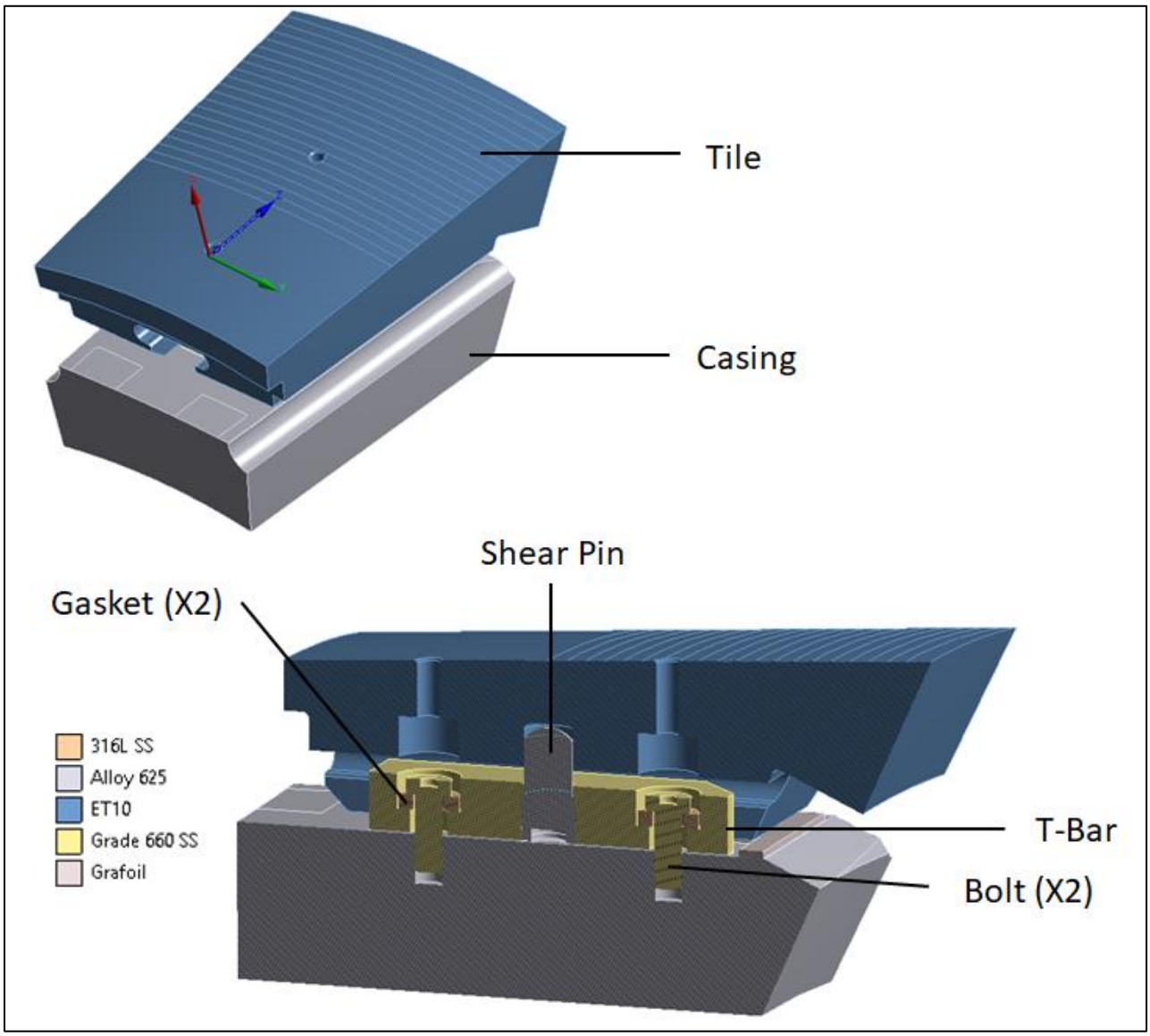

Figure 1: Row 5 Geometry, Coordinate System, and Material Specifications

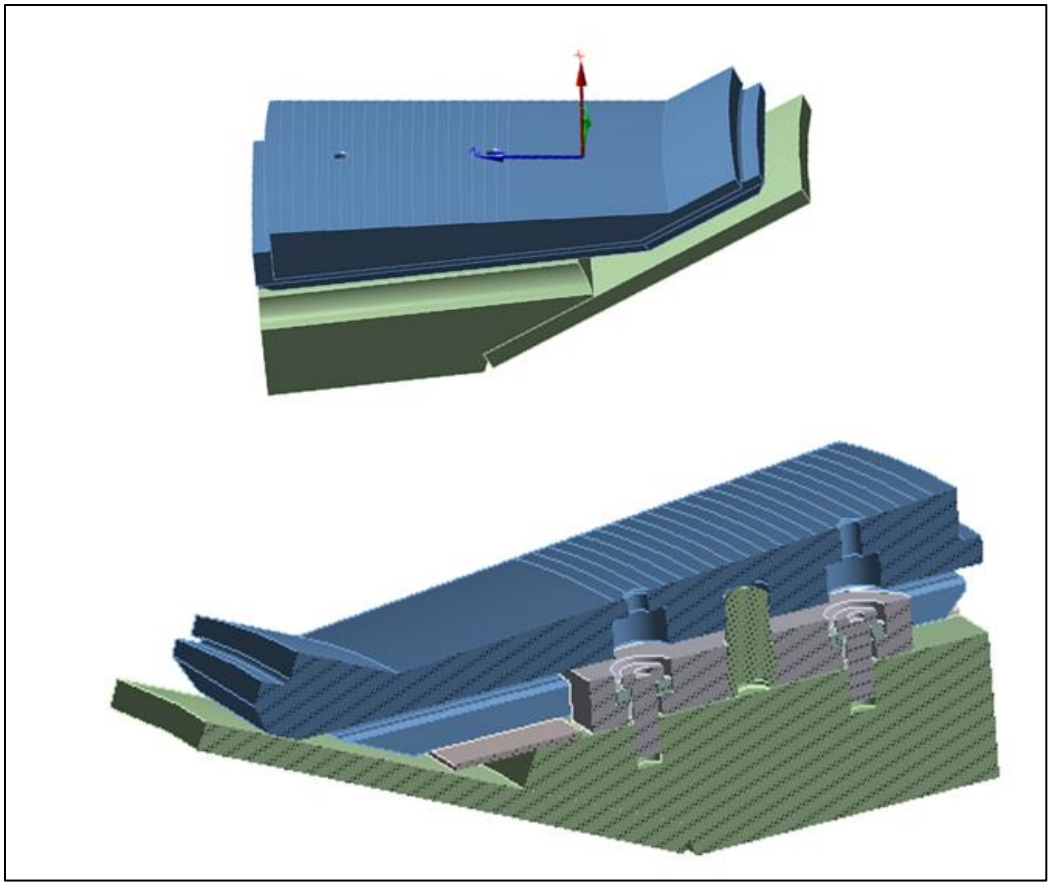

Figure 2: Row 6 Geometry and Coordinate System

3.2 Electromagnetic Analysis

3.2.1 FE Mesh

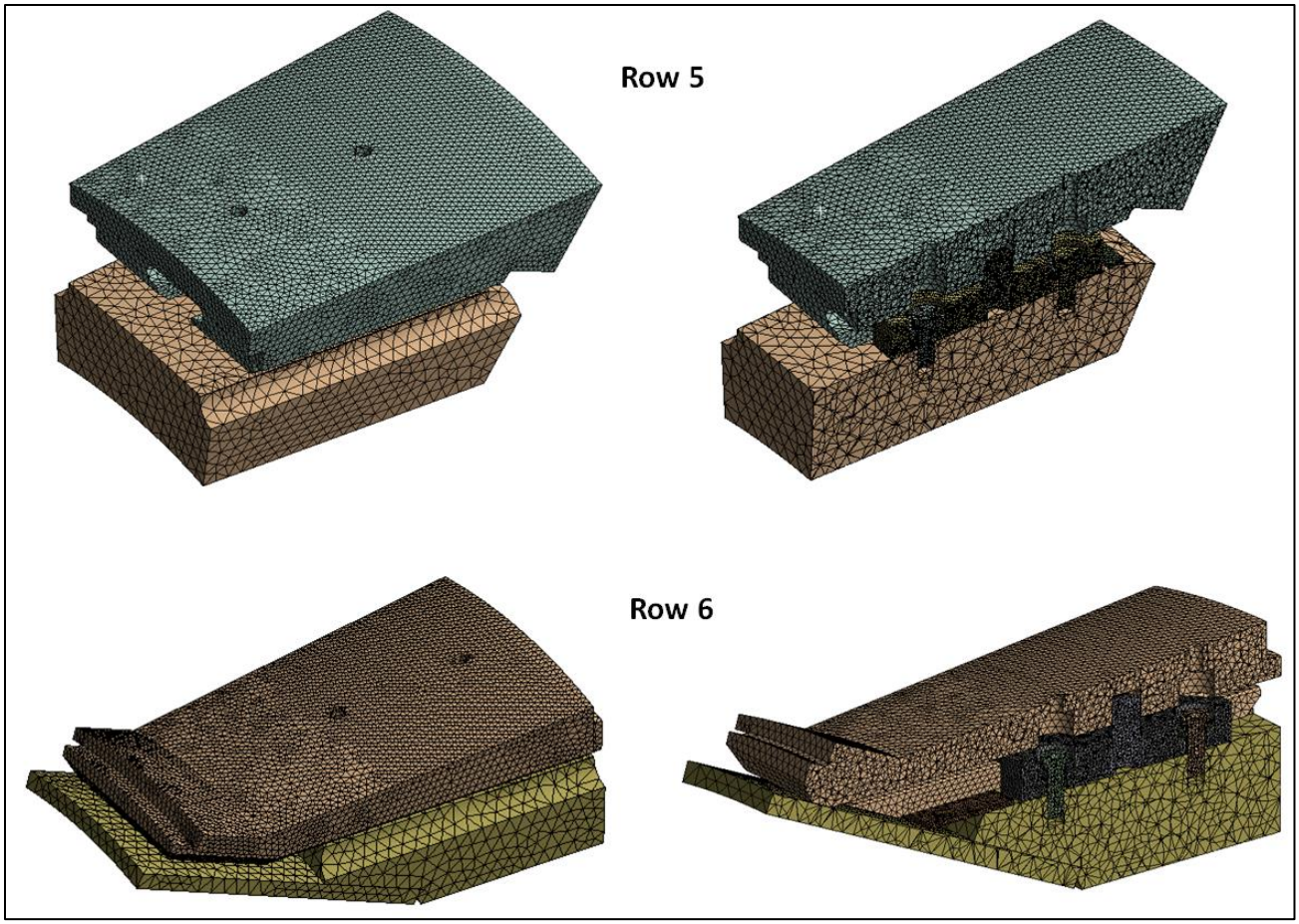

Figure 3: Row 5 and Row 6 Mesh

Figure 3 shows the mesh for rows 5 and row 6. SOLID232 (Current-based Electric Element) elements were utilized for the halo current simulation, while SOLID237 (Electromagnetic Element) elements were used for the eddy current analysis. Both are 10-node tetrahedral elements.

3.2.2 Contact Definitions

For the purpose of an electromagnetic analysis, closed frictionless / frictional and bonded contacts are essentially the same. All surface pairs originally designed to be in contact were defined as closed contacts in the electric model.

3.2.3 Boundary Conditions and Loads

Figure 4 summarizes the boundary conditions, halo strike points and input currents. Table 1 lists the magnetic field components and dB/dt values. These values and the appropriate factors for halo current calculation were taken from the fields document (NSTXU-CALC-11-08-00).

Table 1: Magnetic Field Inputs Summary

	Tile Dimensions [cm]	Nt	Final Magnetic Field Values [Tesla, T]			Field dB / dt [T/s]		
Row	Poloidal Length		Bx	By	Bz	dBx / dt	dBy / dt	dBz / dt
5	13.809	24	-0.62	2.46	1.98	574	0	-1,920
6	15.525	24	-0.65	2.83	1.93	592	0	-1,863

The input halo current was determined as follows:

Plasma Current, Ip = 2E6 Amps
Halo Current Factor, hf = 0.10
Toroidal Peak Factor, Tp = 2
Number of Tiles, Nt = 24
Poloidal length of tile, L = 13.809, 15.525 [cm]
Halo Current = Ip*hf*Tpf*L / (Nt*20)

Figure 4 shows the current and ground application for CSA rows 5 and 6.

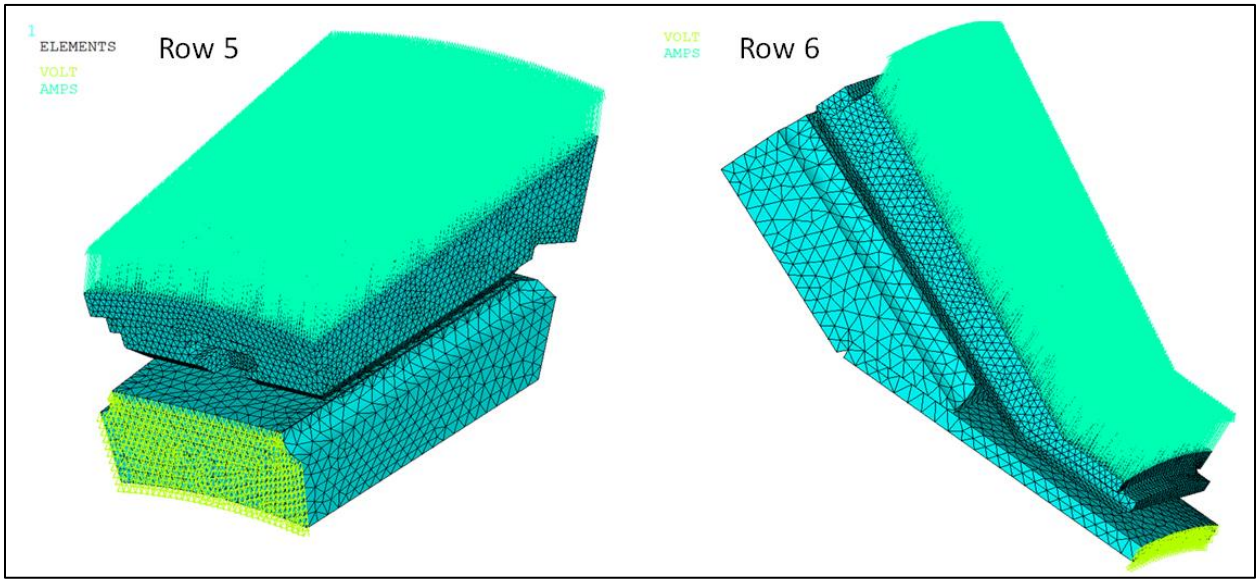

Figure 4: Boundary Conditions and Load

3.2.4 Results

Table 2: Loads and Moments Summary

Tile	Fx [N]	Fy [N]	Fz [N]	Mx [N.M]	My [N.M]	Mz [N.M]
CSA 5	472	859	-897	-3.03	-25.6	37.7
CSA 6	-393	291	-952	-4.52	-19.0	31.4

Table 2 lists the halo forces and eddy moments experienced by the tiles (See Figure 1 and Figure 2 for coordinate system). The halo forces shown are the sum of all the nodal forces in the tiles. These are provided for reference only. The nodal force information (Node coordinates, Fx, Fy, Fz, volume, body force densities) was output to a text file. The body force densities are defined as nodal force / nodal volume, and may be imported to a Multiphysics model to study the effect of combined loading (structural, thermal and electromagnetic).

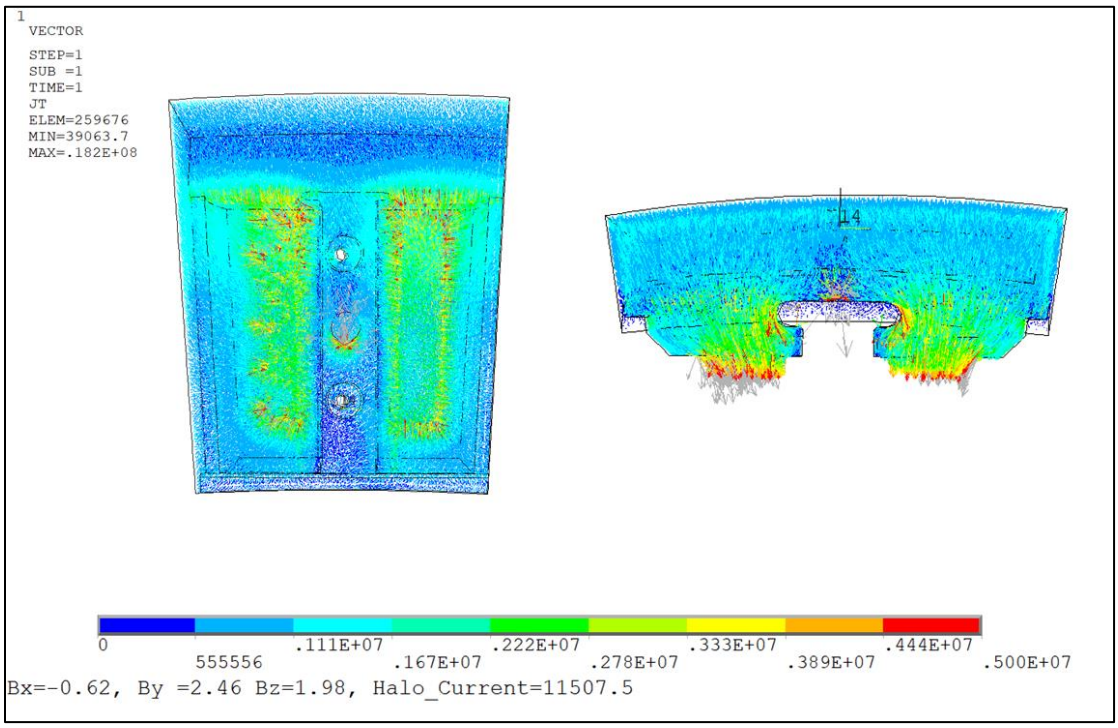

Figure 5: Halo Current Density, Row 5

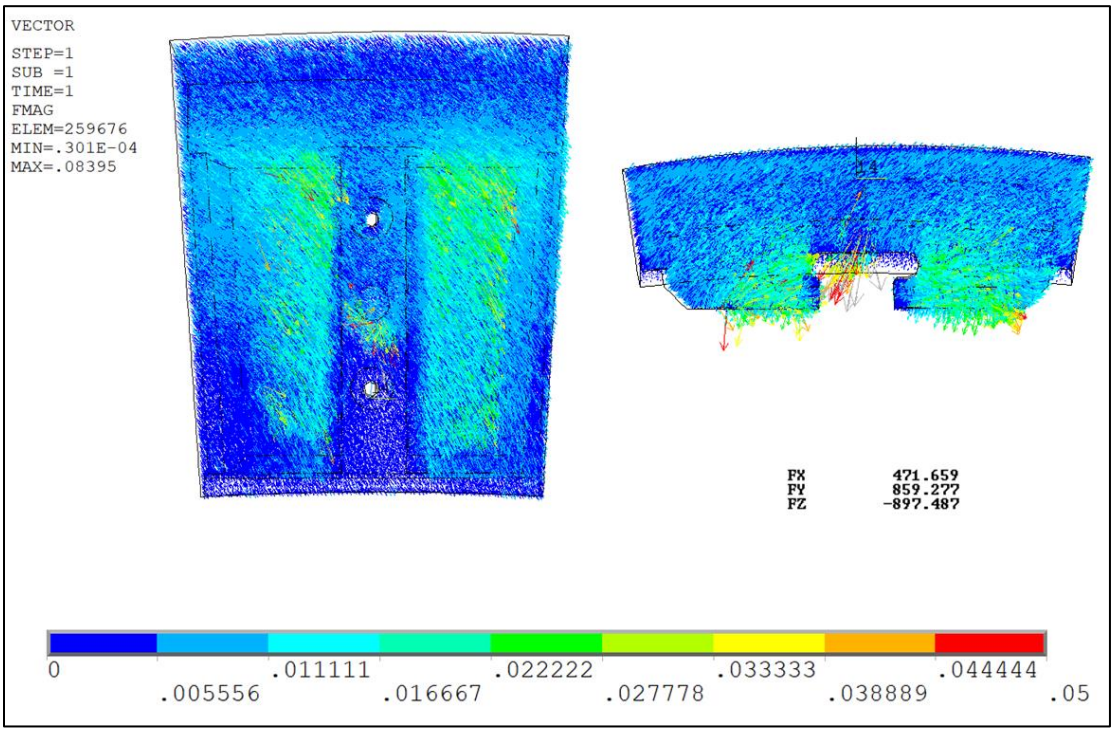

Figure 6: Halo Current EM Load distribution, Row 5

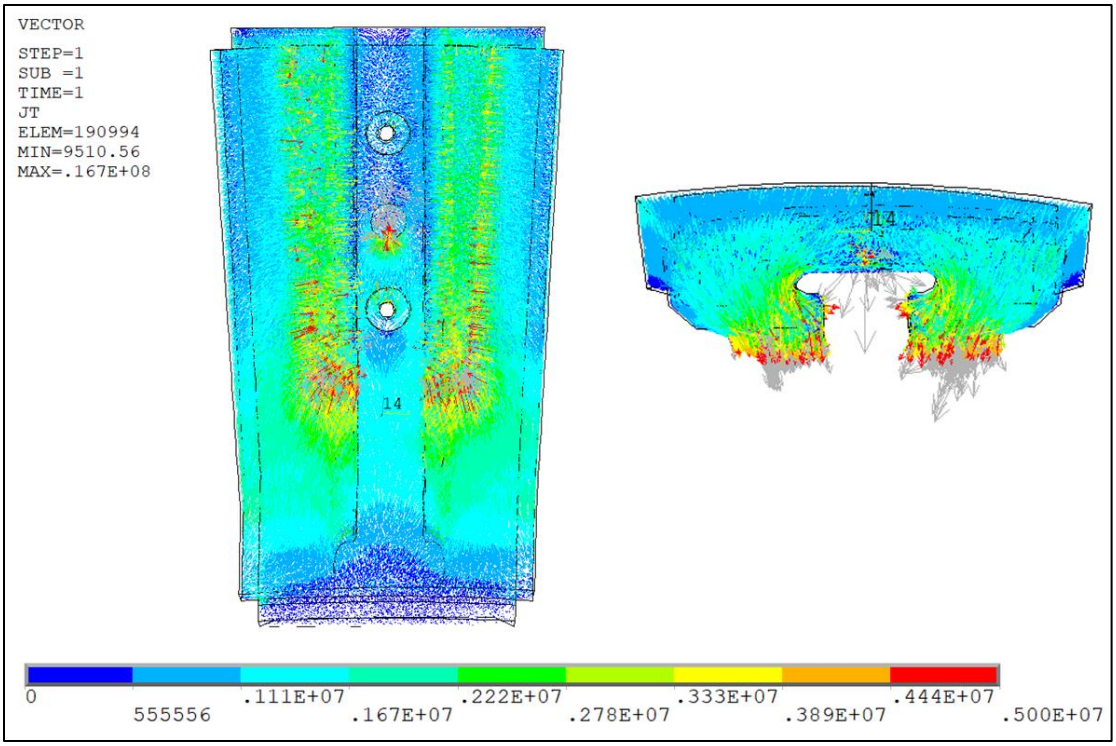

Figure 7: Halo Current Density, Row 6

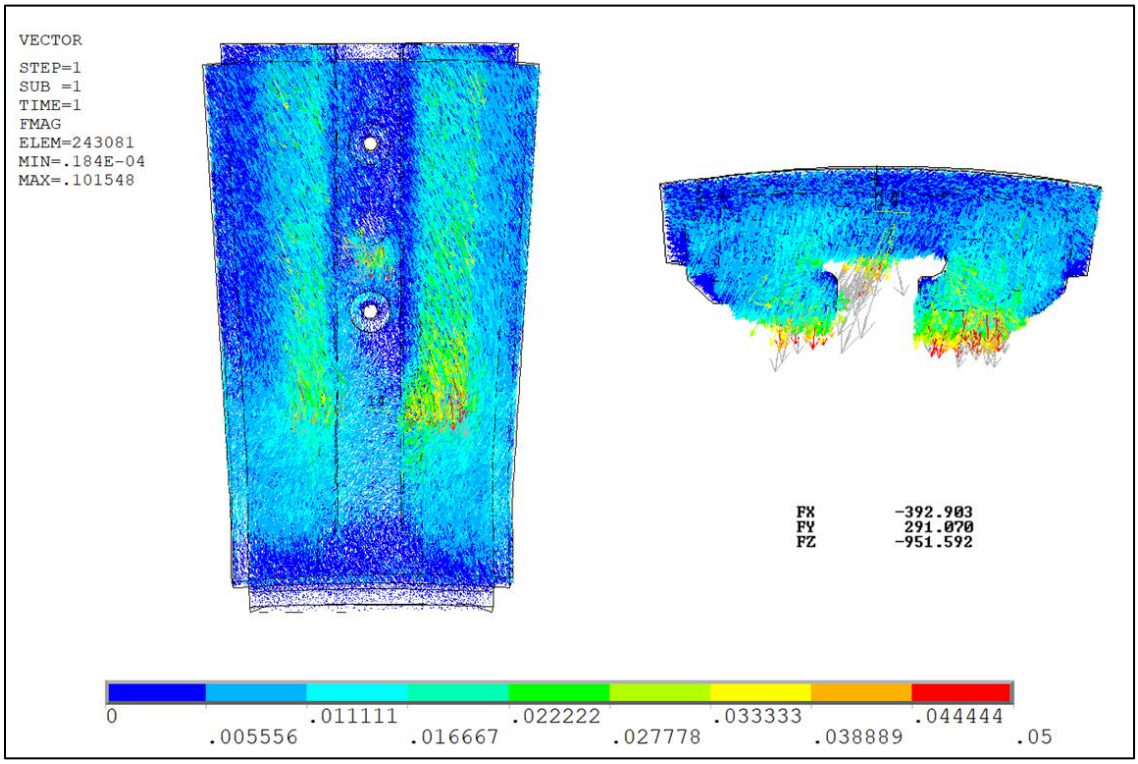

Figure 8: EM Load Distribution, Row 6

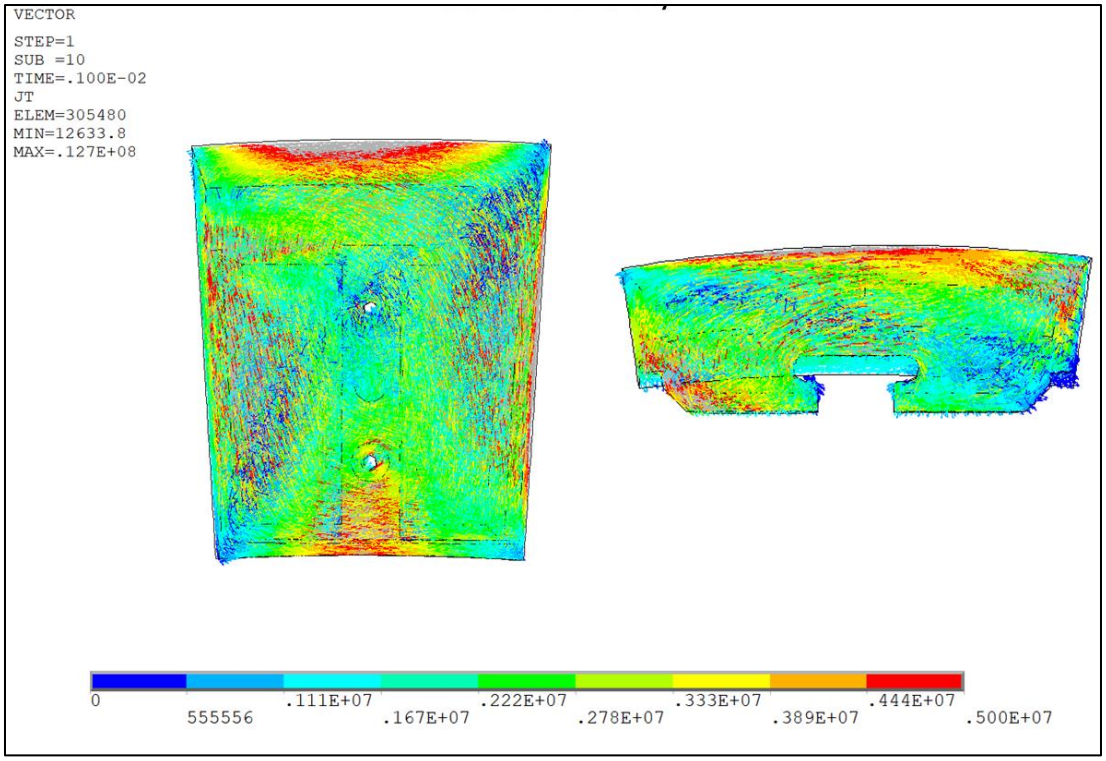

Figure 9: Eddy Current Density, Row 5

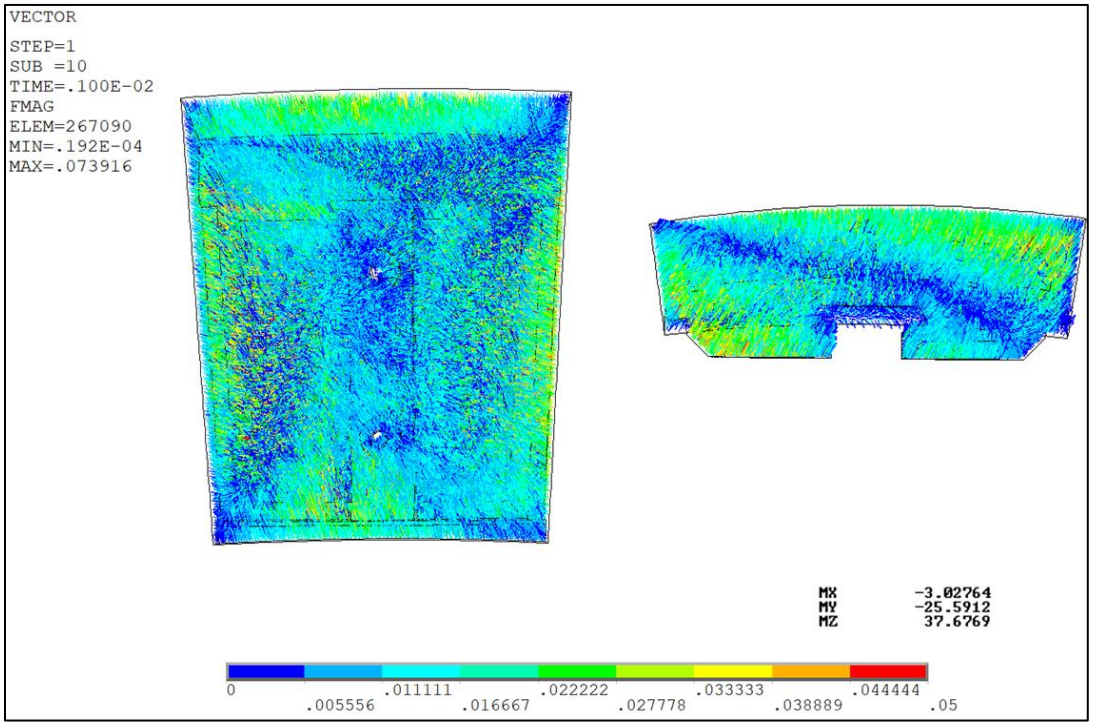

Figure 10: Eddy Current EM Loads, Row 5

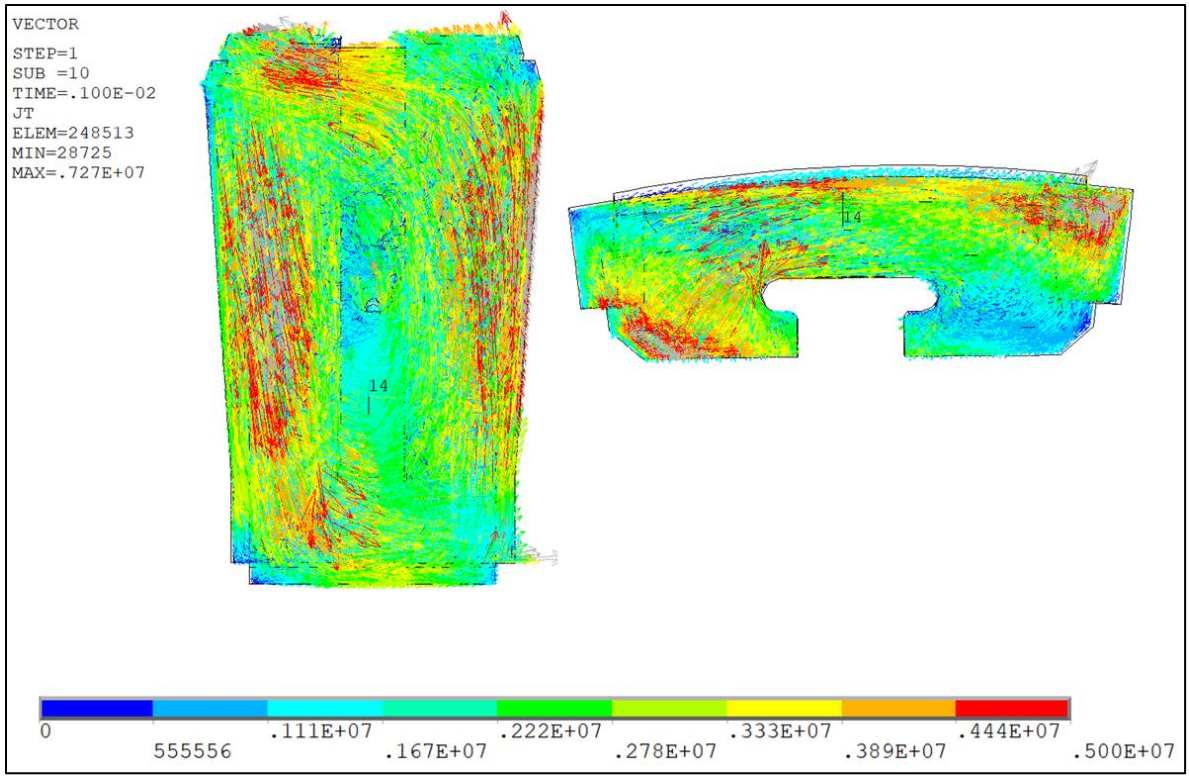

Figure 11: Eddy Current Density, Row 6

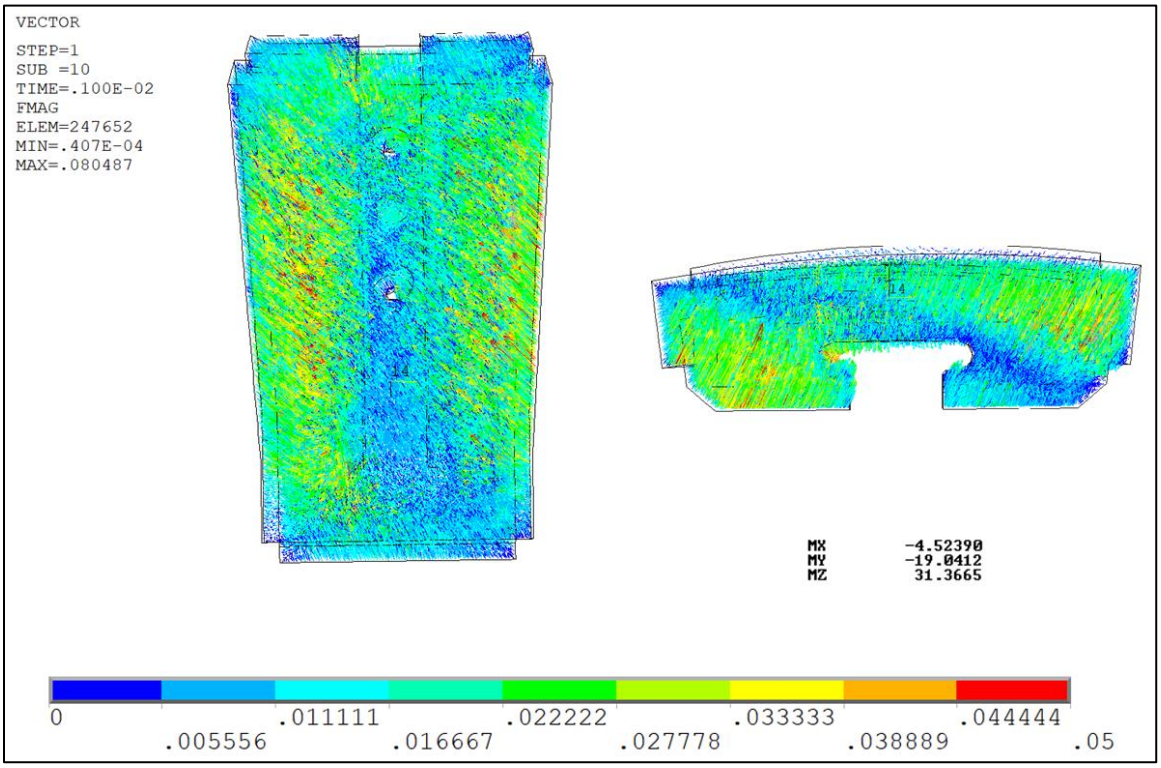

Figure 12: Eddy Currents EM Load, Row 6

Conclusion:

Electromagnetic forces and moments have been determined for CSA tiles row 5 and row 6 tiles. There are no specified load criteria for the tiles. However, the stresses resulting from these loads must be below established allowable stress limits.

The loads calculated thru this analysis may be used as inputs to a structural finite element model to determine the resulting stresses in the tile bodies. The moments can be applied to all surfaces of the tiles. The forces should be imported as body force densities (N/M^3), utilizing the stored nodal data.