Fracture and Creep in an All-Tungsten Divertor for ARIES

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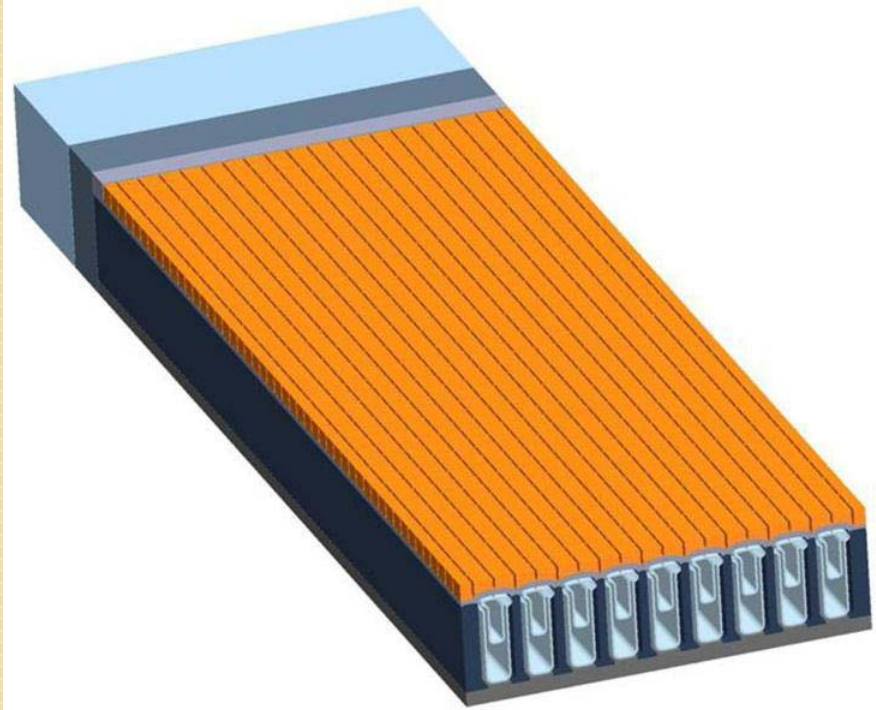
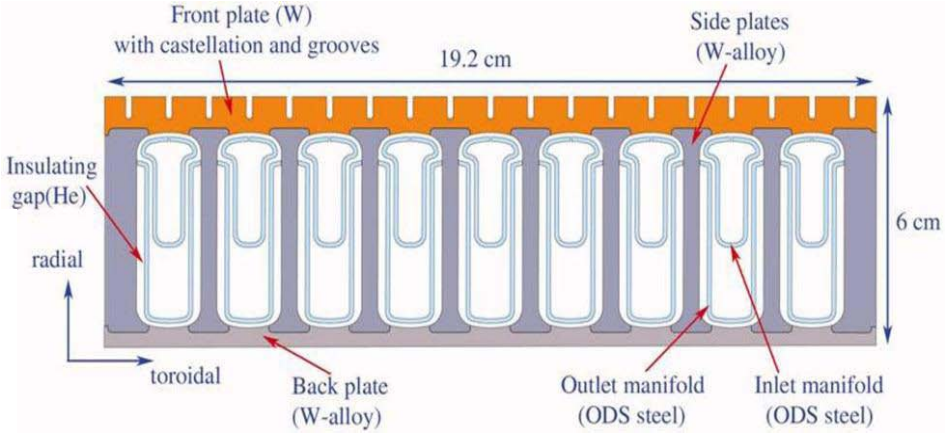
Introduction

- The ARIES Project is exploring the feasibility of using tungsten as a structural material for plasma-facing components
- For now, we are assuming the material is pure tungsten, but alloys may be necessary
- This talk addresses two key failure modes that must be addressed by these designs
  - Fracture
  - Thermal creep

The Design

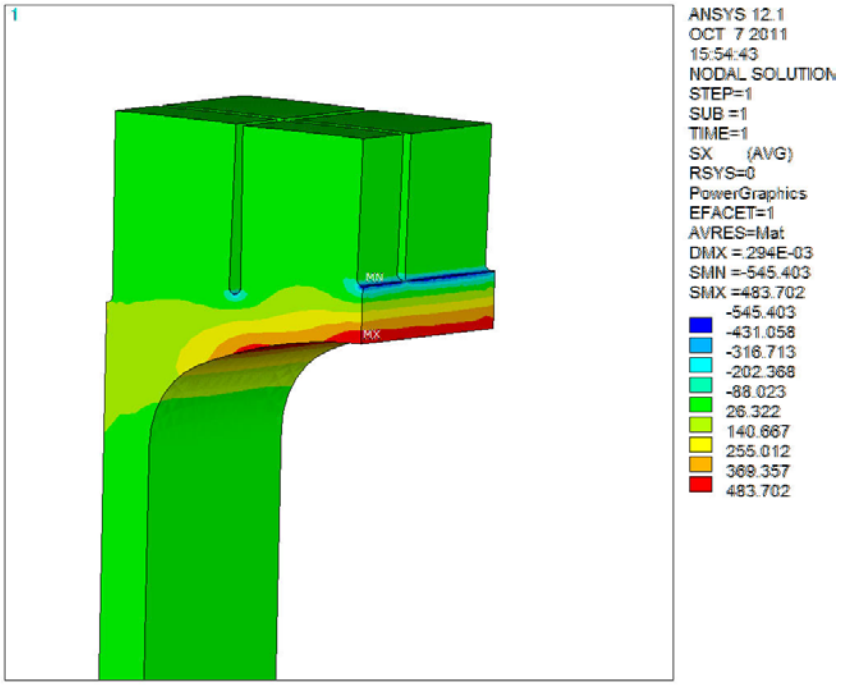



Front plate (W)
with castellation and grooves
19.2 cm
Side plates
(W-alloy)
Insulating
gap(He)
radial
toroidal
6 cm
Back plate
(W-alloy)
Outlet manifold
(ODS steel)
Inlet manifold
(ODS steel)

Major Input Parameters

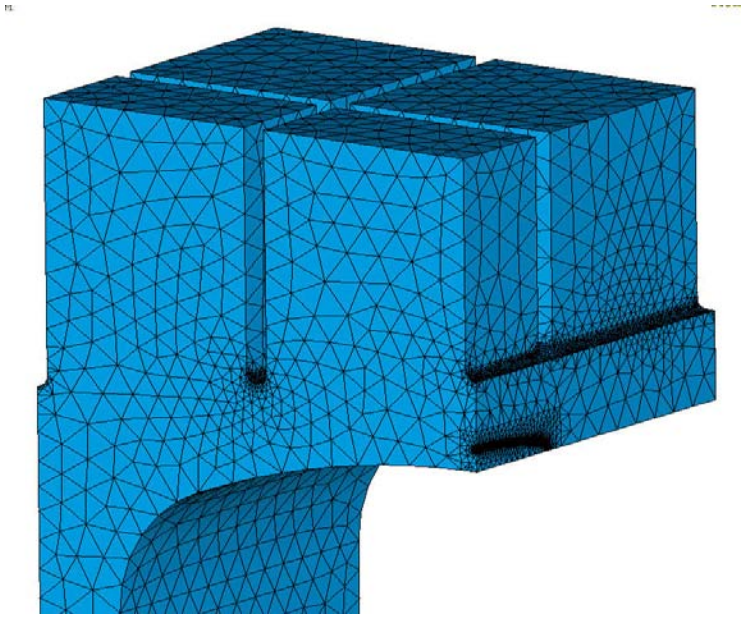
Parameter	Value	Units
Surface Heat	11	MW/m^2
Volumetric Heating	17.5	MW/m^3
Coolant Pressure	10	MPa
Bulk Coolant Temperature	600	C

Crack Location



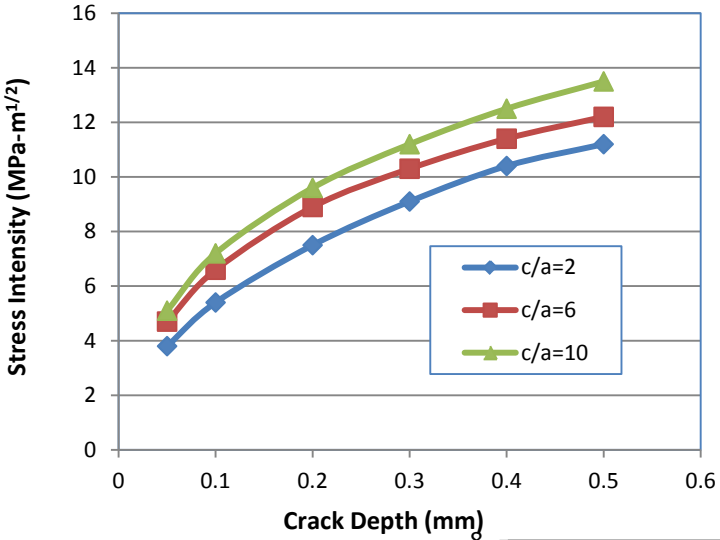
Crack-Free Stress State

Finite Element Model with Crack on Coolant Channel Surface

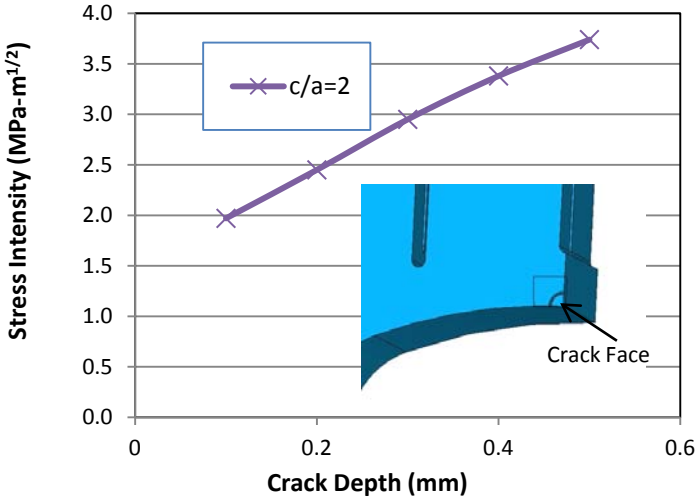


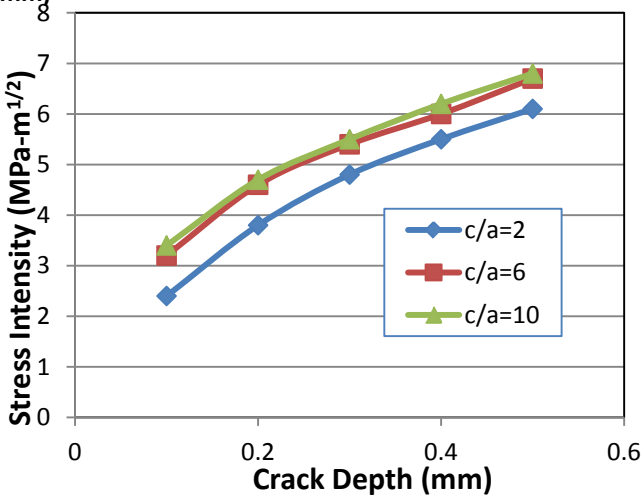
Fracture Results

Results for Crack on Previous Slide



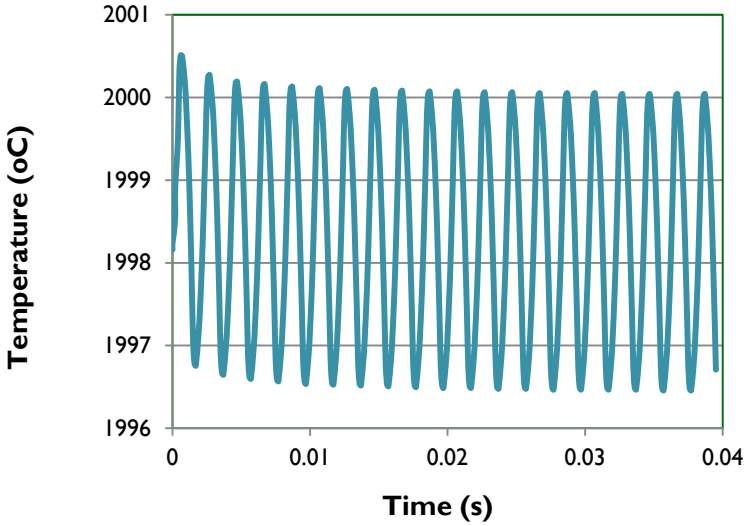
Results for Crack Perpendicular to Cracks Shown





Results for Crack in Notch (at shutdown)

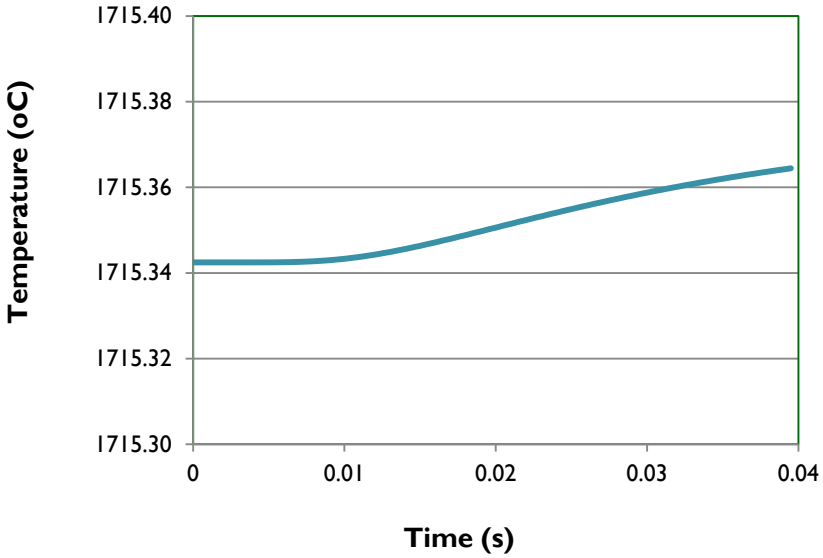
Effect of Transients



Surface Temperature

Vary nominal heat flux by +/-20% and apply 20 cycles

No discernible variation below surface

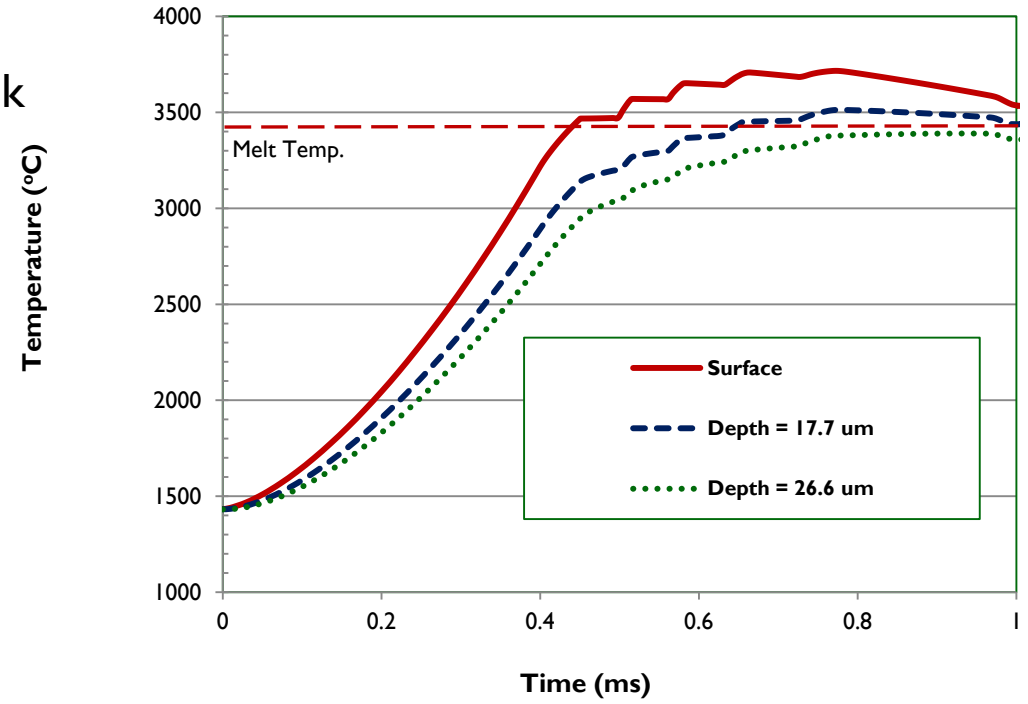


Temperature 2.5 mm below surface

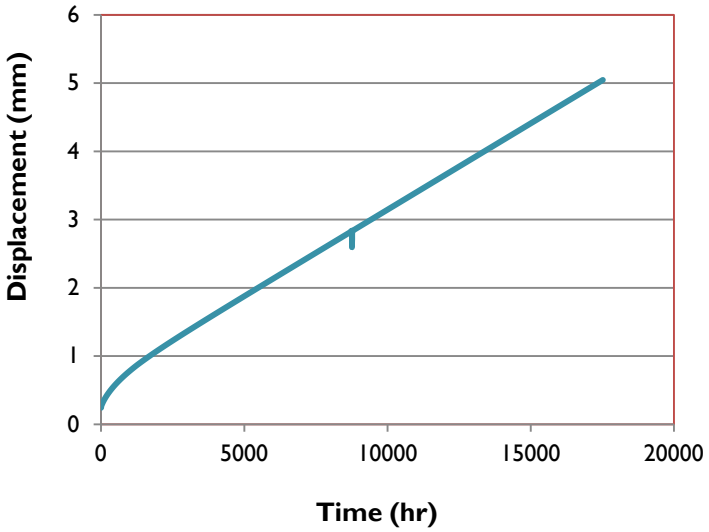
Surface Effect of "Small" ELM

Assume 1.95 MJ deposited on divertor surface over 1.2 milliseconds

Melt layer is 20 microns thick



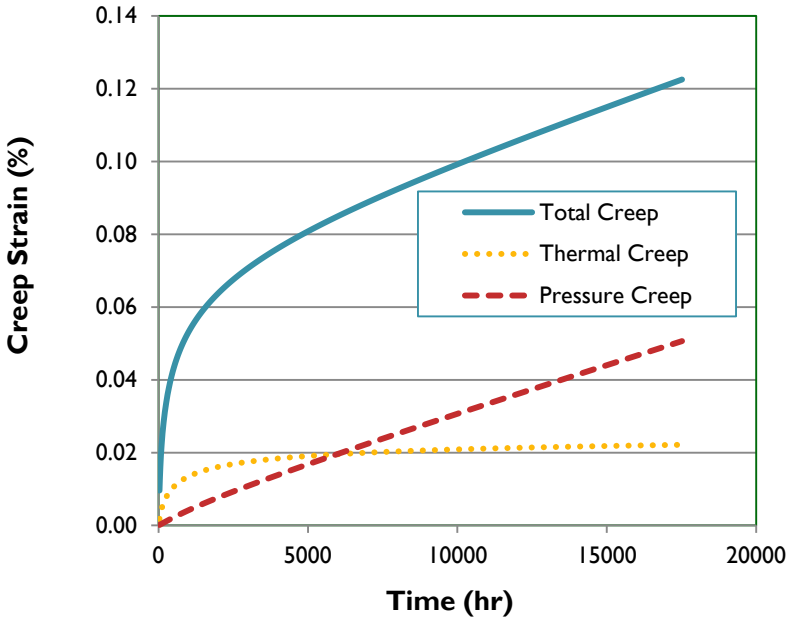
Thermal Creep



Nominal Heat Flux

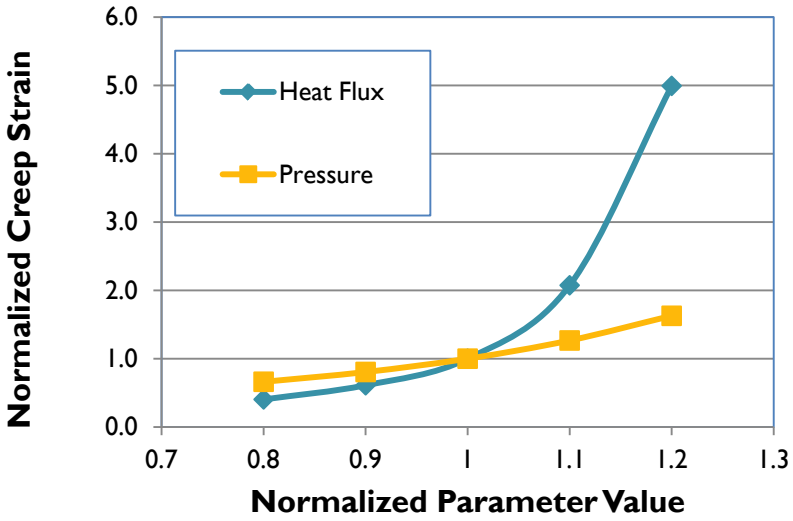
Add Thermal Creep Model for Tungsten

Creep rates are excessive at 11 MW/m^2

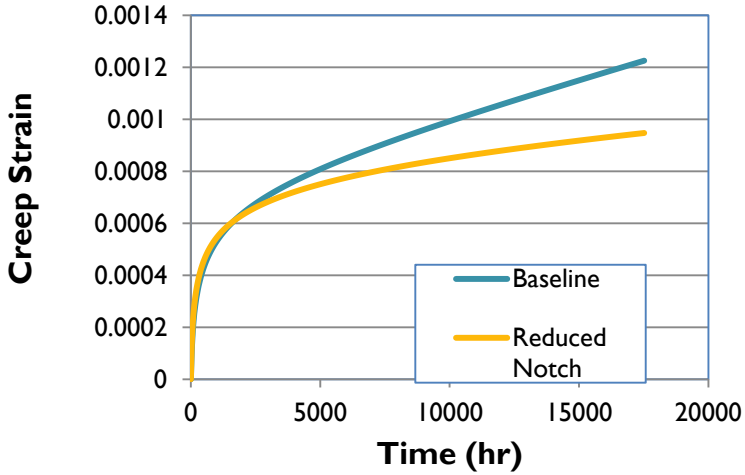


Reduced Heat Flux

Design Modifications



Varying Surface Heating or Coolant Pressure



Reducing Notch Depth

Conclusions

- We have not identified any "show-stoppers" with respect to an all-tungsten divertor for ARIES
- Many uncertainties are still unresolved