



Fracture and Creep in an All-Tungsten Divertor for ARIES

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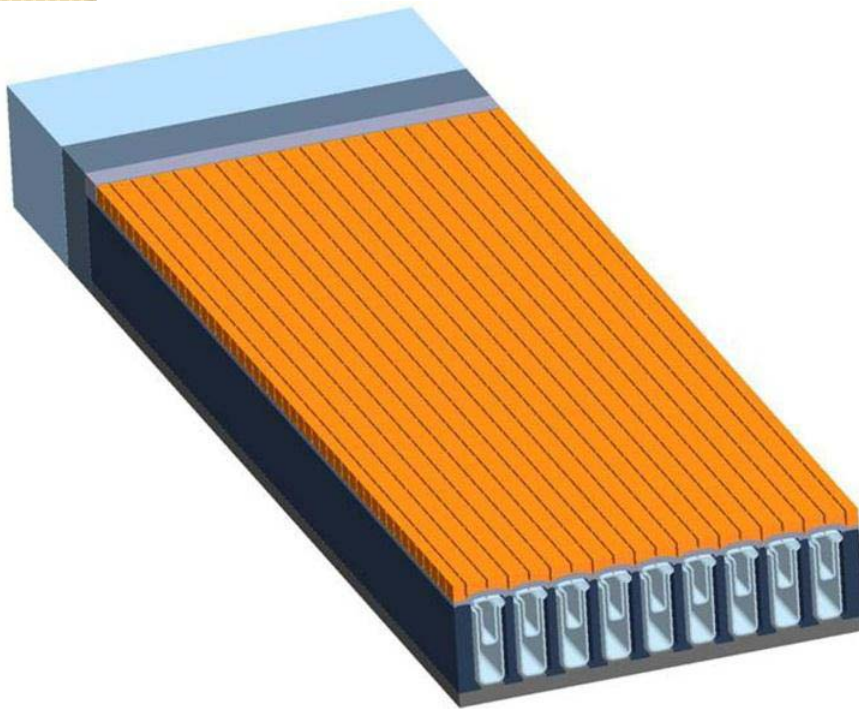
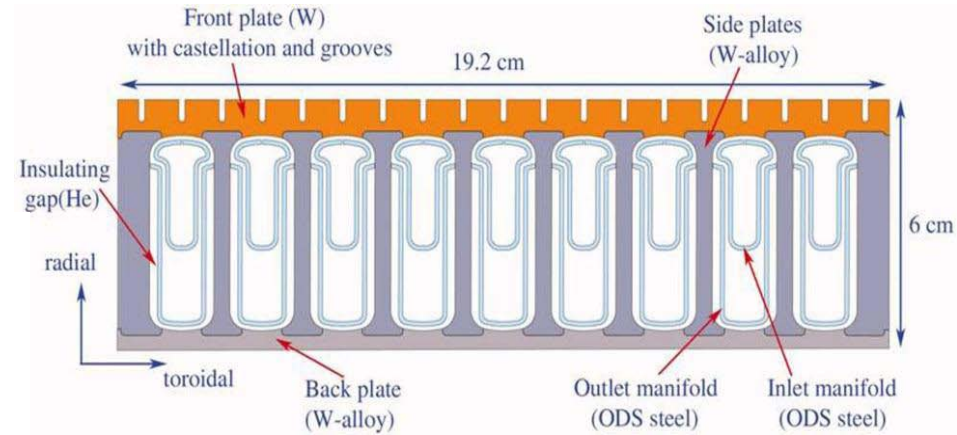
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Introduction

- 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

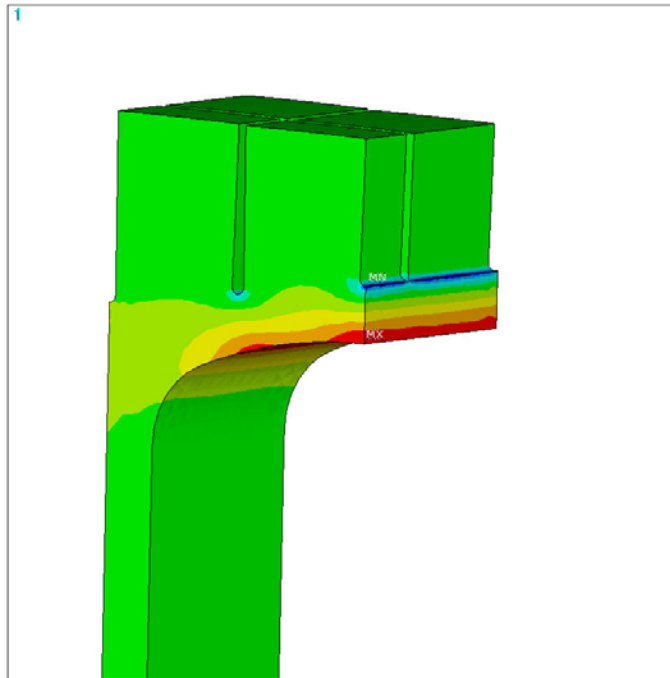
The Design



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

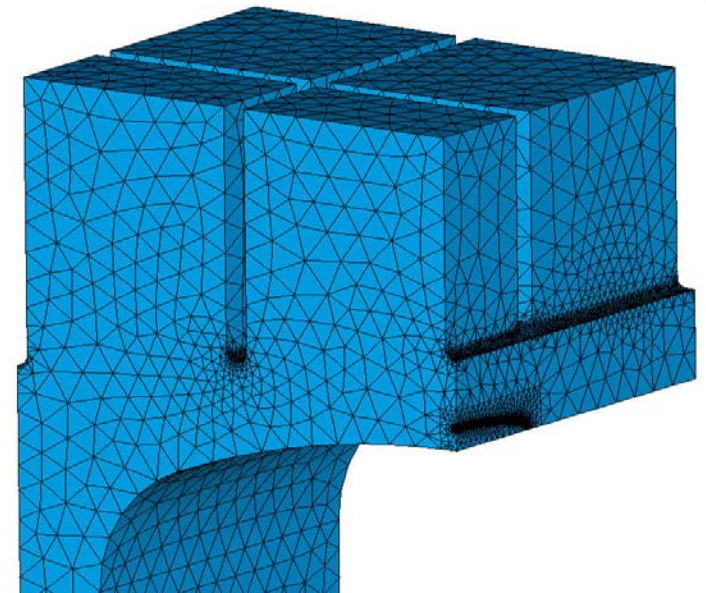
Crack Location



ANSYS 12.1
OCT 7 2011
15:54:43
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
SX (AVG)
RSYS=0
PowerGraphics
EFACET=1
AVRES=Mat
DMX = 294E-03
SMN = -545.403
SMX = 483.702
-545.403
-431.058
-316.713
-202.368
-88.023
26.322
140.667
255.012
369.357
483.702

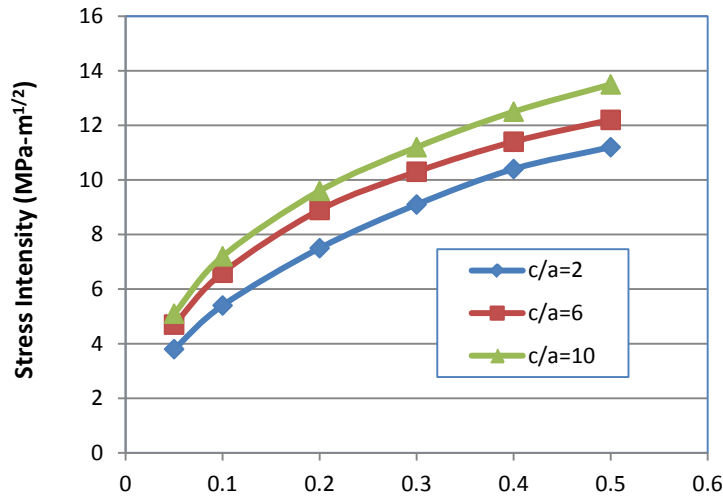
Crack-Free Stress State

Finite Element Model with
Crack on Coolant Channel
Surface

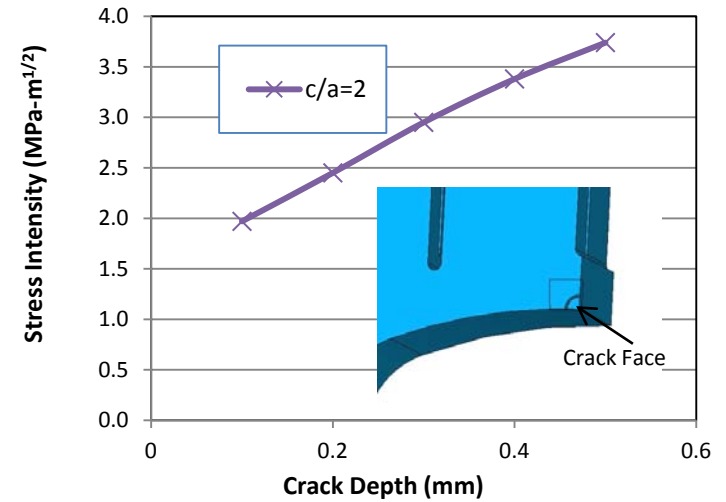


Fracture Results

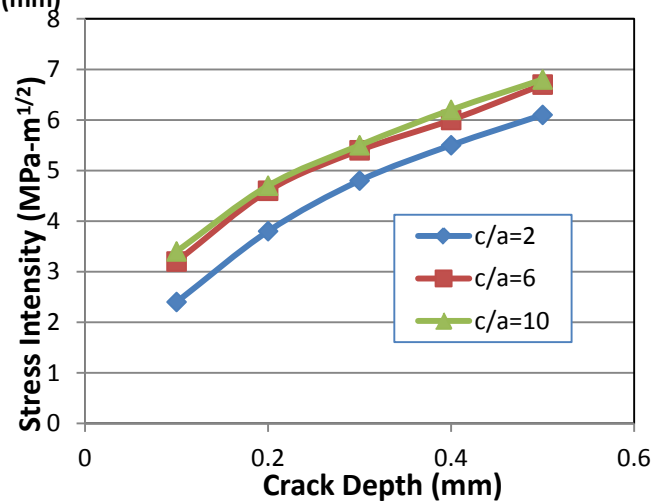
Results for Crack on Previous Slide



Results for Crack Perpendicular to Cracks Shown

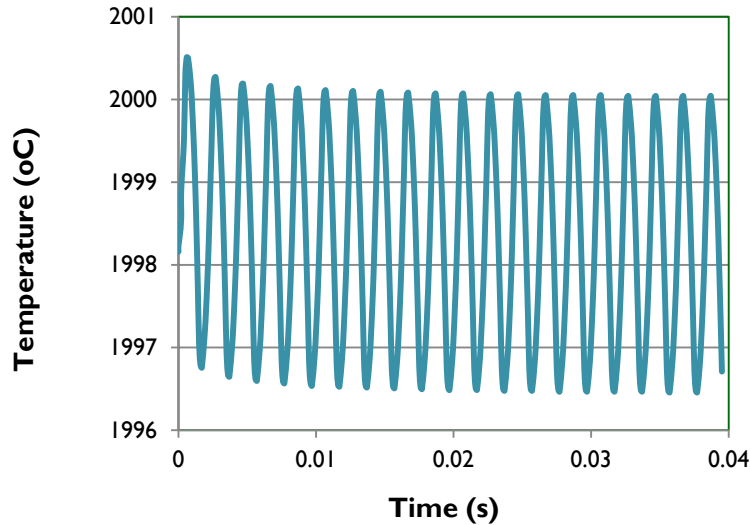


Results for Crack in Notch (at shutdown)



Results for Crack in Notch (at shutdown)

Effect of Transients

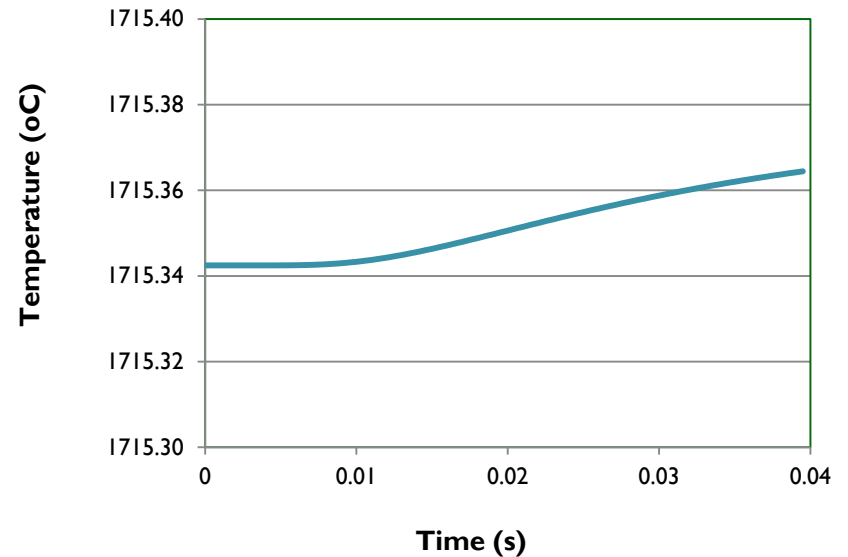


Surface Temperature

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

No discernible variation below surface

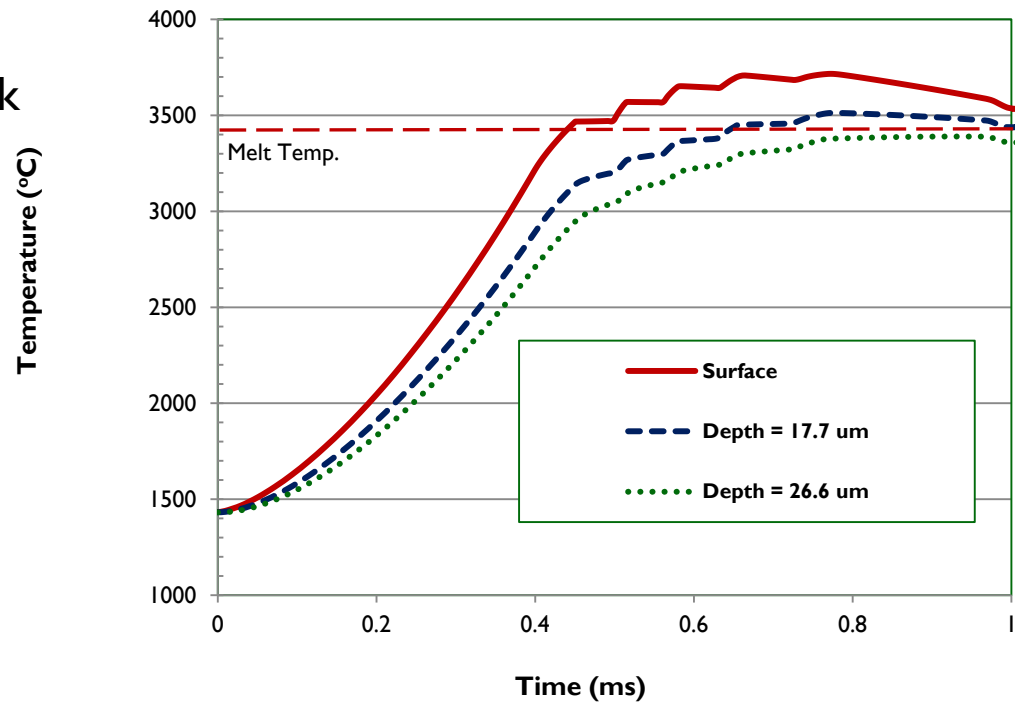
Temperature 2.5 mm below surface



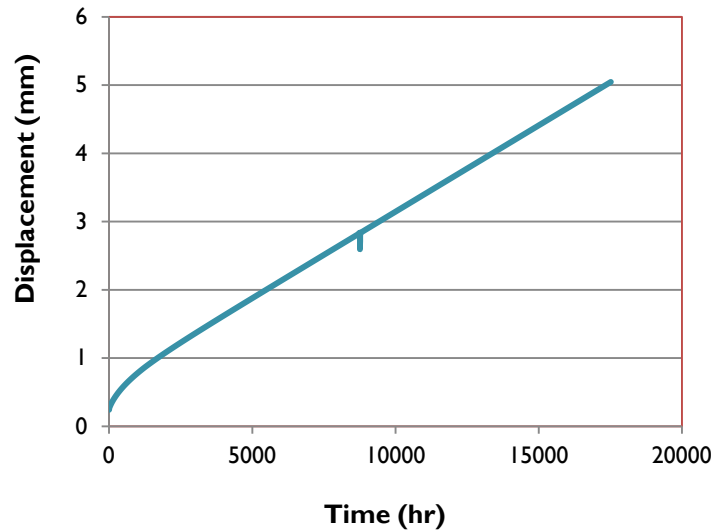
Surface Effect of “Small” ELM

Assume 1.95 MJ deposited on divertor surface over 1.2 milliseconds

Melt layer is 20 microns thick



Thermal Creep

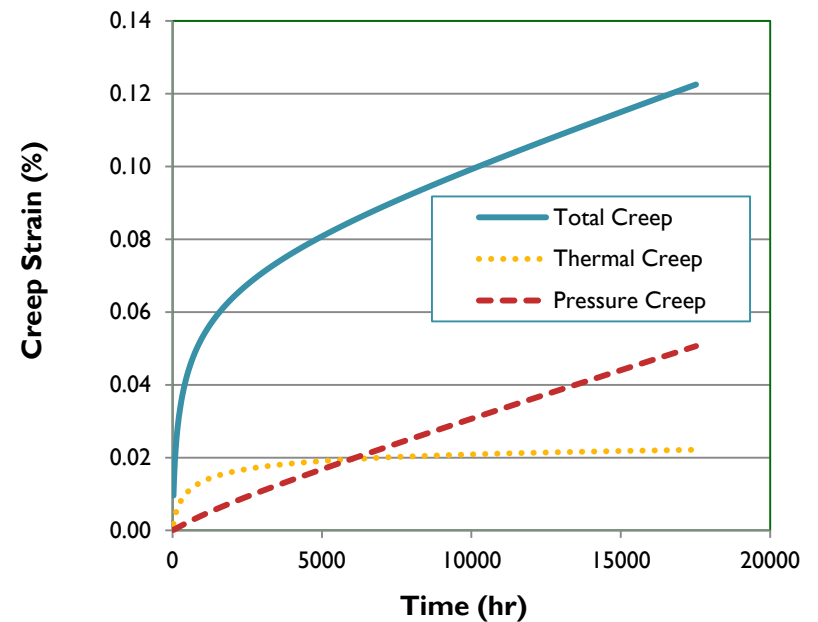


Nominal Heat Flux

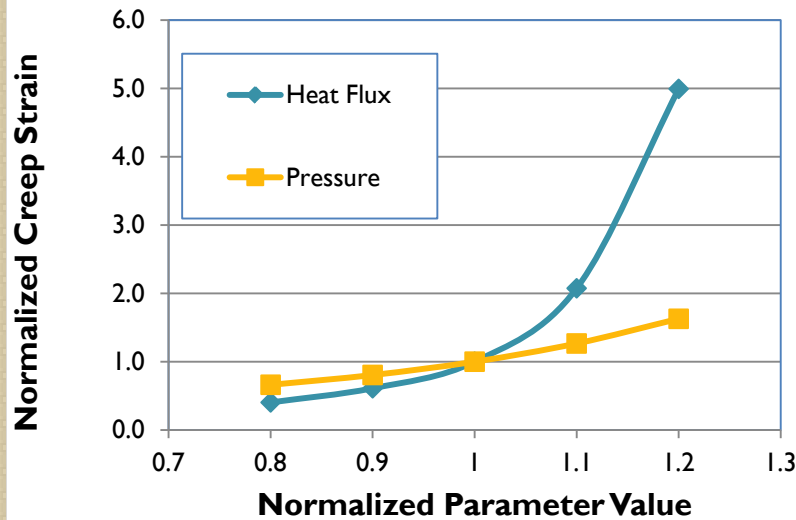
Reduced Heat Flux

Add Thermal Creep Model for Tungsten

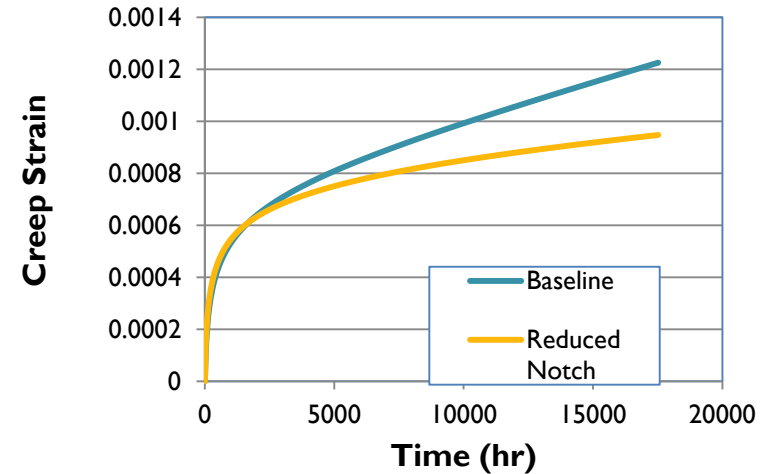
Creep rates are excessive at 11 MW/m²



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