

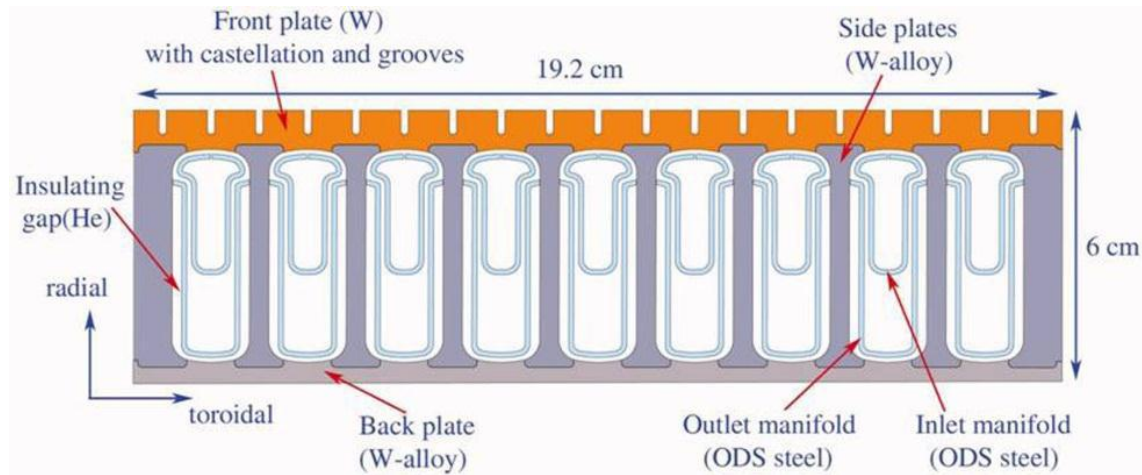
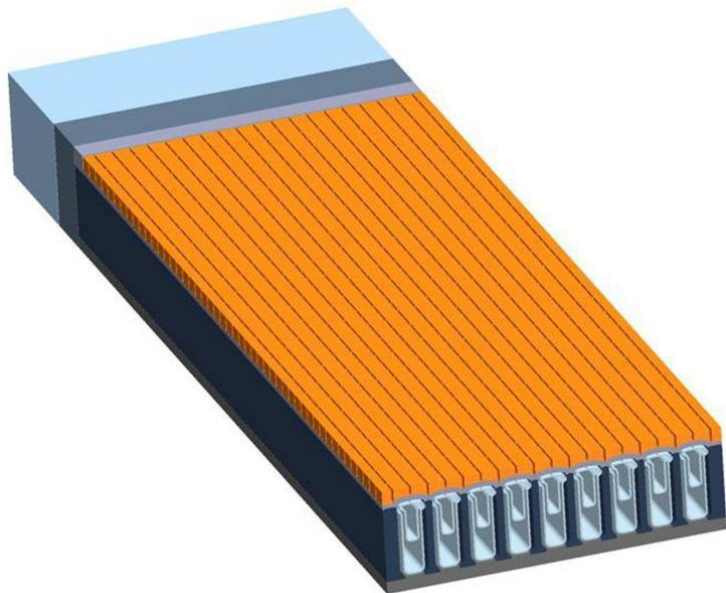


Fracture Studies for ARIES Plate-Type Divertor Concept

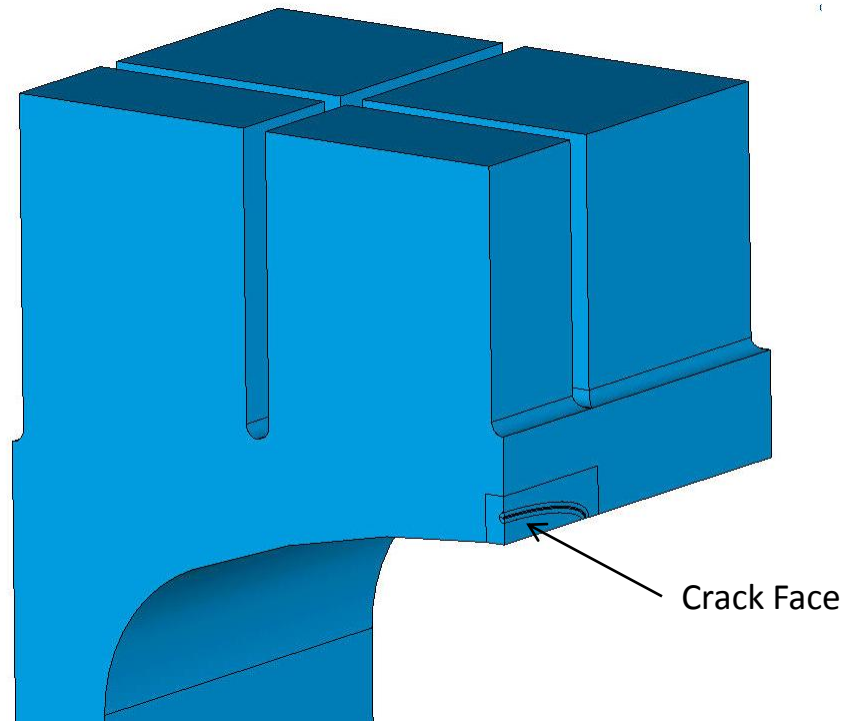
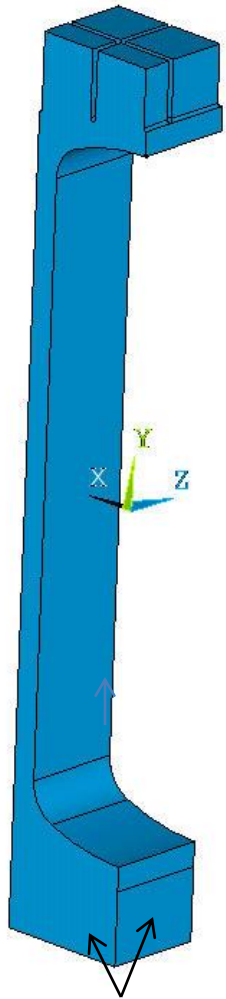
Jake Blanchard – UW Madison

January 2012

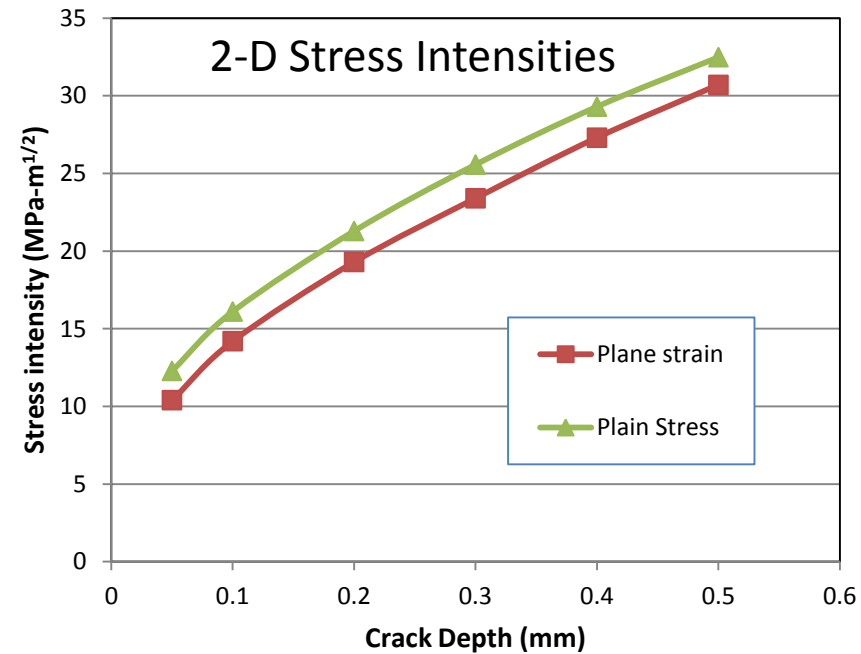
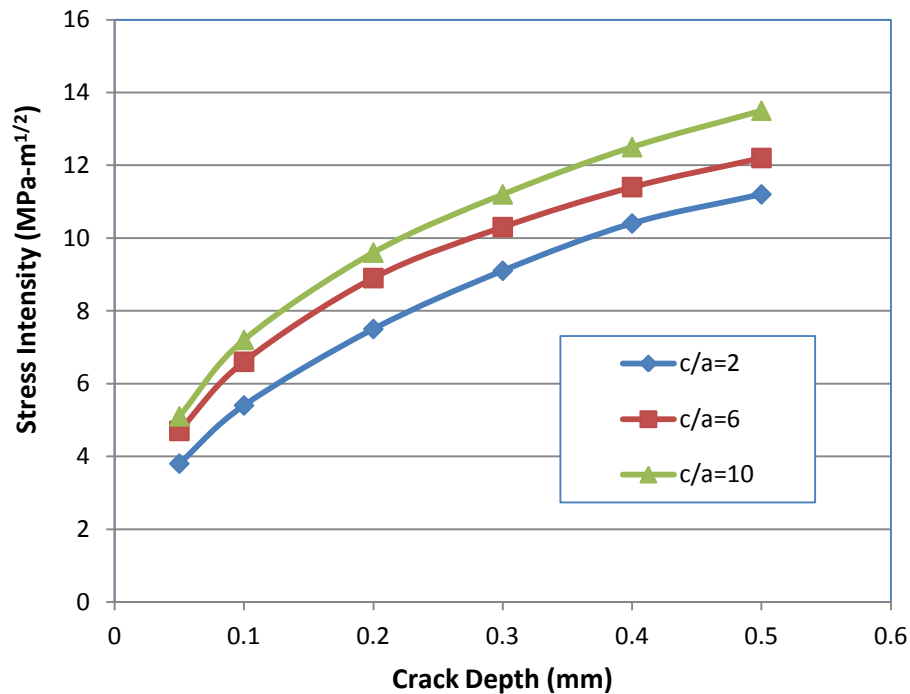
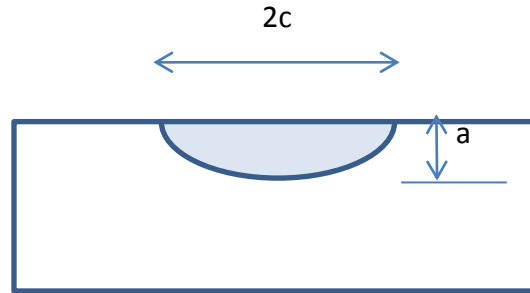
Tungsten HCFP(Helium-cooled Flat Plate) divertor



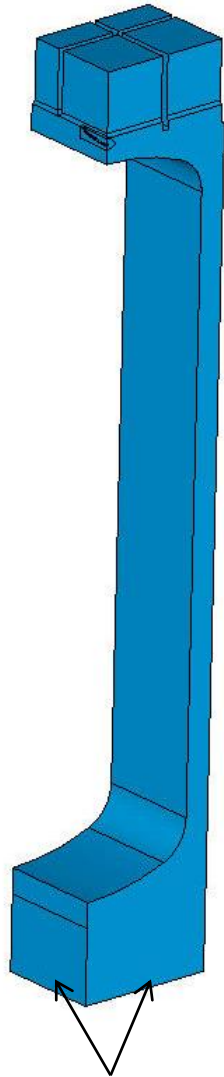
LAST MEETING



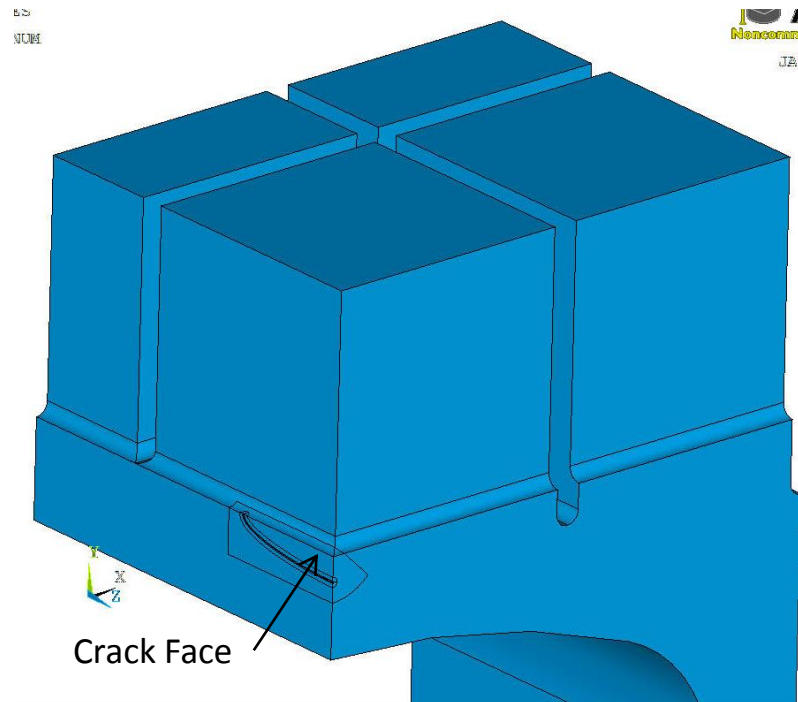
Stress Intensities at Full Power



3-D Model Geometry and Crack Location



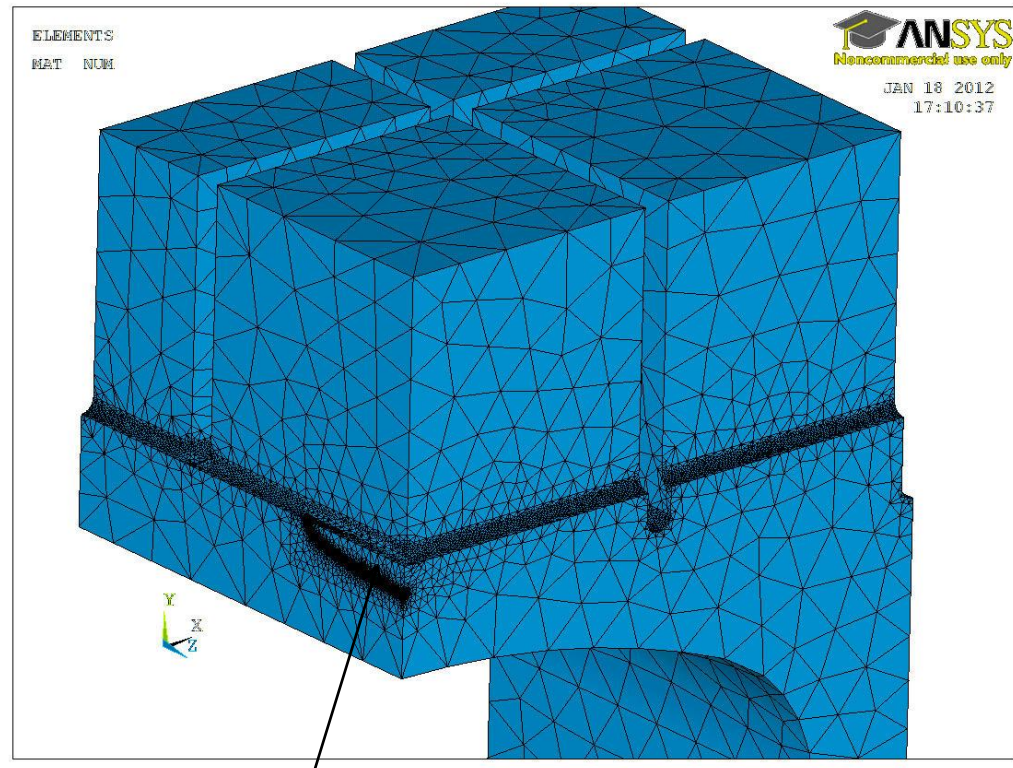
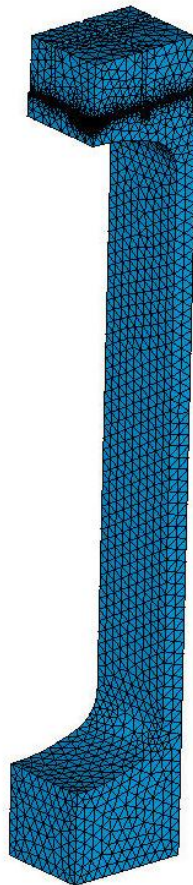
Symmetry planes



Finite Element Mesh

Nodes 441059

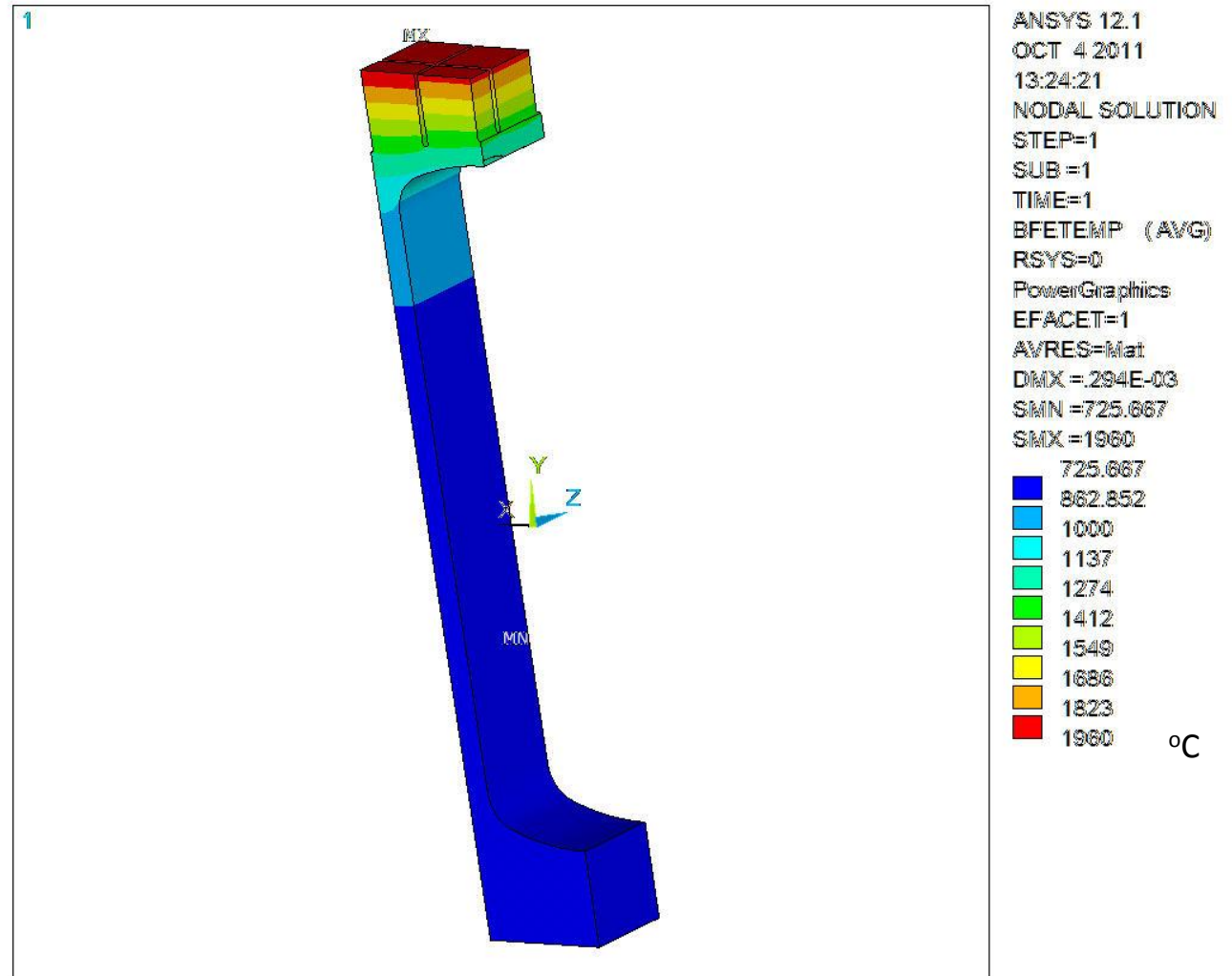
Elements 283354



Crack Face

Temperature Distributions Simulated Using ARIES Design Loads with Simplified Convection Cooling

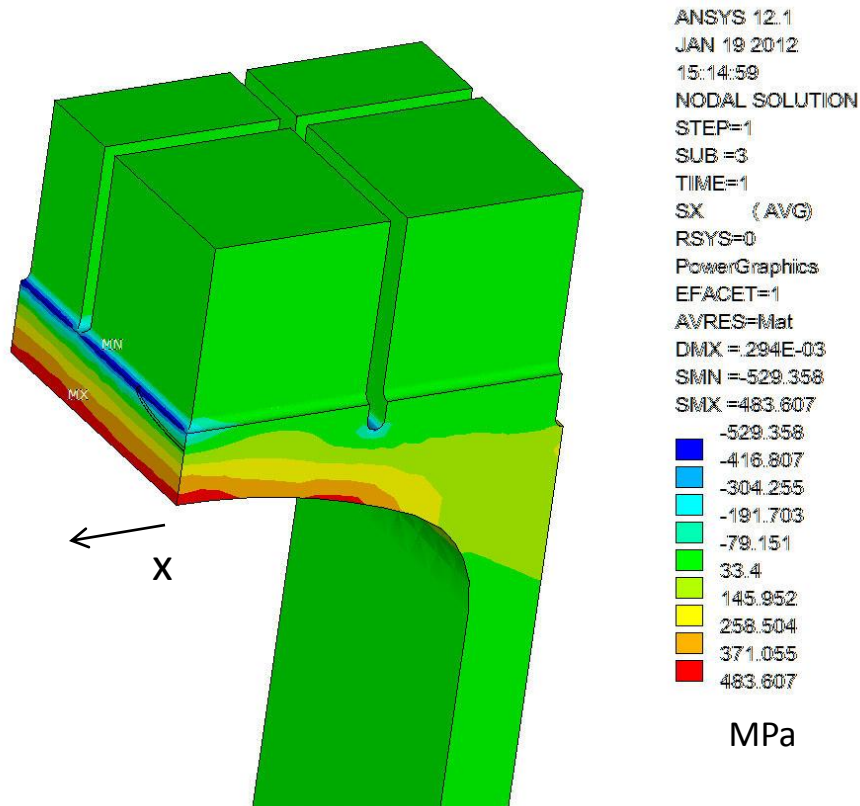
$q''=11 \text{ MW/m}^2$
 $q'''=17.5 \text{ MW/m}^3$
 $P=10 \text{ MPa}$
 $T_{\text{coolant}}=600 \text{ }^{\circ}\text{C}$
 $\text{Max. } T_{\text{armor}}=2000 \text{ }^{\circ}\text{C}$
 $\text{Max. } T_{\text{structure}}=1310 \text{ }^{\circ}\text{C}$
 $\text{Min. } T_{\text{structure}}=725 \text{ }^{\circ}\text{C}$



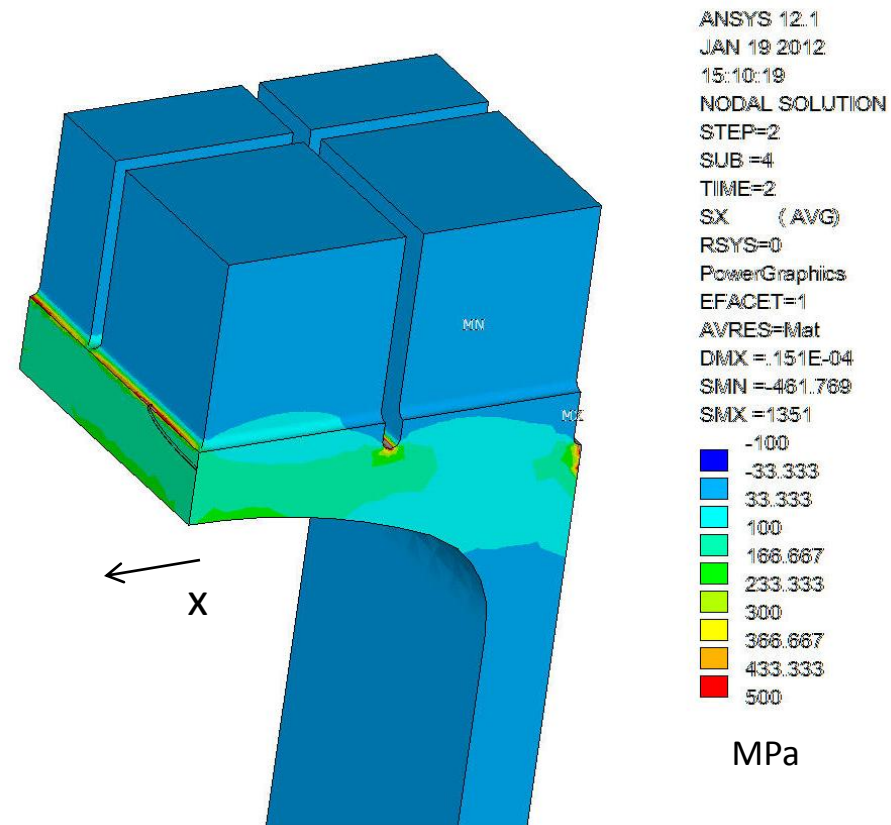
Stresses in Uncracked Structure

- Max stress intensity occurs after cool-down due to plastic deformation.
- Structural boundary conditions adjusted to not over-constrain model. Planar rotations in x and z direction allowed to simulate panel bow.

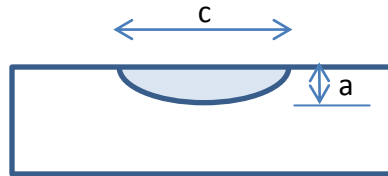
X- Stress Distribution when Hot (MPa)



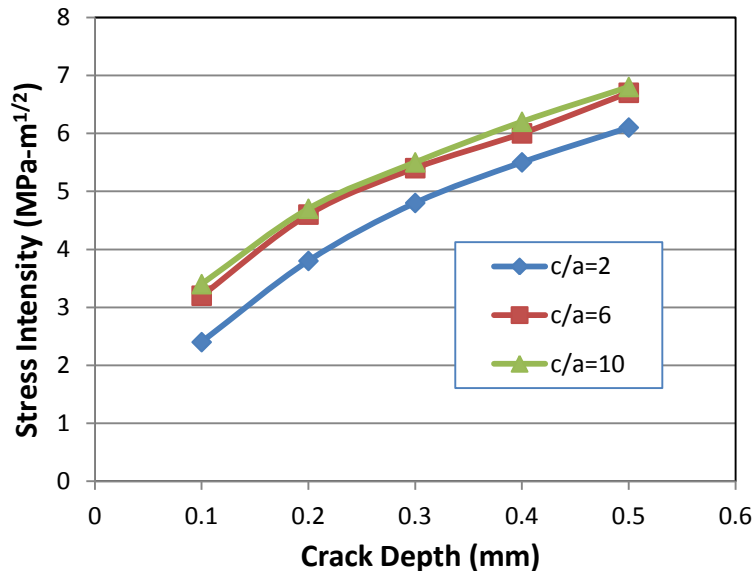
X- Stress Distribution after Cool-down (MPa)



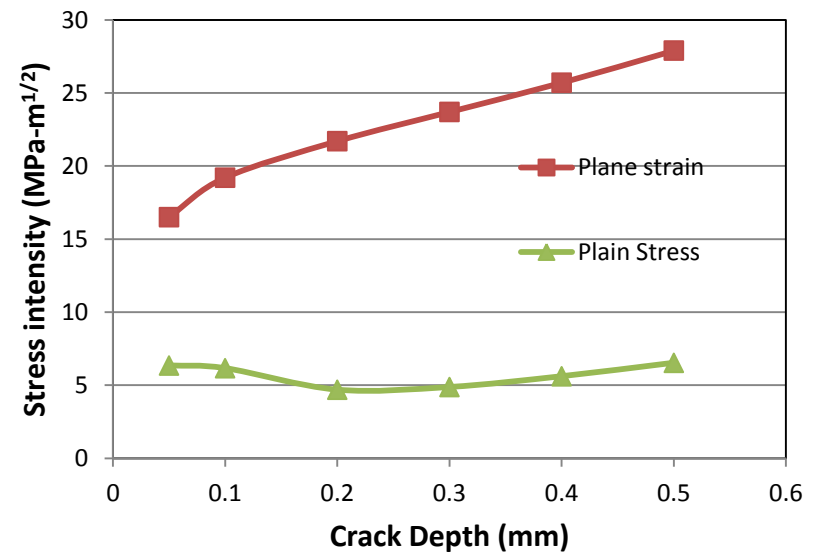
Stress Intensities for 3-D Models Significantly Lower than 2-D Results (Shutdown)



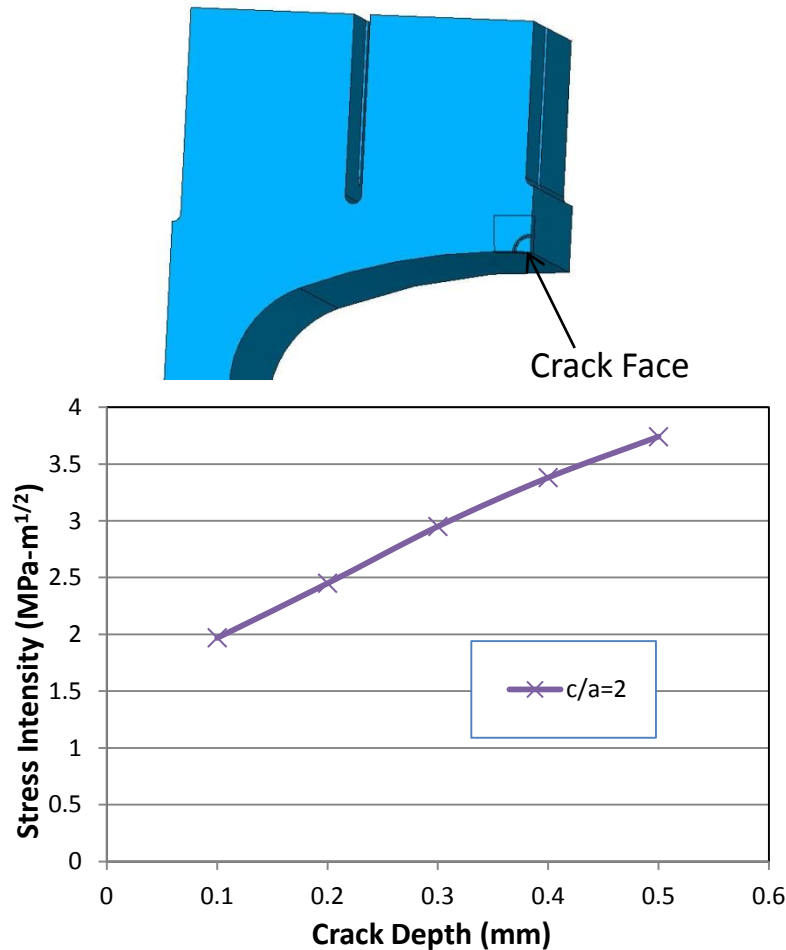
3-D Stress Intensities



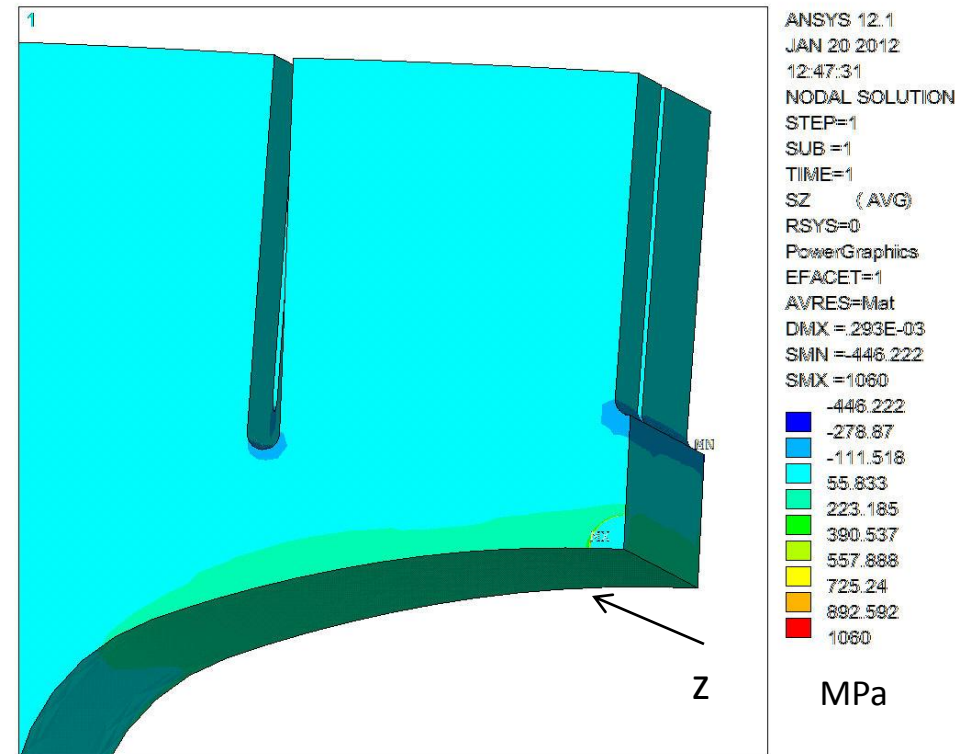
2-D Stress Intensities



Stress Intensities for Crack Perpendicular to Coolant Flow Direction



Z- Stress Distribution when Hot (MPa)



Conclusions

- Critical crack is in notch between “tiles” (as shown on slide 3)
- Stress intensity is highest at full power
- This may change if thermal creep is taken into account
- 2-D modeling is overly-conservative

Data Needs

- Fracture toughness of tungsten
 - As-manufactured, at temperature
 - irradiated
- Crack growth rates
- Creep rates
- Creep rupture data
- Creep-fatigue interaction data

Future Tasks

- Refine fracture calculations
- Ferromagnetic loads during magnet quench
- Disruption calculations