Update on Fracture Analyses

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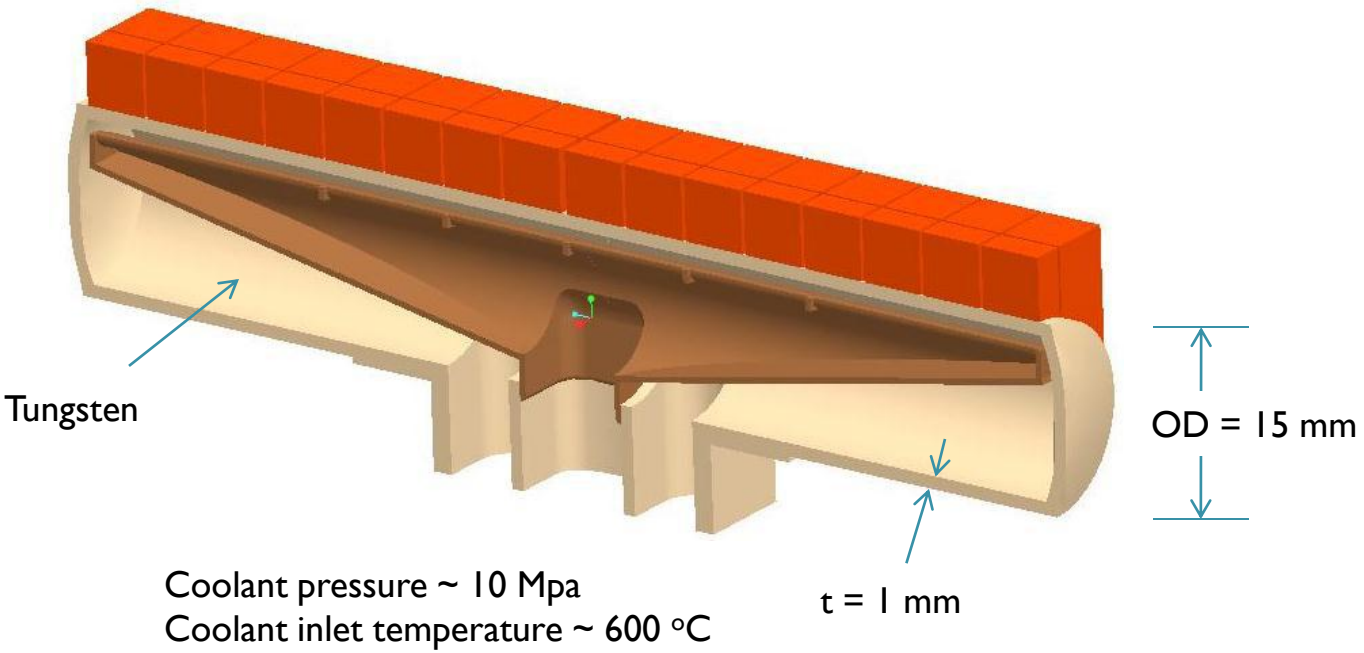
Outline

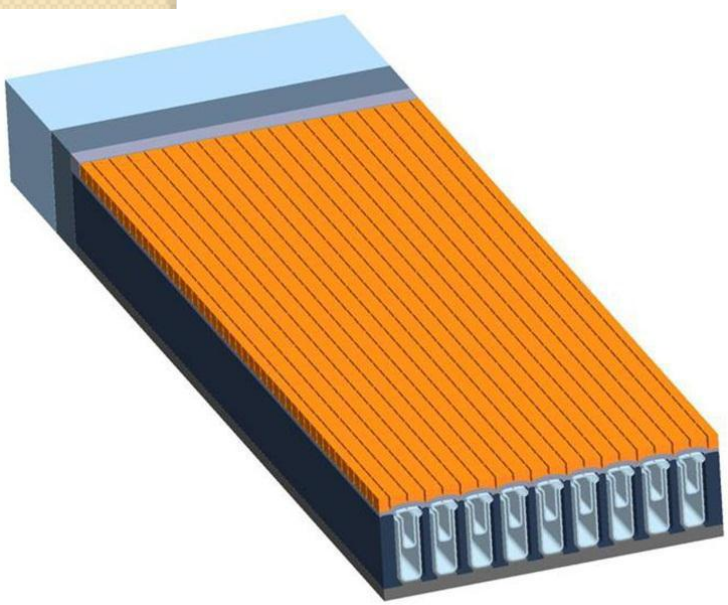
- 2-D Analysis of Flat Plate Divertor
  - High stress areas
  - Crack locations
  - Thermal stress included
  - Consider full power and cool-down
- Future Work
- Conclusions

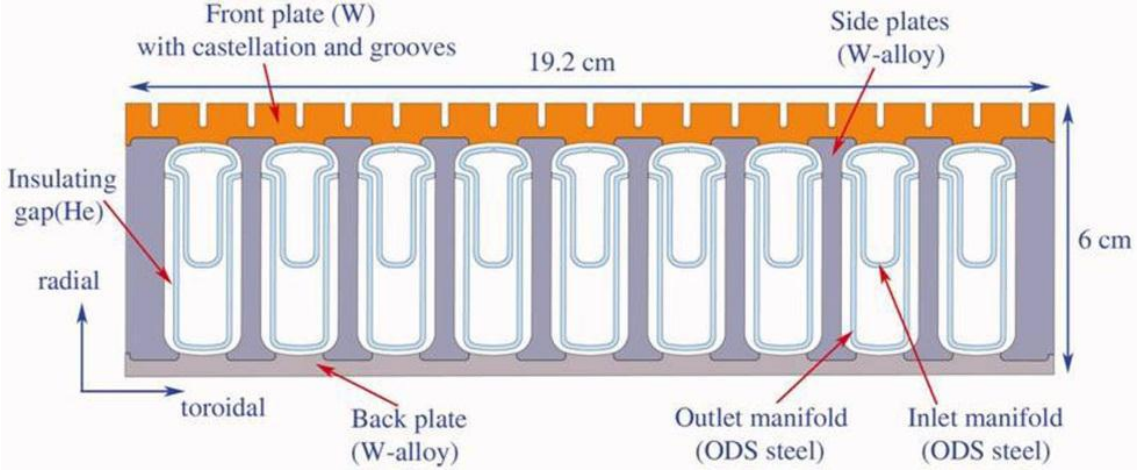
Last Time We Analyzed This Design



Here We Switch to Plate-Type Divertor

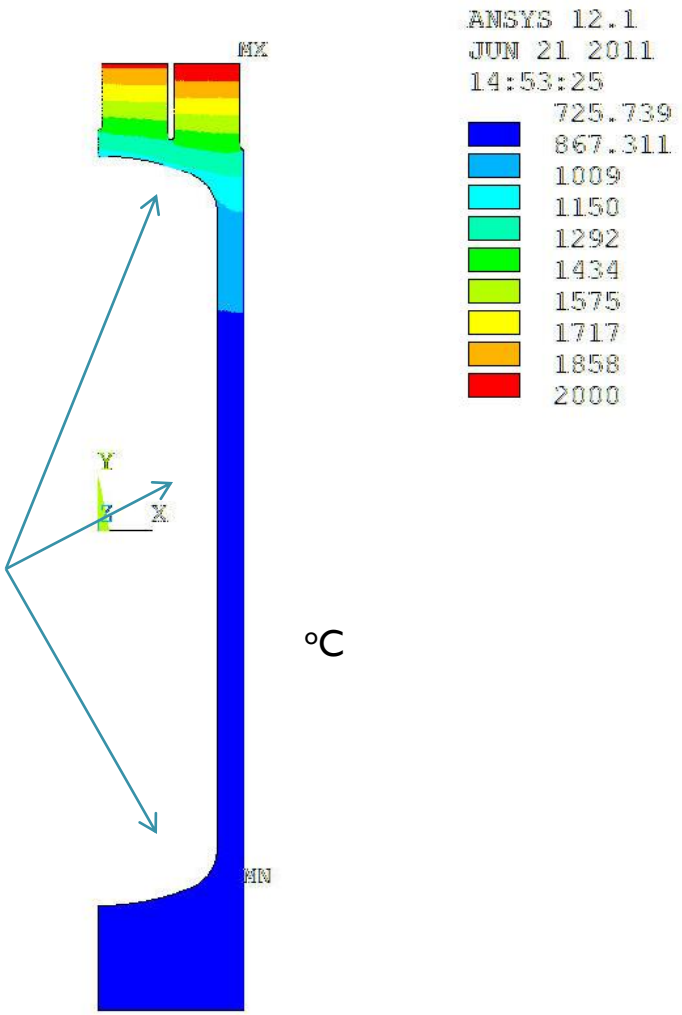
Tungsten HCFP(Helium-cooled Flat Plate) divertor





Temperature Distributions Simulated Using ARIES Design Loads with Simplified Convection Cooling

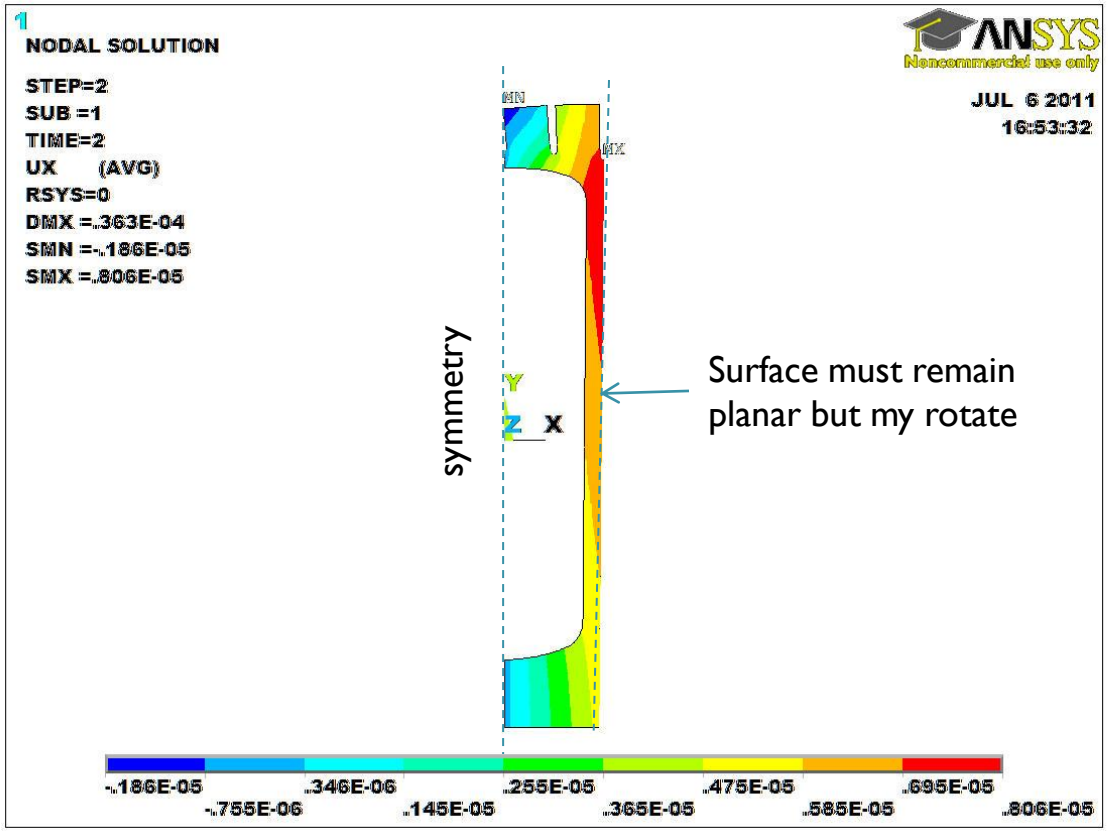
- 2-D Planar models are used in these preliminary studies (simulating long cracks)
- Convection coefficients adjusted to correlate with ARIES CFD results
- Studies show fracture results insensitive to small changes in temperature



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

Structural Boundary Conditions Adjusted to Not Over-Constrain Model

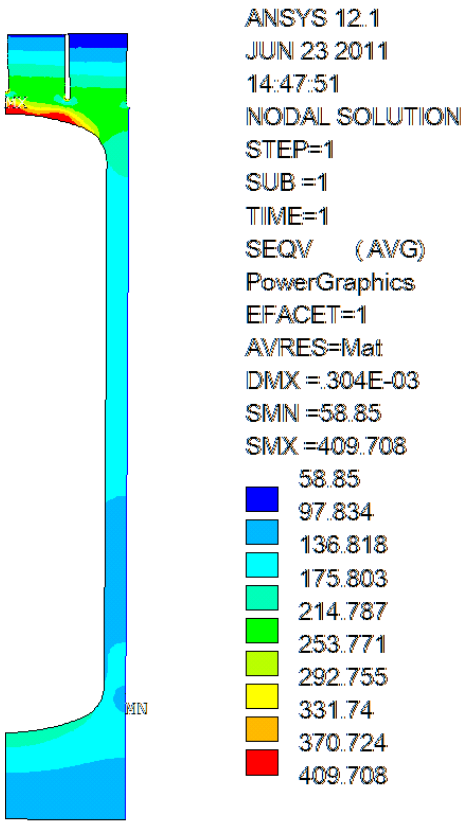
- Planar rotations in x-direction simulate panel bow
- Results calculated with both plane stress / plane strain assumptions in z-direction



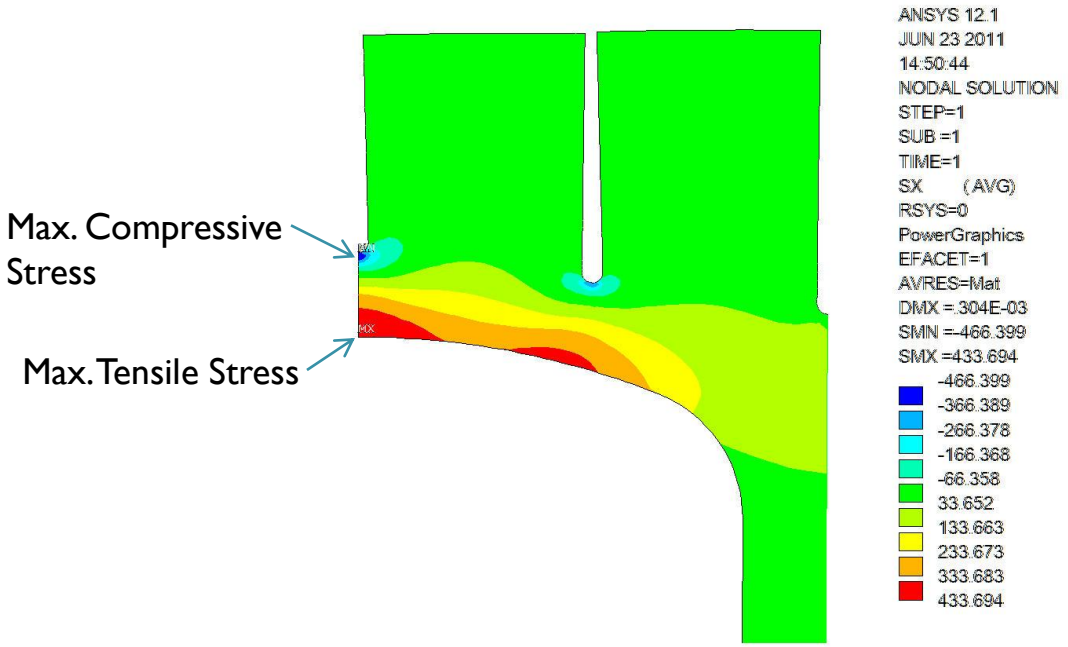
Analysis of Uncracked Structure Identified Two Areas of High Stress

- Crack Stress Intensities investigated for regions of max tensile and compressive stresses
- Region of max compressive stress has tensile stress at cool down due to plasticity

Equivalent Stress (MPa)

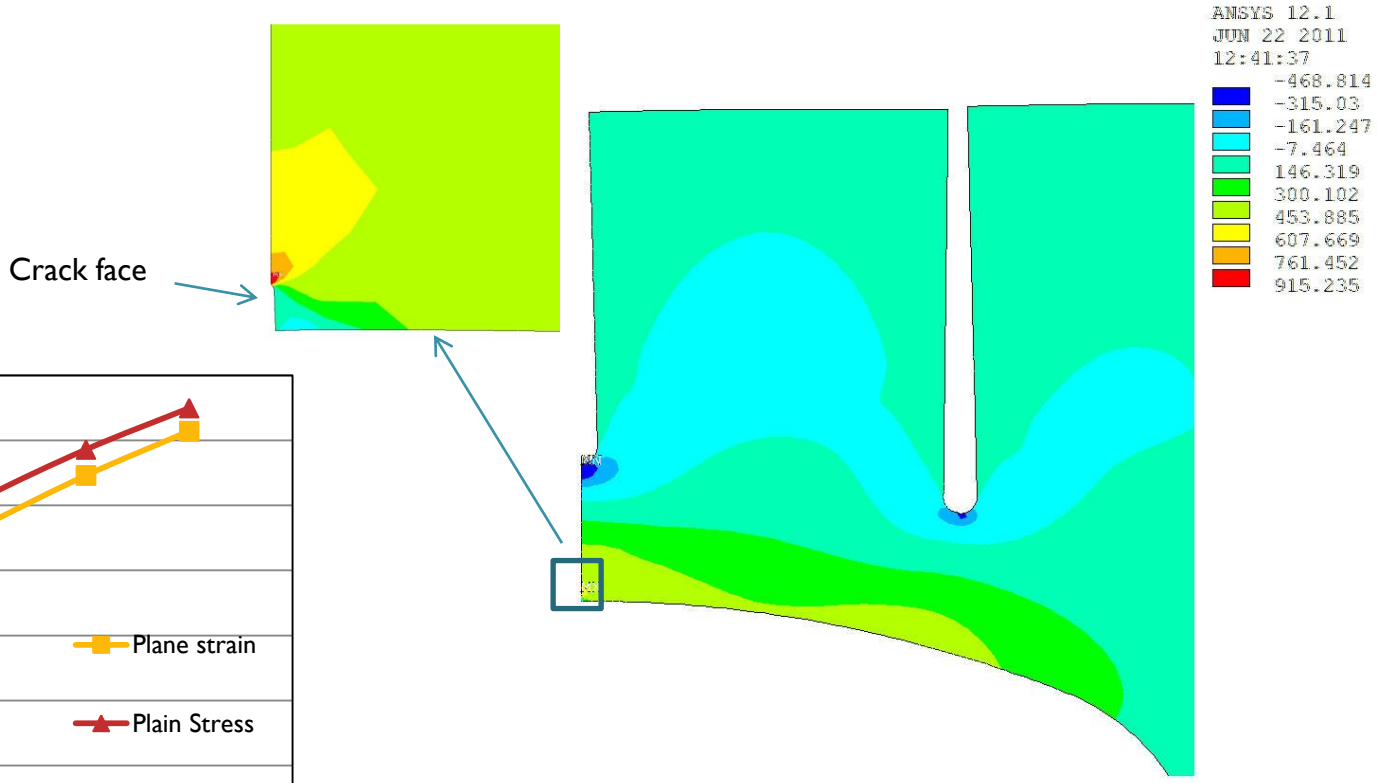


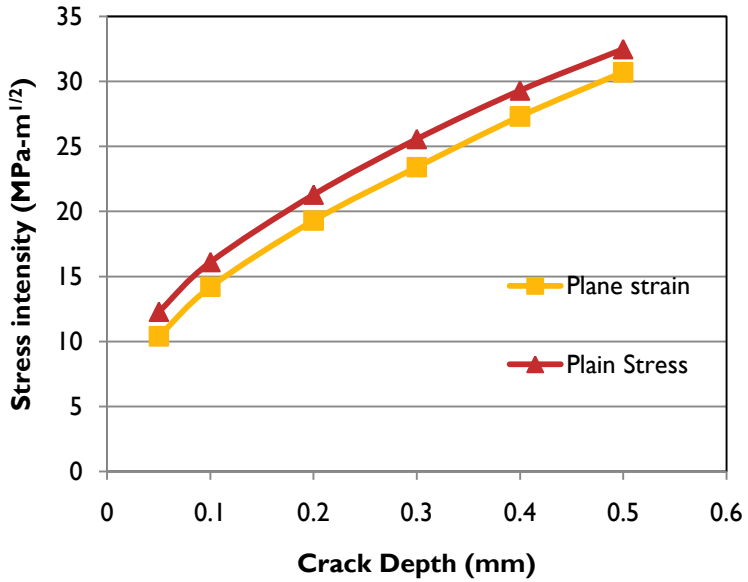
X-Direction Stress (MPa)



Crack on Internal Surface of Outer Wall

- Max stress intensity occurs when hot
- Plane stress / plane strain assumptions give similar results





Fracture Toughness of Tungsten

- This is just a representative data set

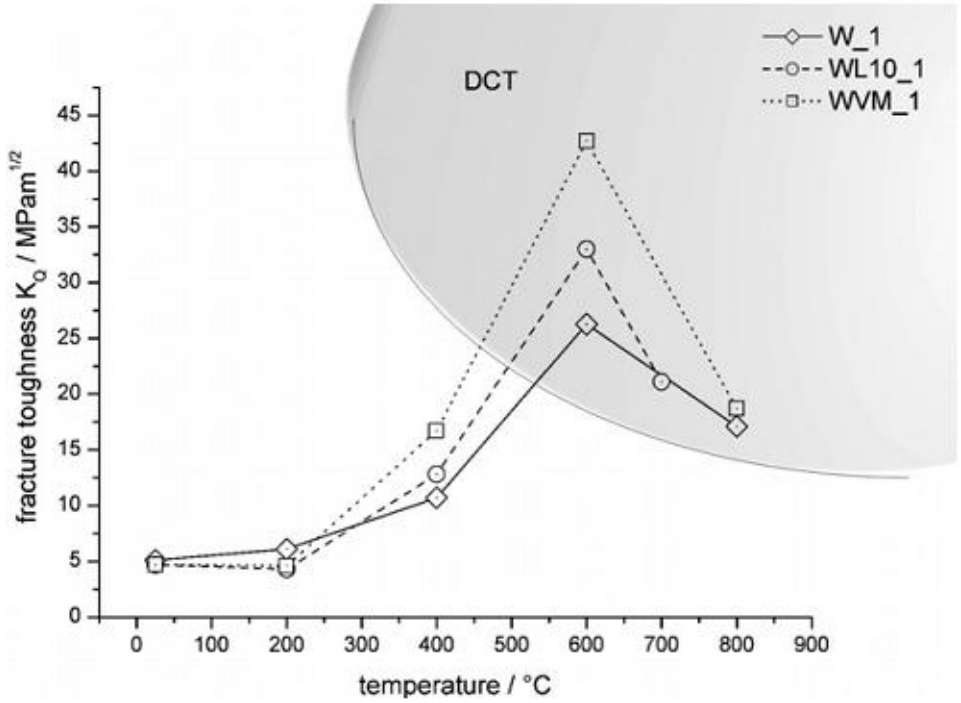
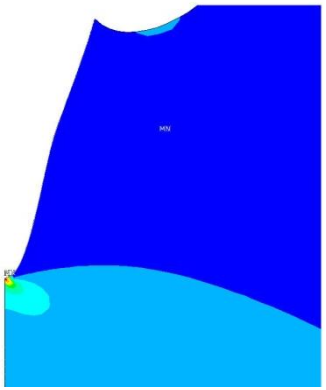
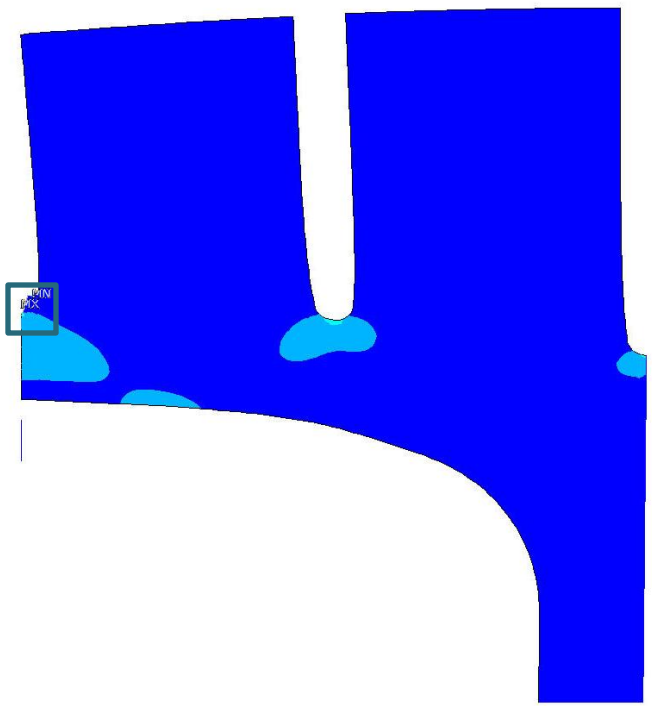


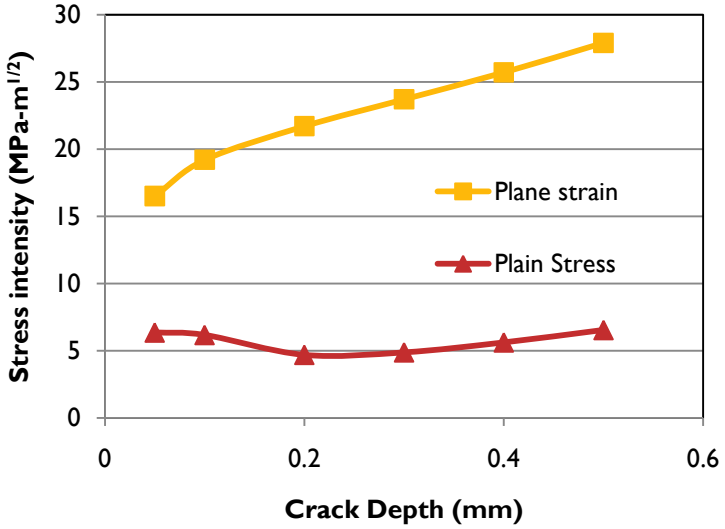
Fig. 1. Fracture toughness of tungsten alloys in the as sintered condition (DCT). The grey area marks the region where linear fracture mechanics is no longer valid.

Crack on External Surface of Outer Wall

- Max stress intensity occurs after cool-down
- Plane stress / plane strain assumptions give radically results – full 3-D model required, but results should be closer to plane strain







Future Work

- 3-D fracture models
- Cracks in “Tiles” and elsewhere
- Try to clarify appropriate toughness data for failure analysis

Conclusions

- For this design, stress intensity is highest on inner surface at full power
- Stress intensity is also quite high at outer surface on shutdown
- It appears that permissible crack depths will be less than 50 microns
- 3-D analysis, toughness review, and review of NDE capabilities are needed to make concrete design recommendations