Update on High Performance Divertor Target

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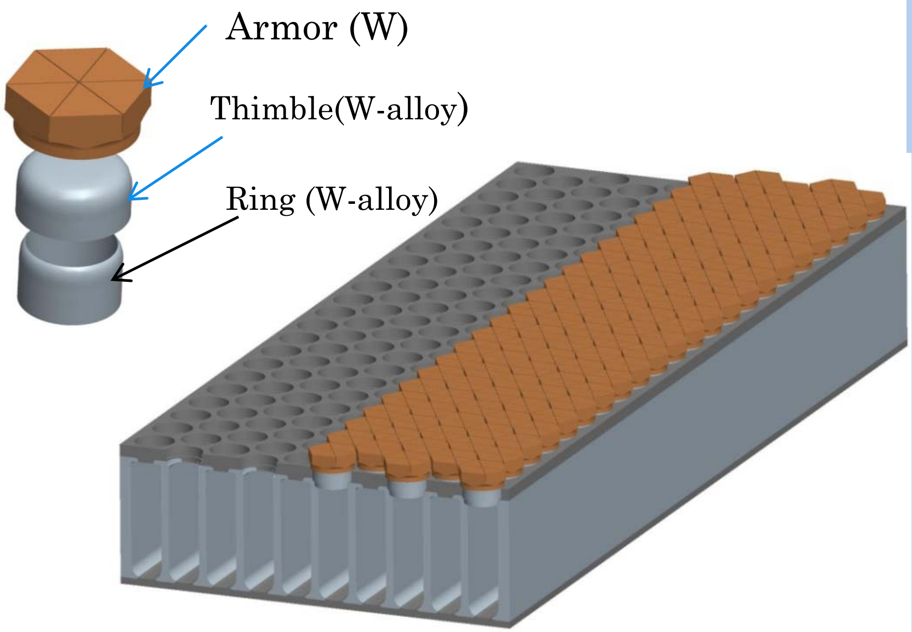
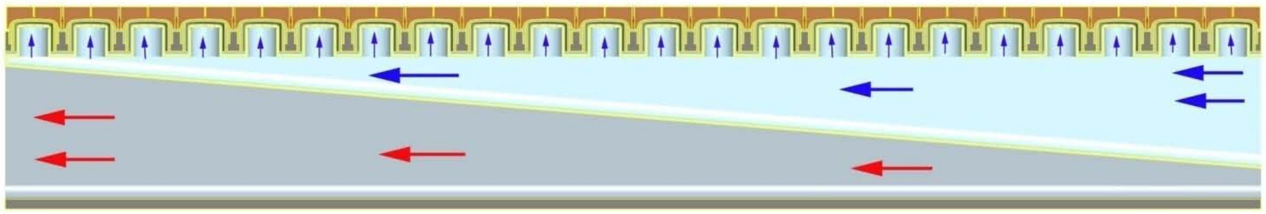
HELIUM-COOLED DIVERTOR WITH A COMBINATION OF PLATE AND FINGER CONCEPTS

- Major features of the helium-cooled W target plate with a combination of plate and EU finger concepts has been investigated.

✓Multiple-jets cooling
✓W-base plate fabricated by brazing together front plate, back plate and side walls.
✓Small modules at the plasma side arranged over the entire plate
✓No transition between W-alloy and steel at the modules(EU Finger design, joints are between W and steels)



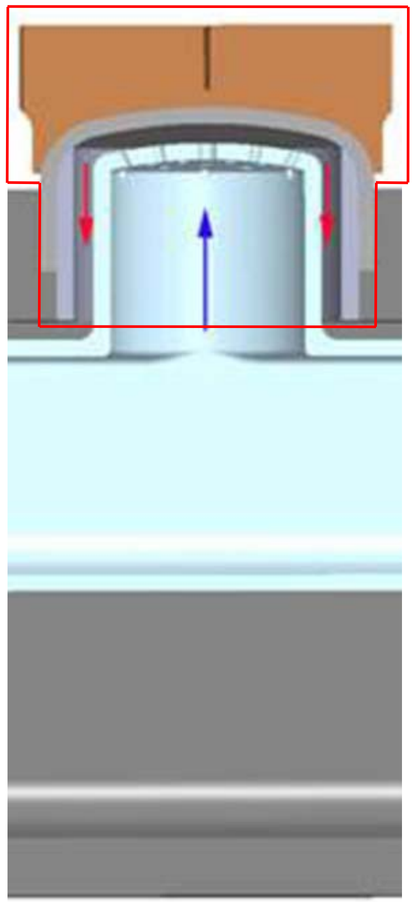
He-cooled W target plate



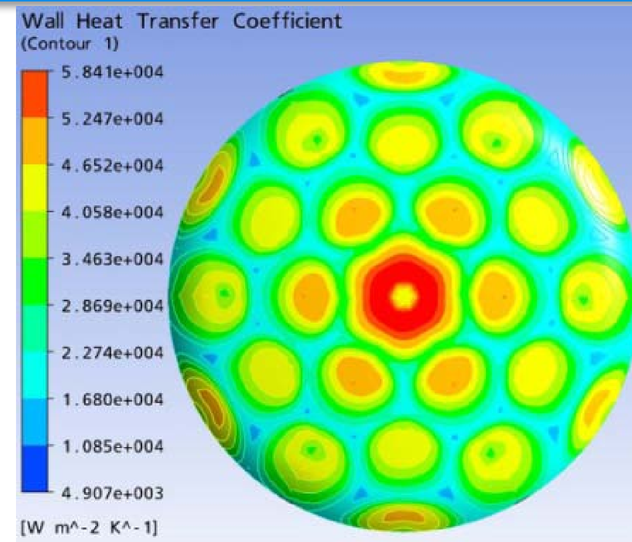
ANALYSES WERE FOCUSED ON THE HIGH TEMPERATURE COMPONENTS

- Each finger and cooling channel of the target plate are identical on the geometry and thermo-fluid and thermo–mechanical behaviors.
- One finger, including the W armor, W thimble, W cylindrical ring and the steel cartridge was simulated during past analyses.
- It is important to confirm the temperature and stresses of the back elements are within design limits.

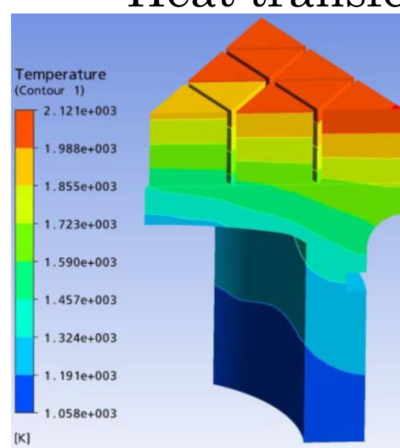
Hot Components



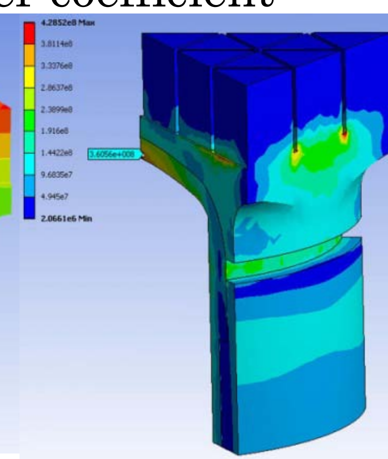
Finger unit including manifold



Heat transfer coefficient

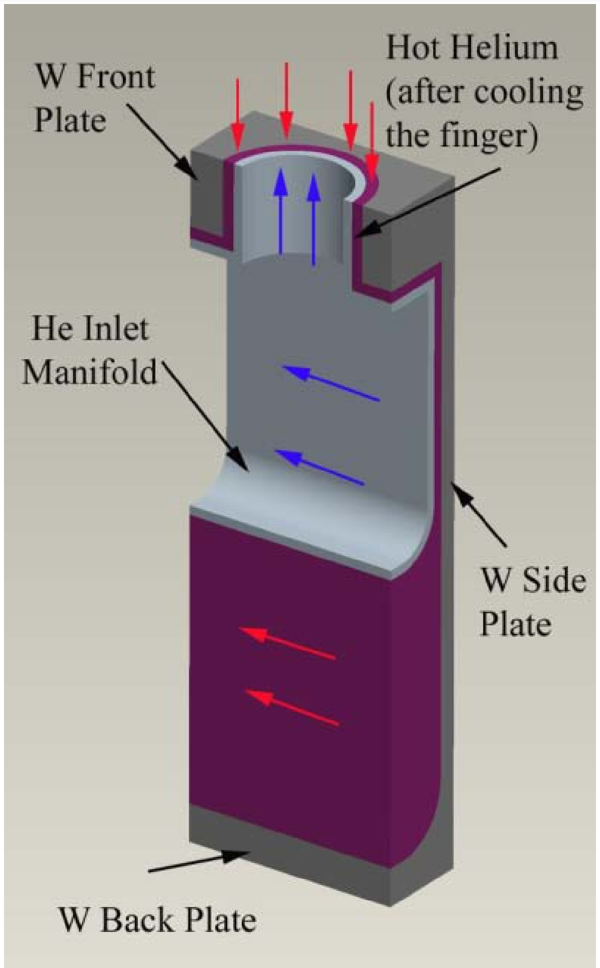


Temperature

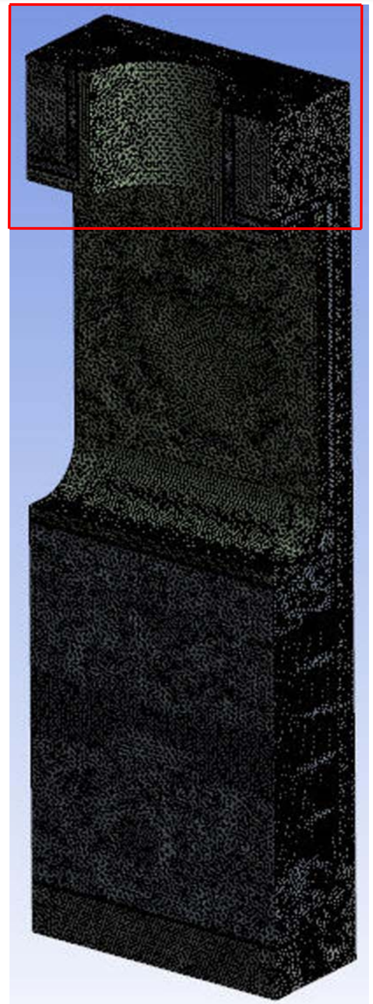


Stresses

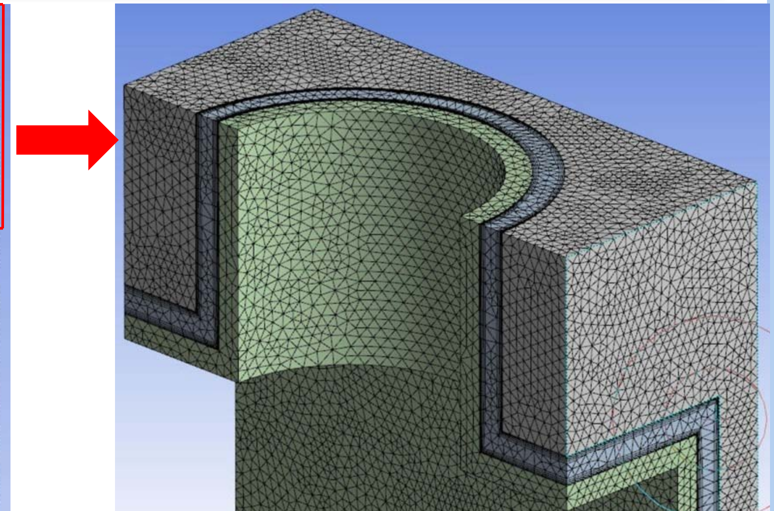
CFX Model for Thermo-Fluid Analysis



CAD model for CFD analysis

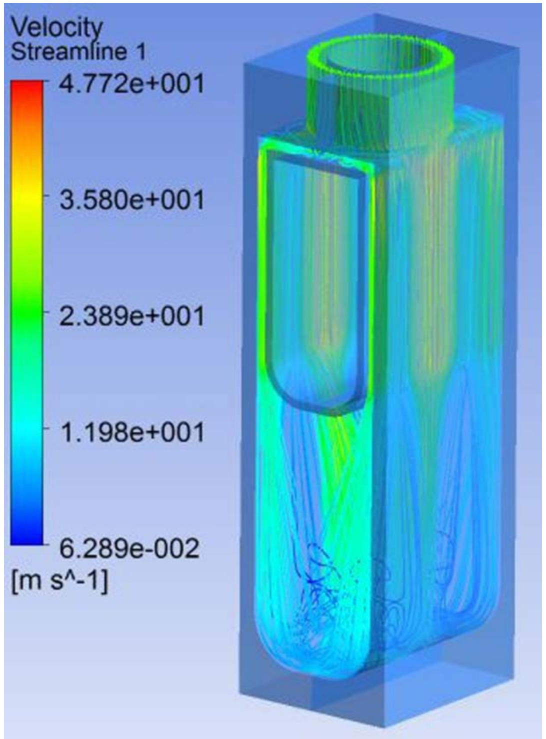


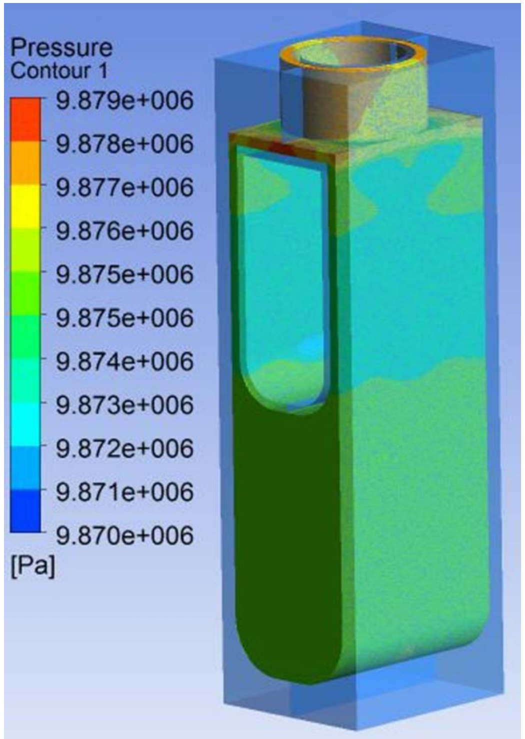
FEA Model

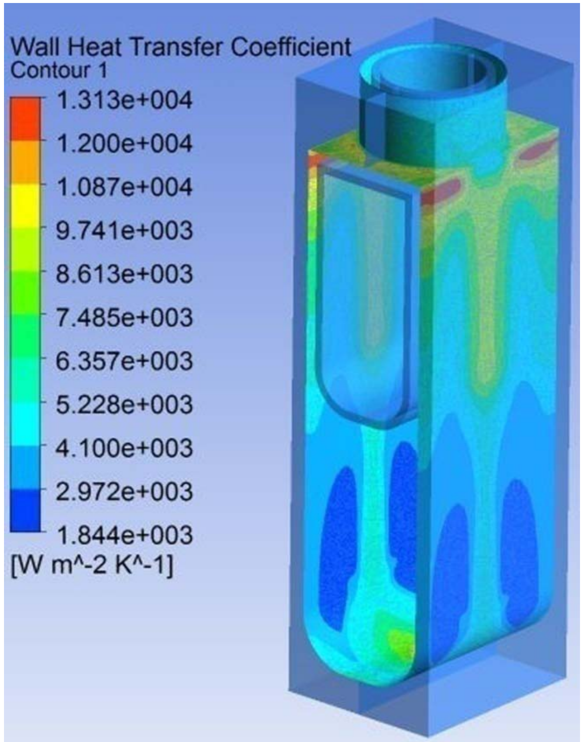


- There are 1.8 million tetrahedral elements in CFX model.
- Standard k-ε turbulent model is utilized.
- Inlet boundary condition is assumed to be identical to the outlet flow of the finger.

THERMO-FLUID RESULTS OF THE COOLING CHANNEL INCLUDING FRONT/BACK PLATES



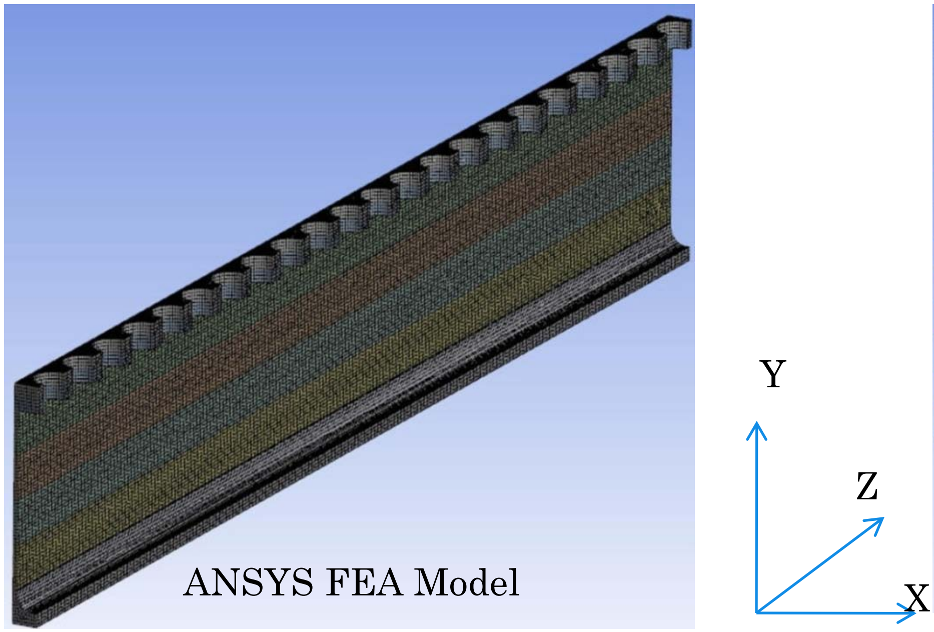


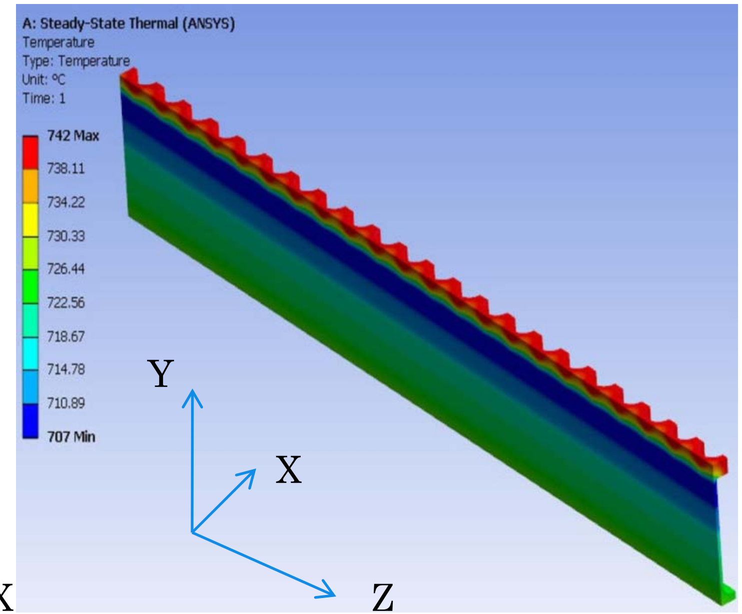


Velocity　　Pressure distribution　　Heat transfer coefficient

- Maximum velocity v=47.7 m/s
- Pressure drop ΔP=0.01 MPa (ΔP=0.13 MPa for the finger)
- Local heat transfer coefficient h=1.313×10^4 W/m^2-K

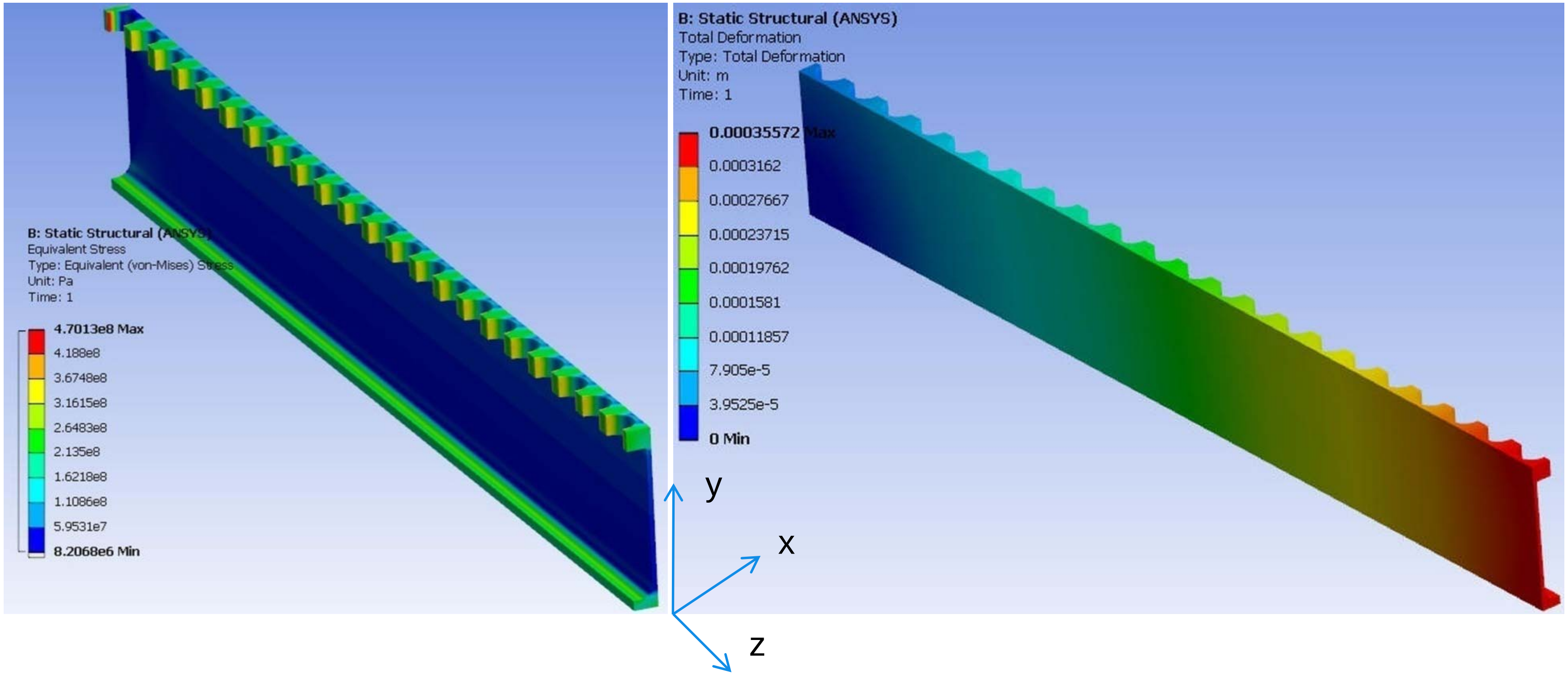
Thermo-Mechanical Model of the Back Elements





- ➢Half W-base cooling channel (~0.5 m) is considered in the thermo-mechanical model.
- ➢Thermal results show the temperature of the cooling channel is uniformly distributed (ΔT~35 °C), and the results will coupled into structural analysis.
- ➢Boundary conditions for structural analysis
  - ✓Symmetry boundary is applied at both Y-Z planes (x=0 and x=10 mm).
  - ✓At one end (X-Y plane, Z=0) is assumed free, and at another end (X-Y plane Z=0.5 m), the symmetry boundary is applied.
  - ✓Bending is suppressed at the bottom plane (X-Z)

Example Stresses of the Back Elements

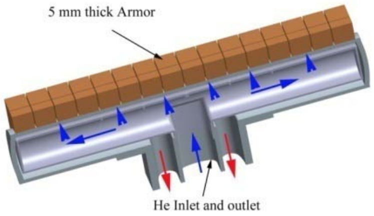


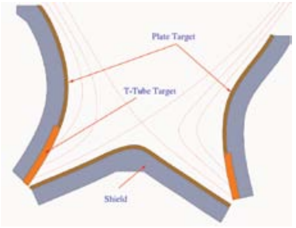
- ➢The maximum combined primary and secondary stresses are 470 MPa (< 3Sm =752 MPa for W temperature T=750 °C)
- ➢Maximum total deformation is about 0.4 mm

SUMMARY

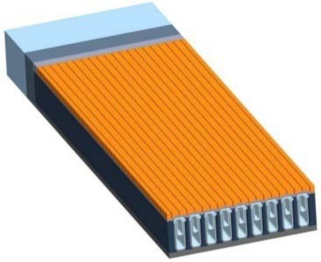
- Thermal-fluid and thermo-mechanical calculations including both the finger and back elements (beneath of the finger) have been performed, and the results confirm the expected high performance of the concept with a maximum allowable heat flux > 10 MW/m^2.
- As a next step, the nonlinear structural behaviors of the divertor target plates should be investigated, including
  - ✓ Under thermal cyclic loading condition
  - ✓ Under anticipated fast transients
  - ✓ During plant start-up and off-power

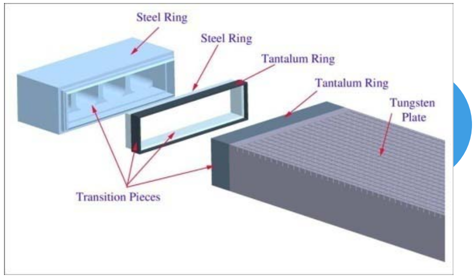
Other Activities on Helium-Cooled Divertor Concepts





- Jeremy Burke is working on expanded T-Tube divertor design to improve performance
  - ✓ T-Tube divertor was design to accommodate a surface heat flux of 10 MW/m^2 for ARIES-CS. (by Thomas Ihli)
  - ✓ It was expanded to two heat-flux-zone divertor concept without changing configuration except the thickness of W armors.
  - ✓ The coolant cartridge can be tapered to maintain more uniform velocity and heat transfer coefficient, then improve thermal stresses. However, it needs supporting analysis to confirm.





- Harshit Chitalia is working on transient analysis of joints with proper accounting of plastic deformation.
  - ✓ Transition joints between W and steel is critical for the helium-cooled W-based divertor concepts because thermal expansion of steel is ~2-3 times higher than W and it causes high stresses during operation.
  - ✓ The joints were designed using Ta as a transition material between W and Steel. Transition joints for the plate-type divertor were analyzed at UCLA, and a 2-D axis-symmetry model and 3-D cylindrical model were utilized.
  - ✓ Detailed non-linear analysis to be performed to include plastic deformation.