ANSYS Simulations of Water Cooled Positron Target Average Temperature and Thermal Stress

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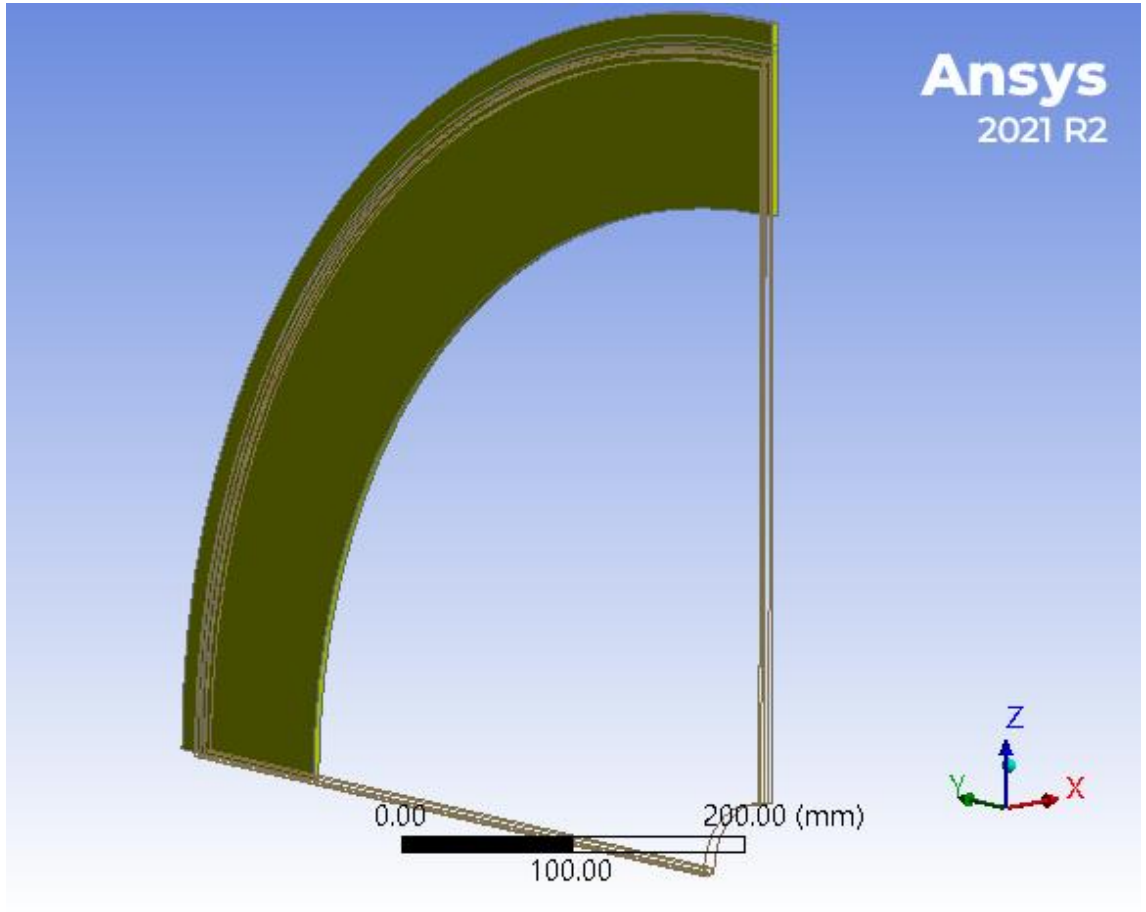
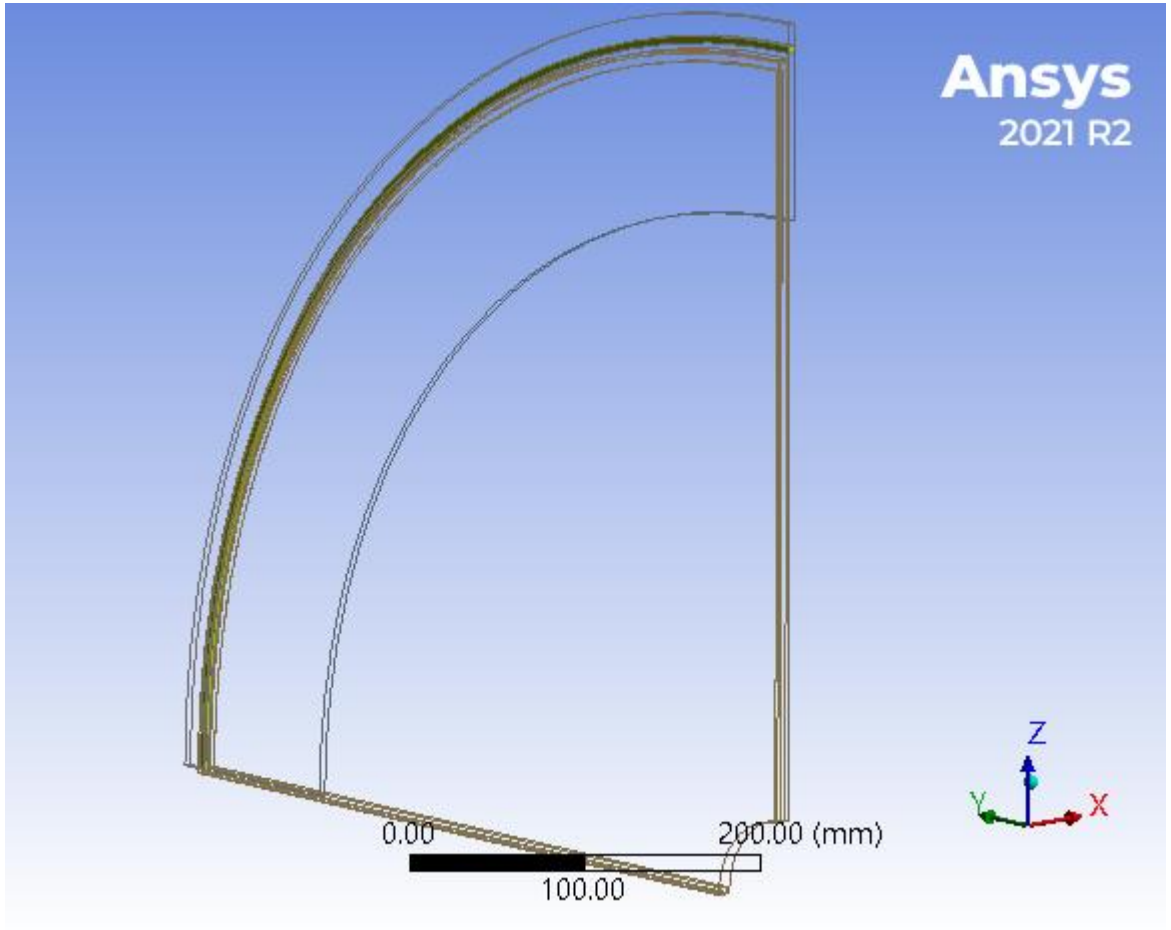
Parameters of Positron Target

- 17 kW average power deposited by 1 mA e^- beam at 120 MeV
- Electron beam passes the 4 mm tungsten target at radius of 50 cm
- Deposited power distributed equally in volume V,
  $V = \pi \cdot (502^2 - 498^2) \cdot 4$ [mm^3] = 12566 [mm^3] and average deposited power density P = 1.35 W/mm^3
- Target is cooled by water flowing inside Cu disk with velocity of 10 m/s

Geometry of Tungsten Rim with Thickness of 4 mm

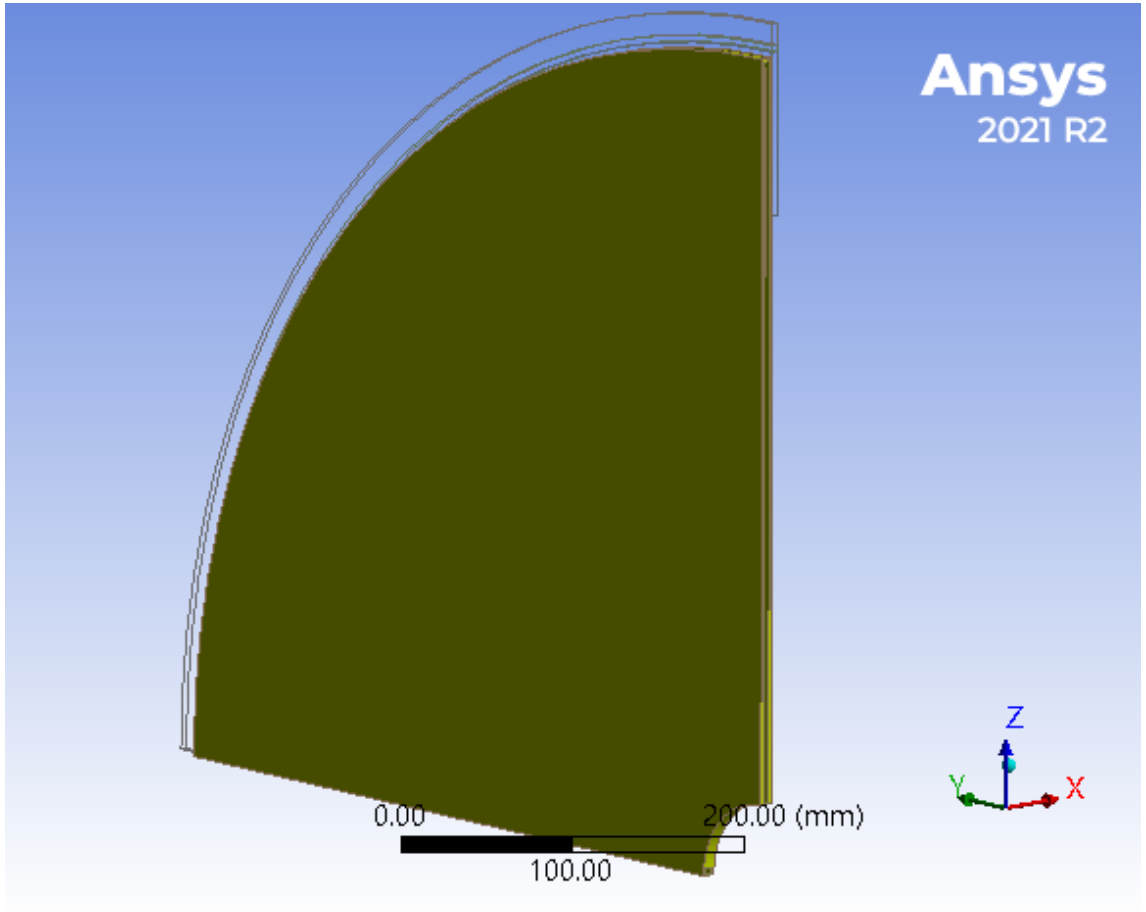


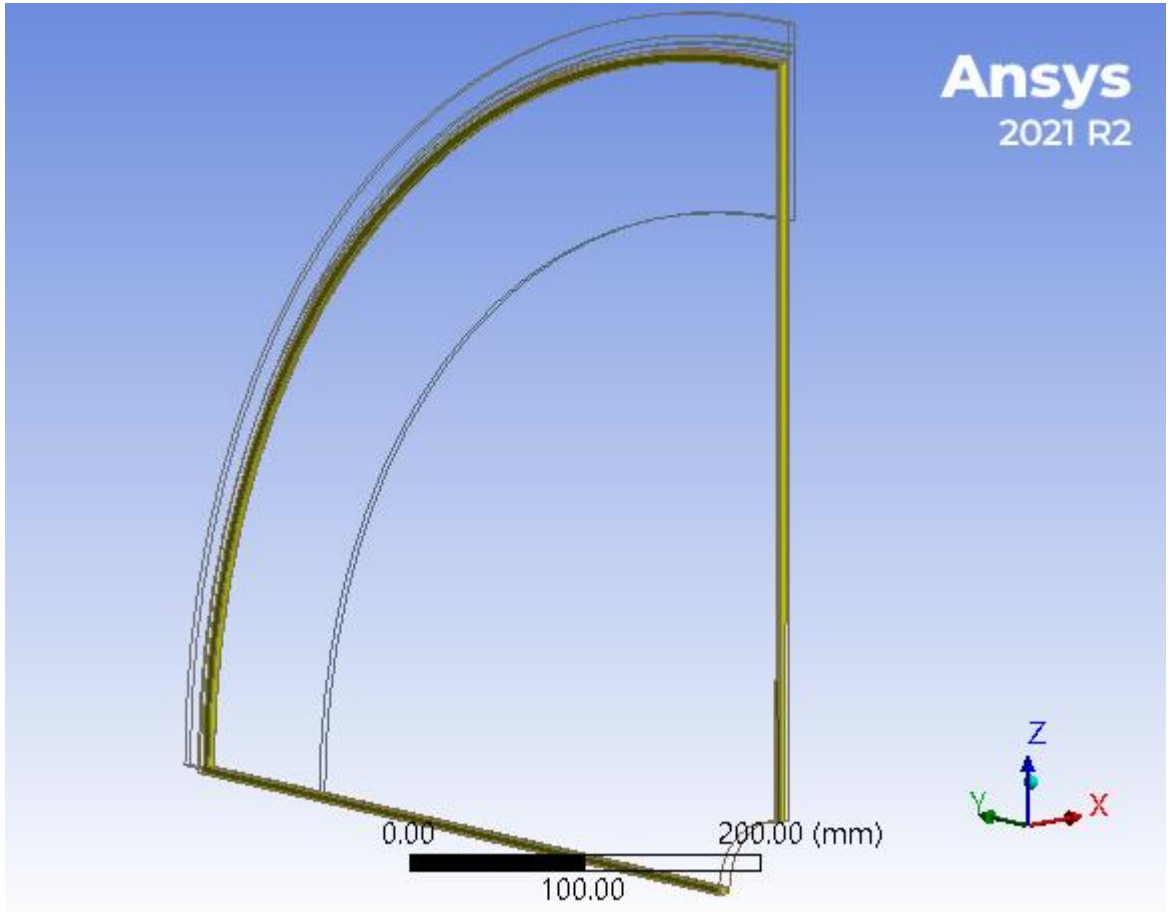


R_{max} = 515 mm, R_{min} = 400 mm

R_{beam} = 500 mm, ΔR_{min} = 4 mm

Geometry of Cu Disk with Thickness of 8 mm (left) and Water Channel (right)

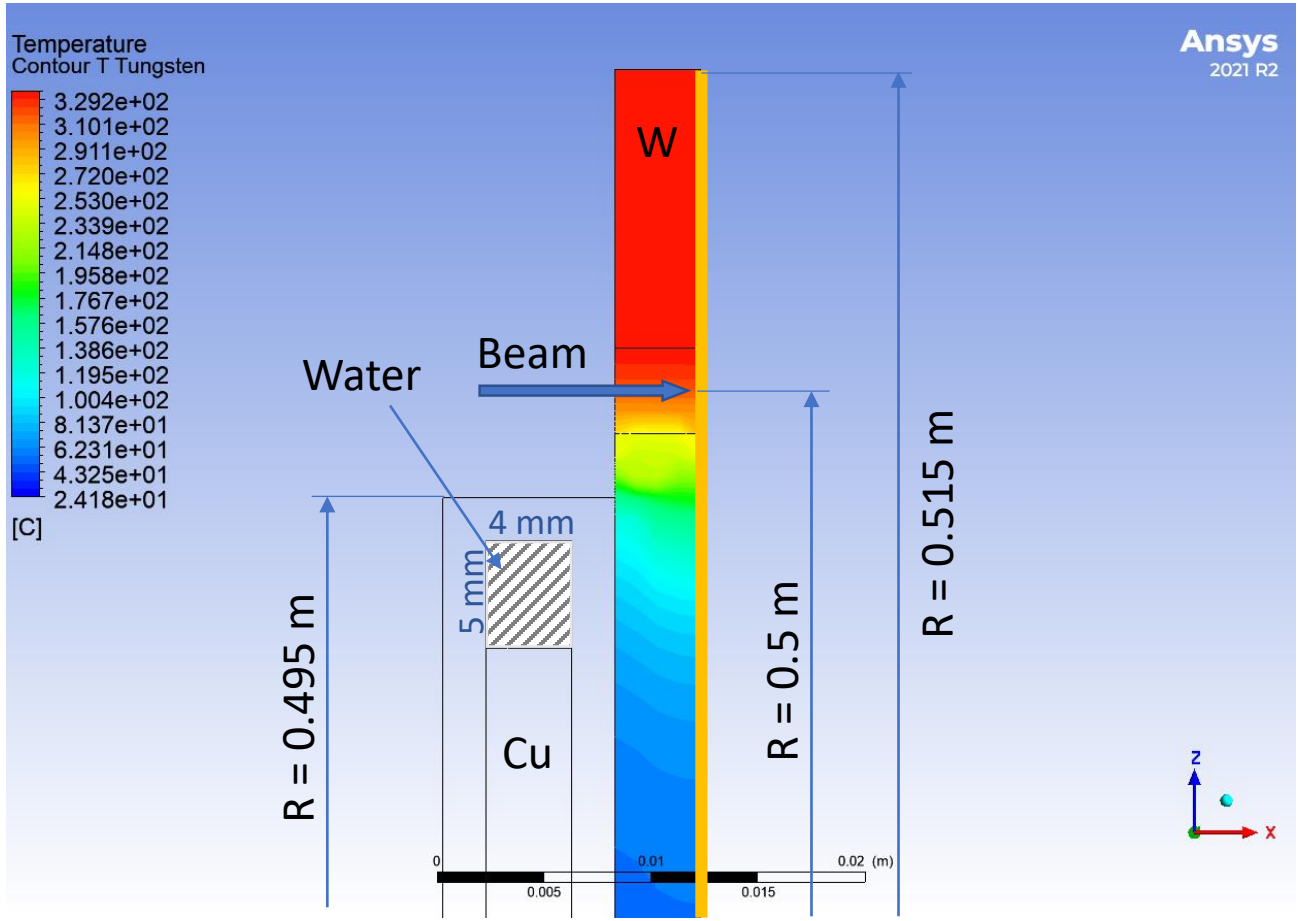




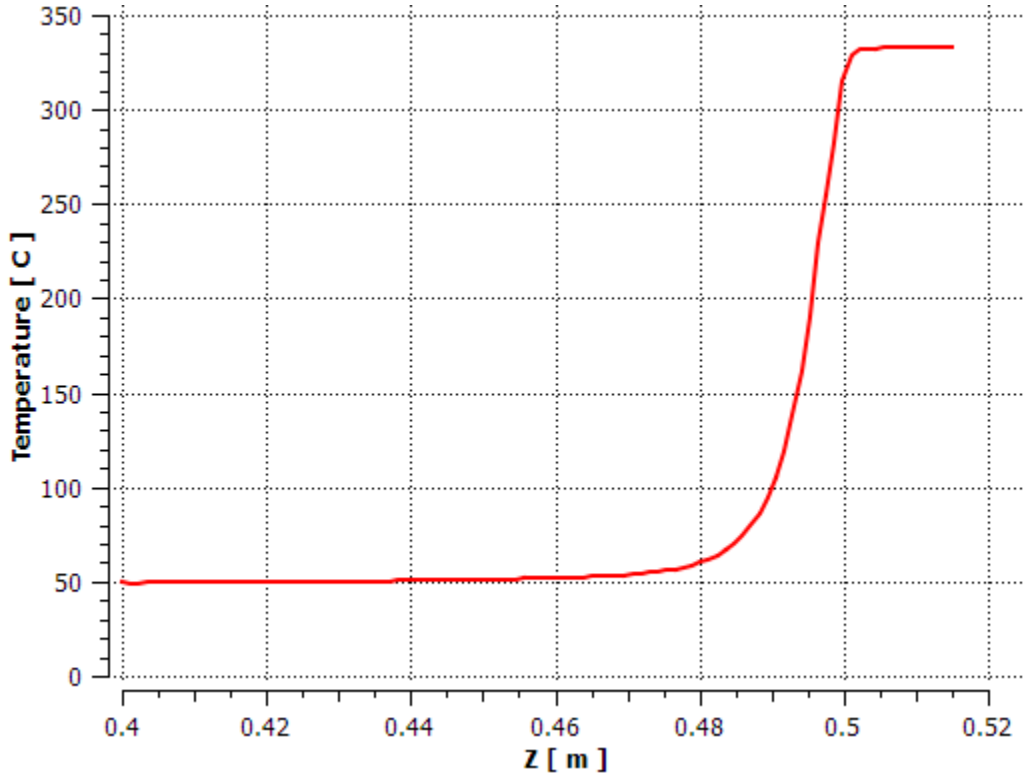
R_{max} = 495 mm, R_{min} = 50 mm

Cross-section of water channel: 4 mm x 5 mm

Temperature Distribution in Tungsten

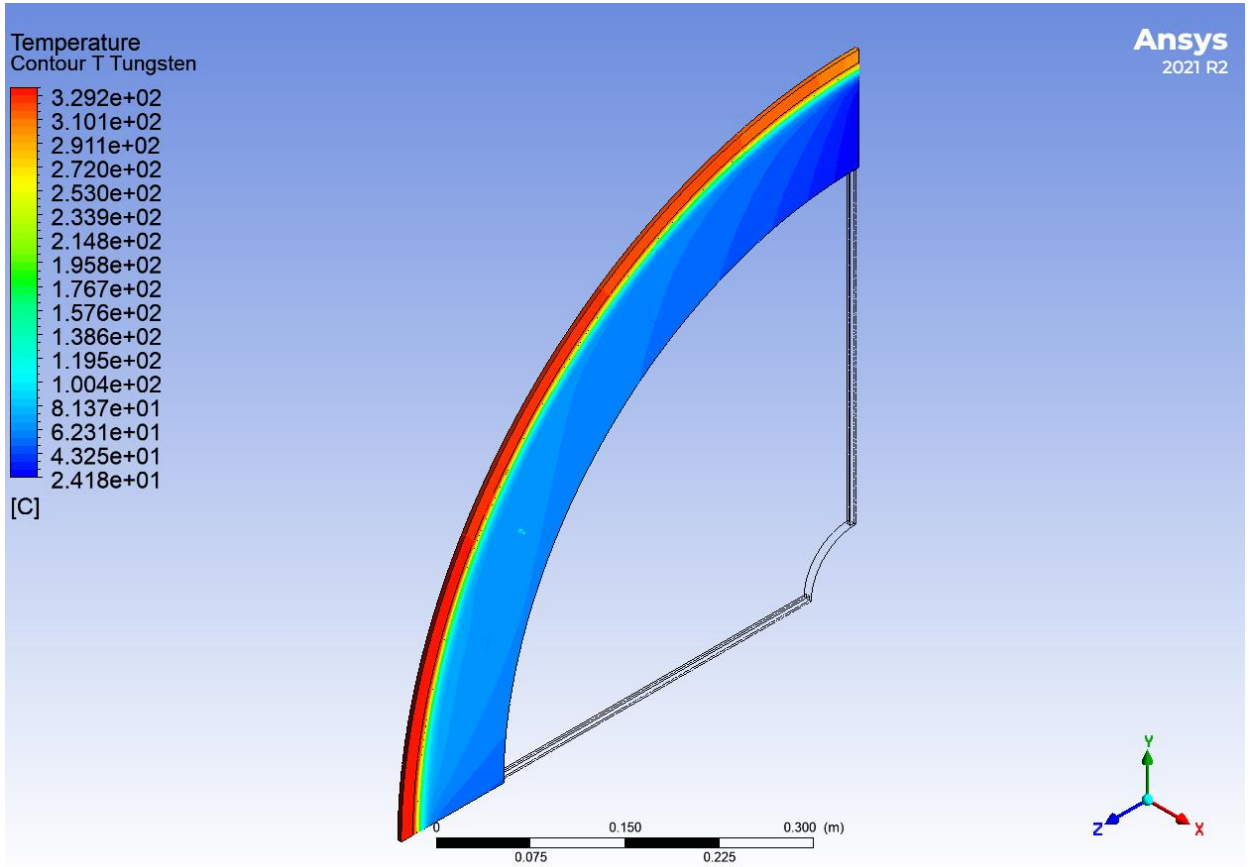


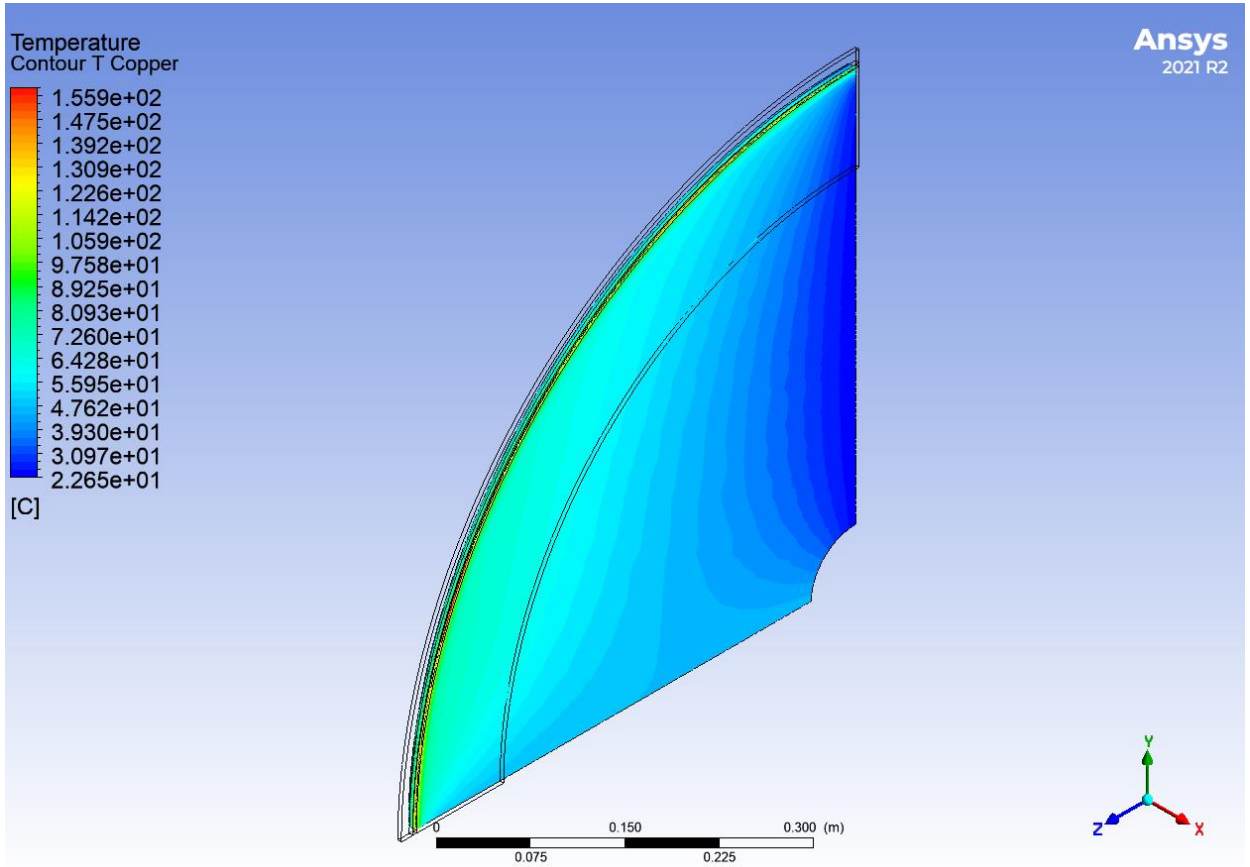
Temperature profile on hottest bottom plane at exit side



T_{max} = 330 °C

Temperature Distributions in Tungsten (left) and Copper (right)

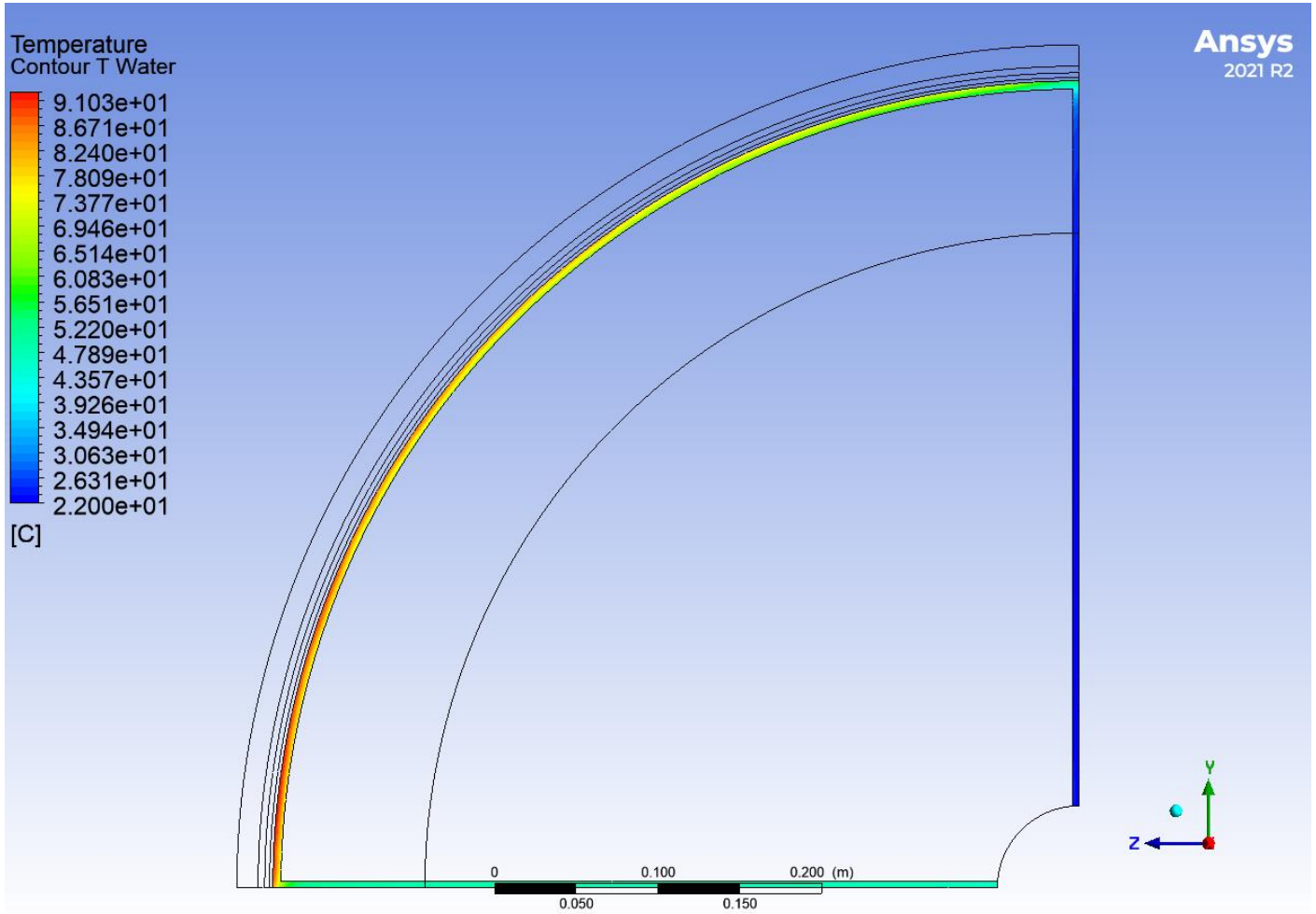




T_{max} (W) = 330 °C

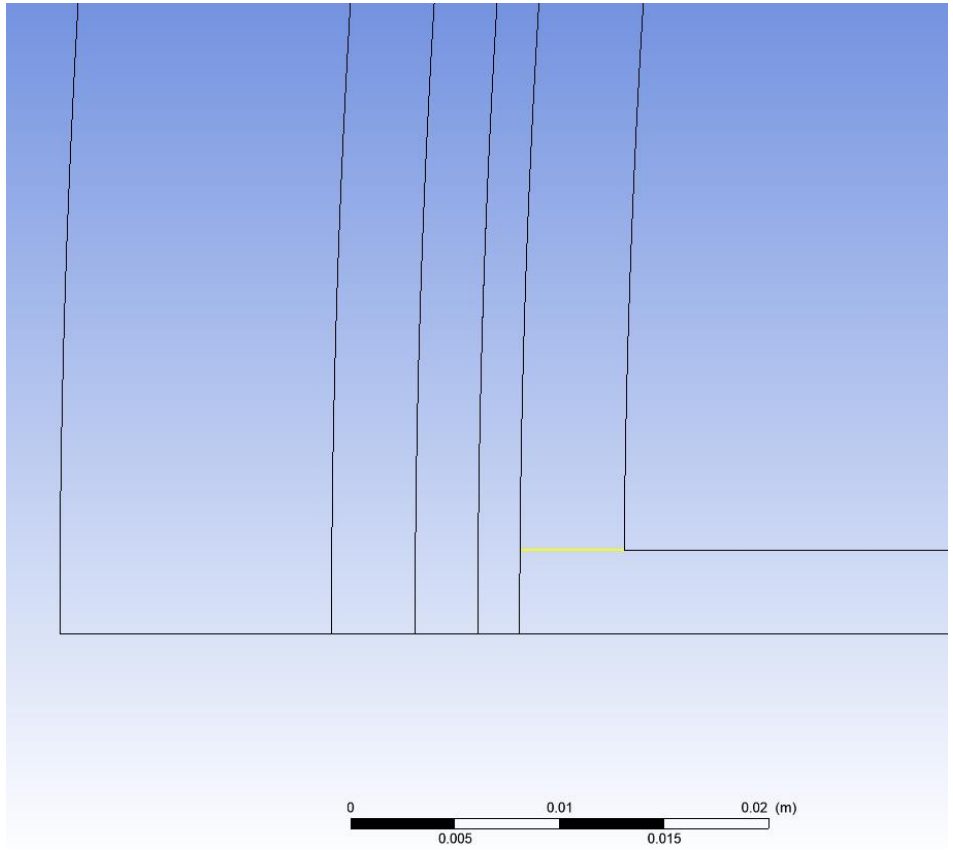
T_{max} (Cu) = 156 °C

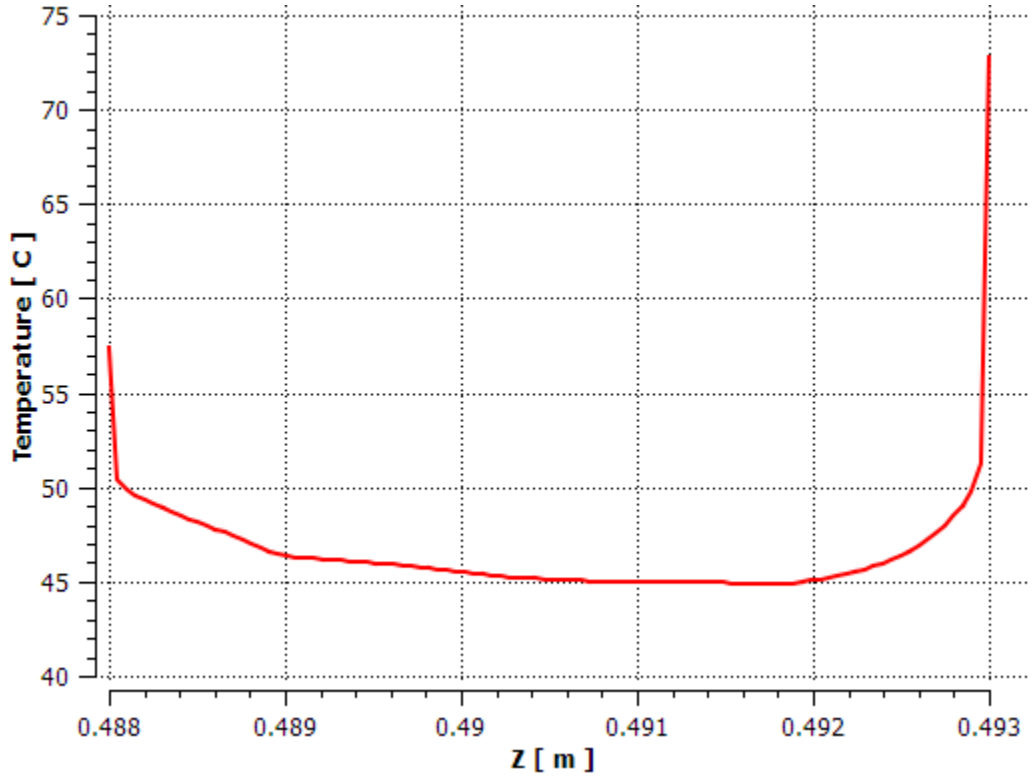
Temperature of Water at 10 m/s velocity



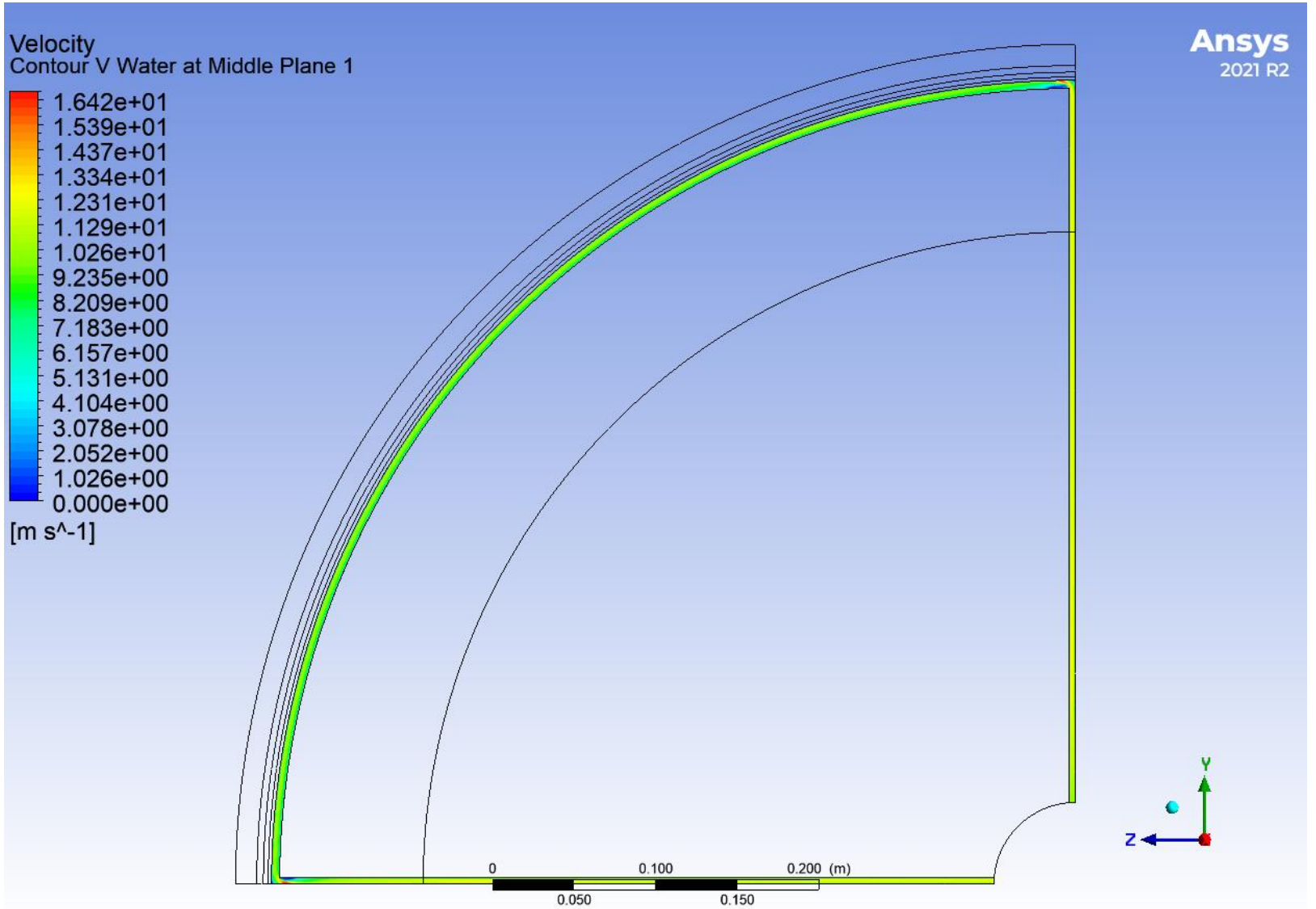
Max temperature of water is 91 °C

Temperature Profile of Water at the End of Circular Path

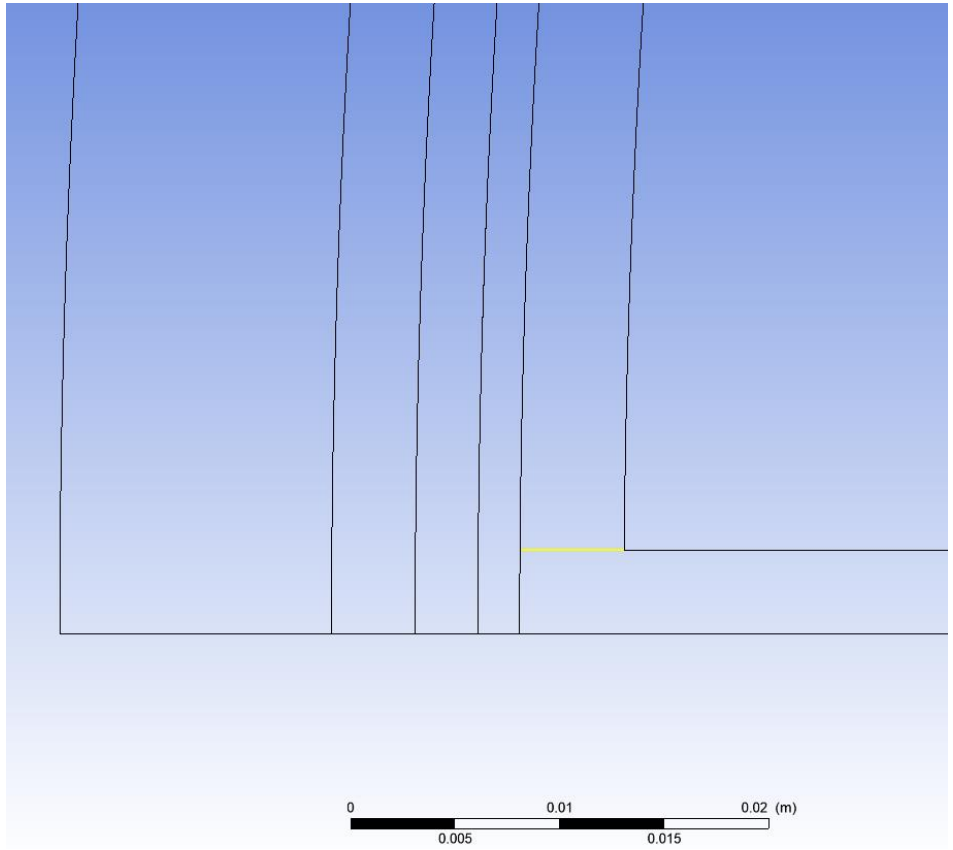


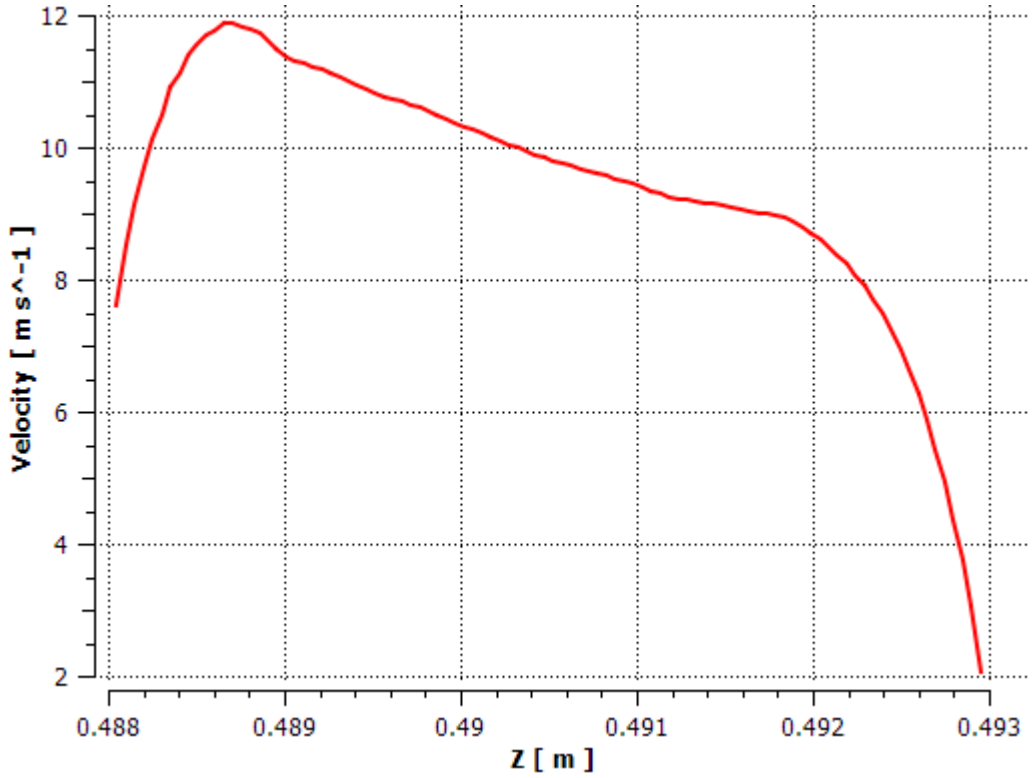


Velocity of Water

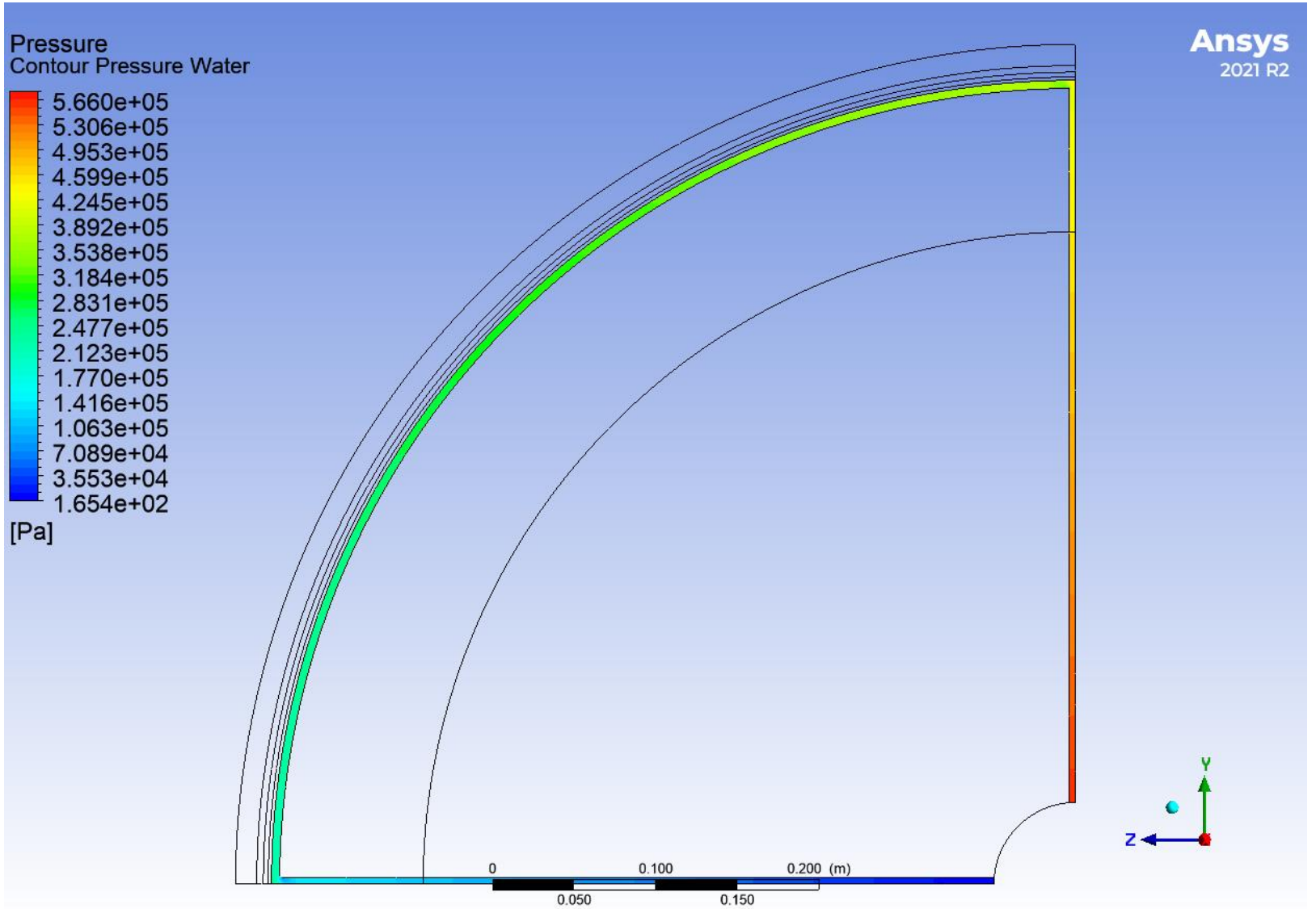


Velocity Profile of Water at the End of Circular Path

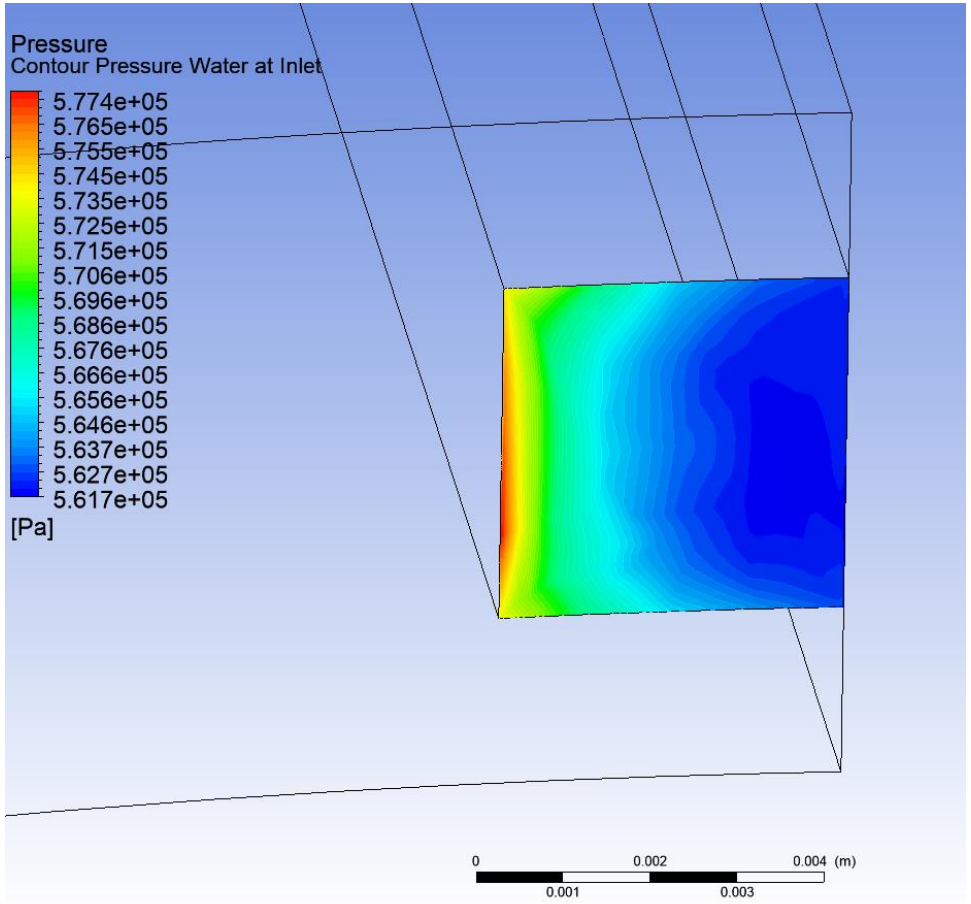


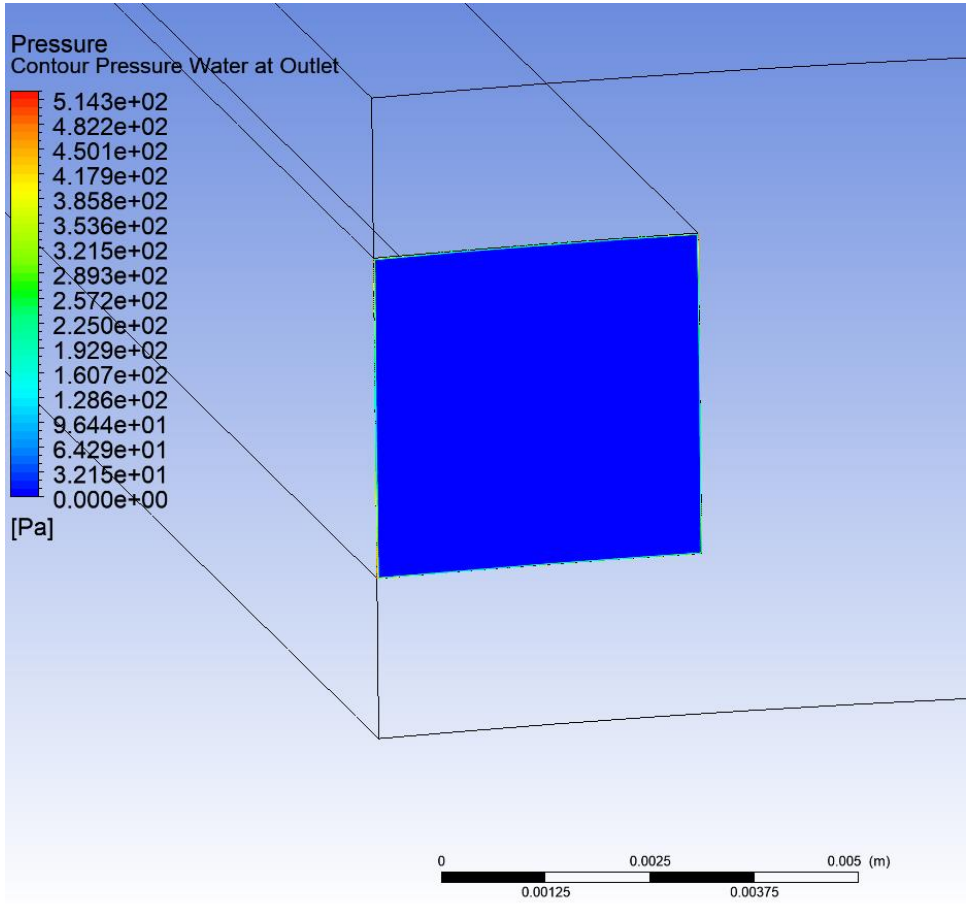


Pressure of Water



Pressure of Water at Inlet (left) and Outlet (right)

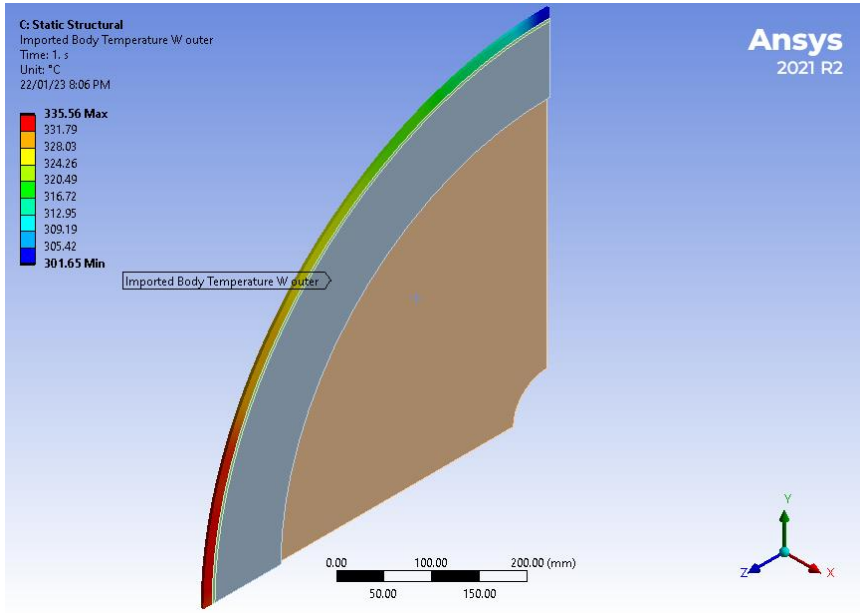


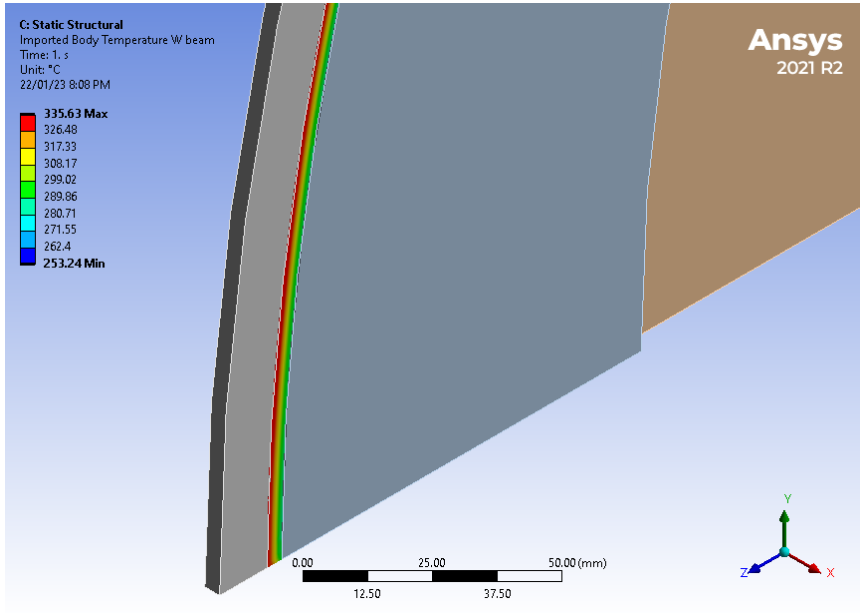


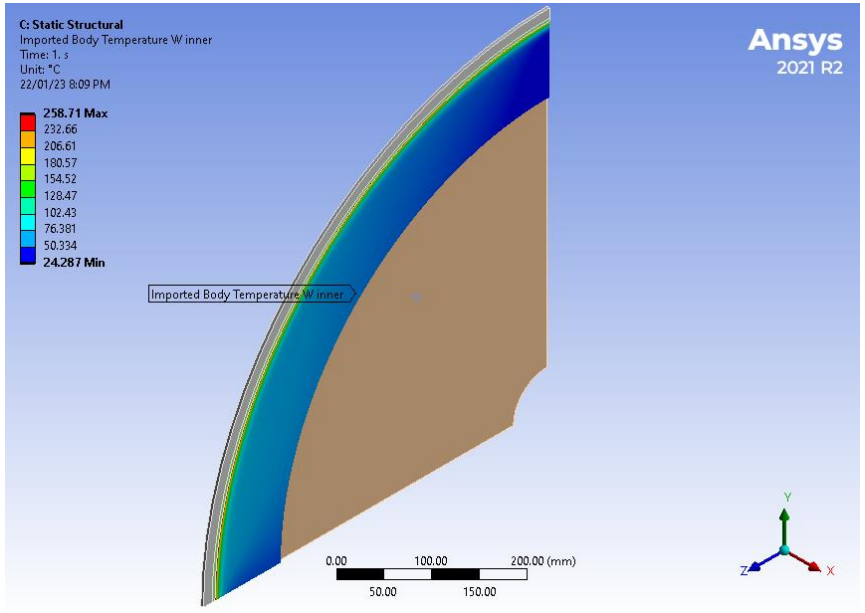
P_{max} (Inlet) = 557 kPa

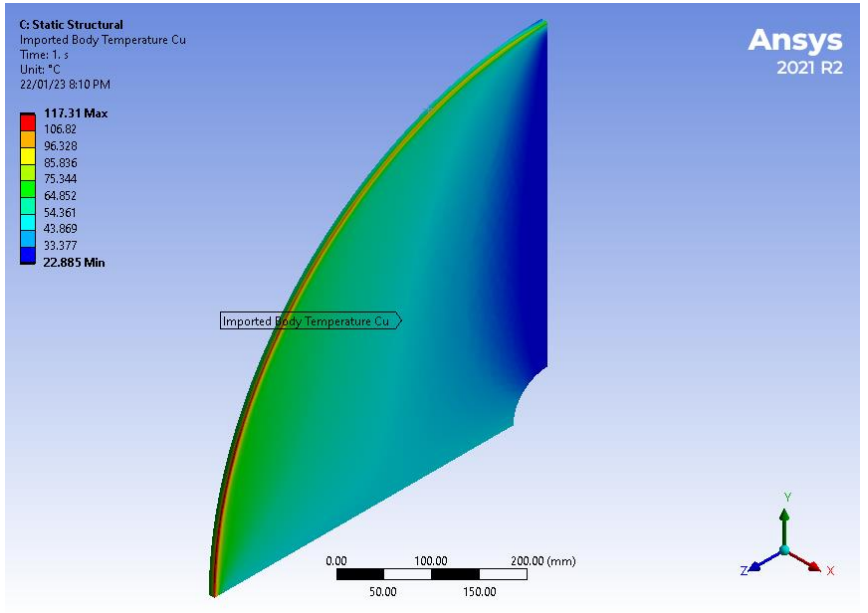
P (Outlet) = 0

Import Temperature into Static Structural Analysis

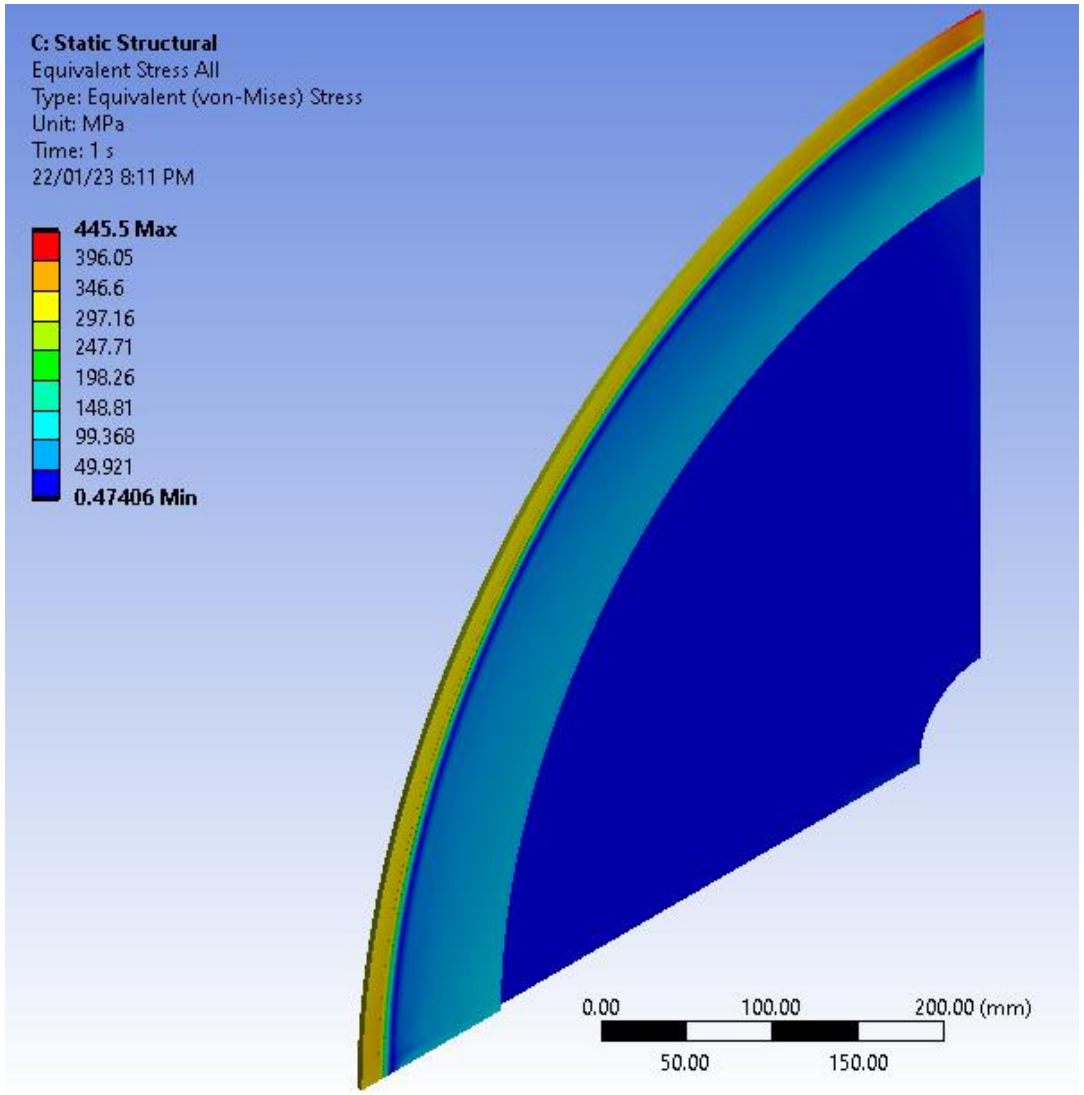


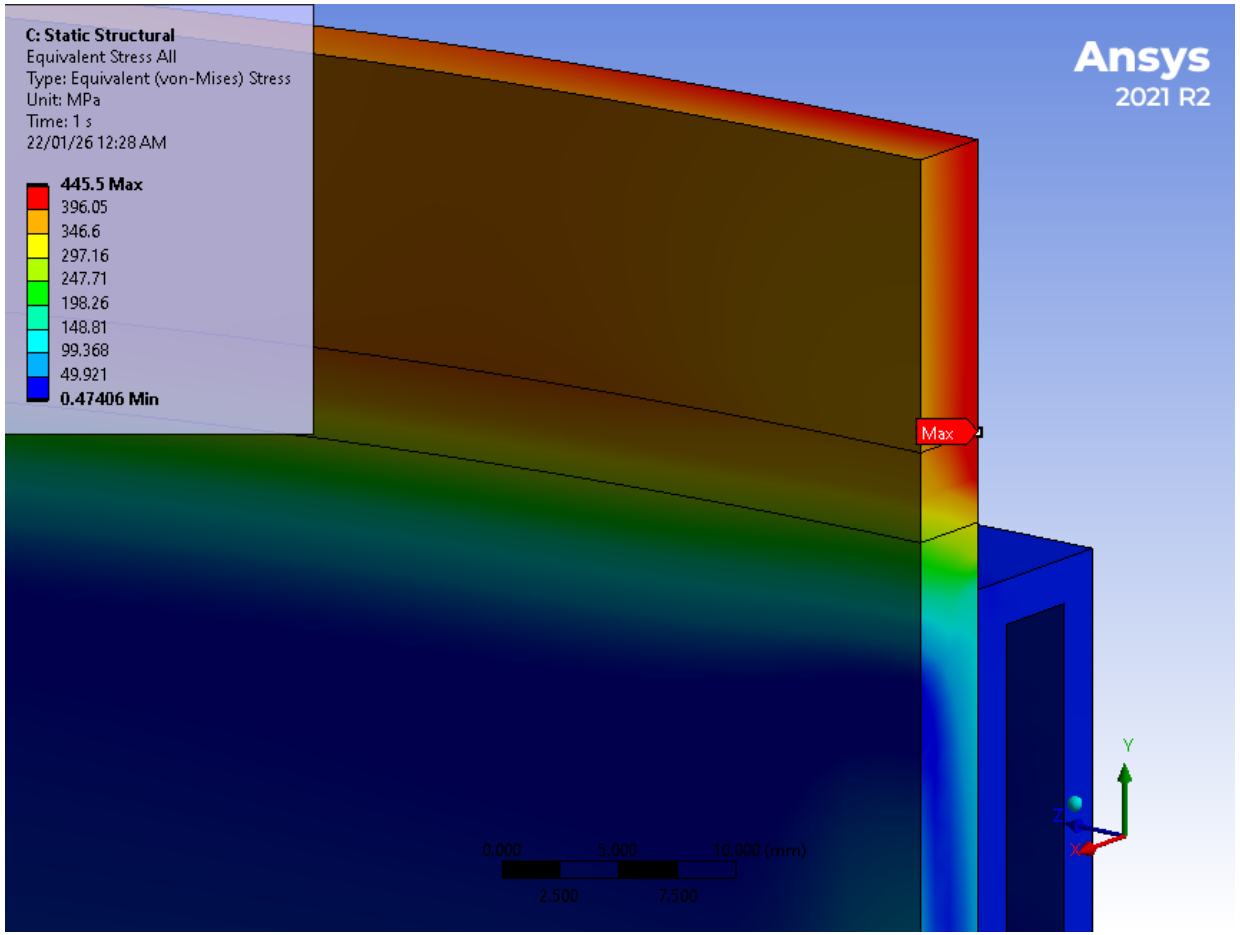






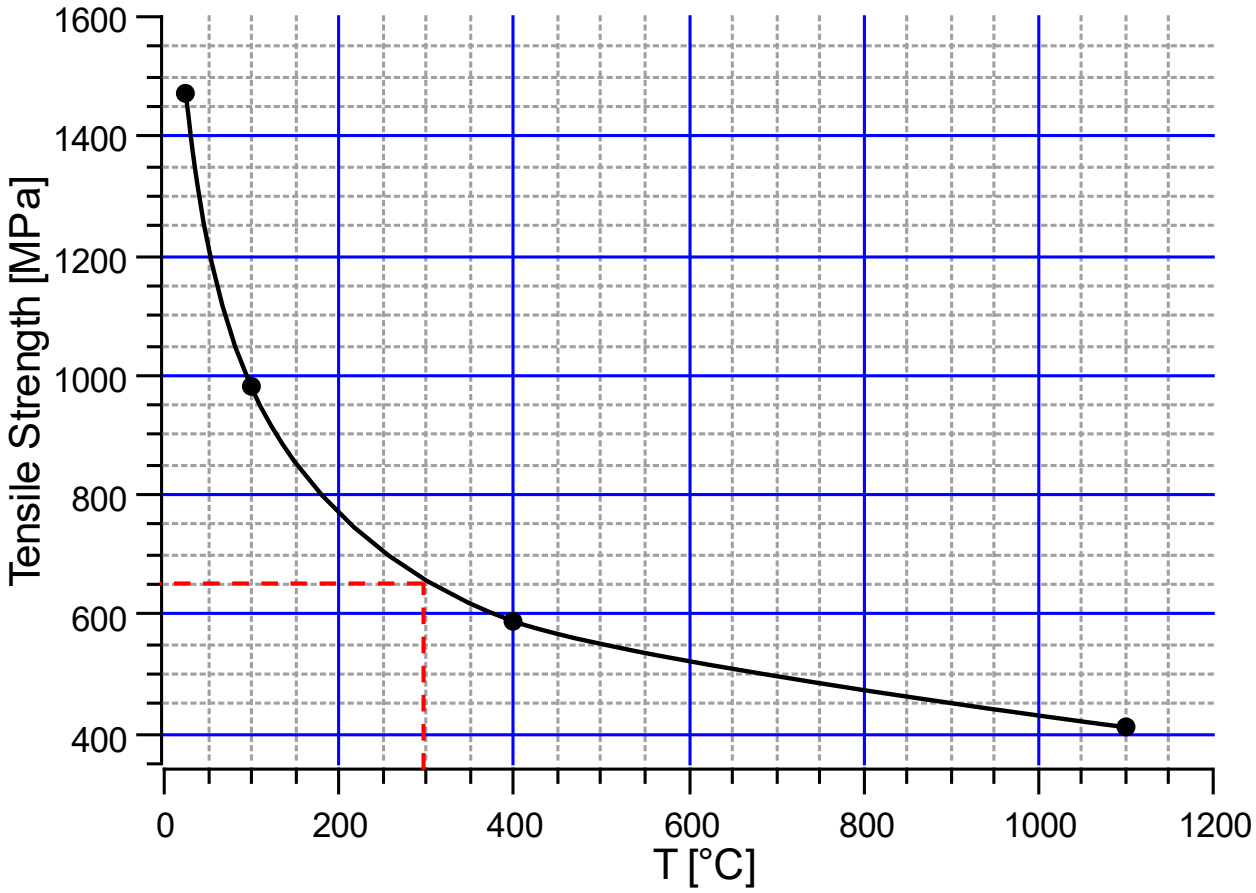
Equivalent von-Mises Stress





Max equivalent von-Mises stress is **445 MPa** is the area where temperature of tungsten is ~**300 °C**

Tensile Strength of Tungsten vs Temperature



Tensile Strength of Tungsten at 300 °C is approx. 650 MPa

Summary

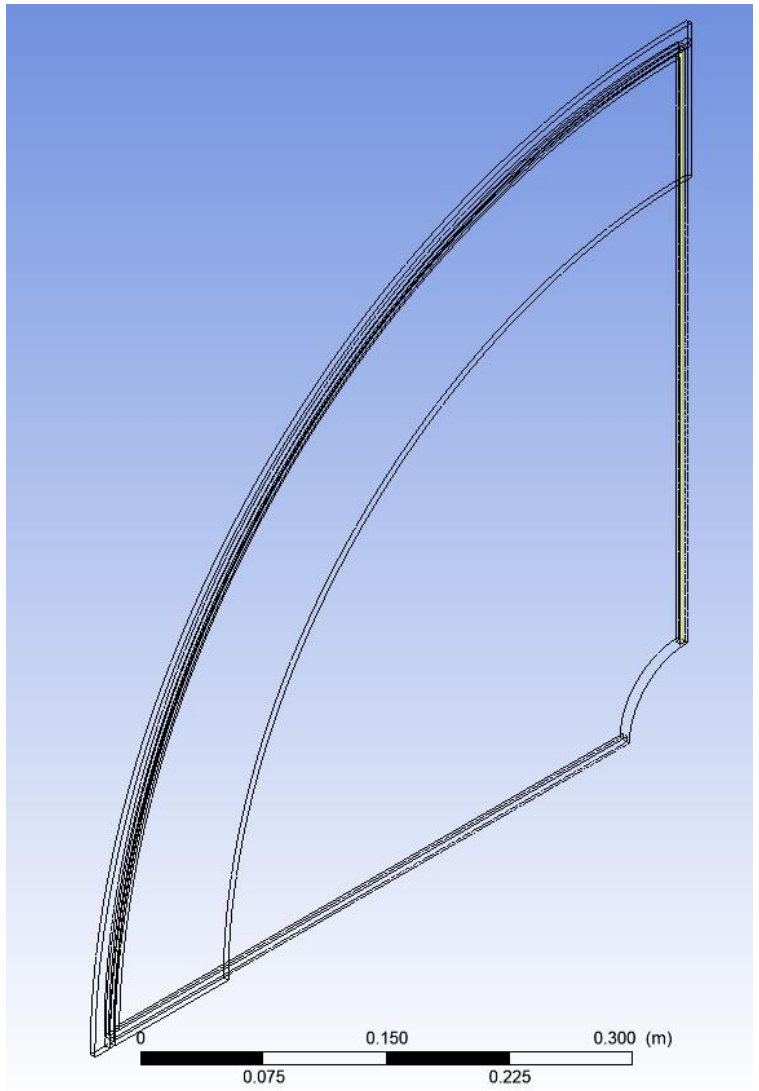
- “1 m” in diameter W target cooled by 10 m/s water flow:
  - T_{max}(W) = 330 °C
  - T_{max}(Cu) = 156 °C
  - T_{max}(Water) = 91 °C
  - $\sigma_{max}(T_W = 300\ °C) = 445\ MPa$, $\sigma_{yield}(T_W = 300\ °C) = 650\ MPa$
  - ΔP_{max}(Water) = 577 kPa

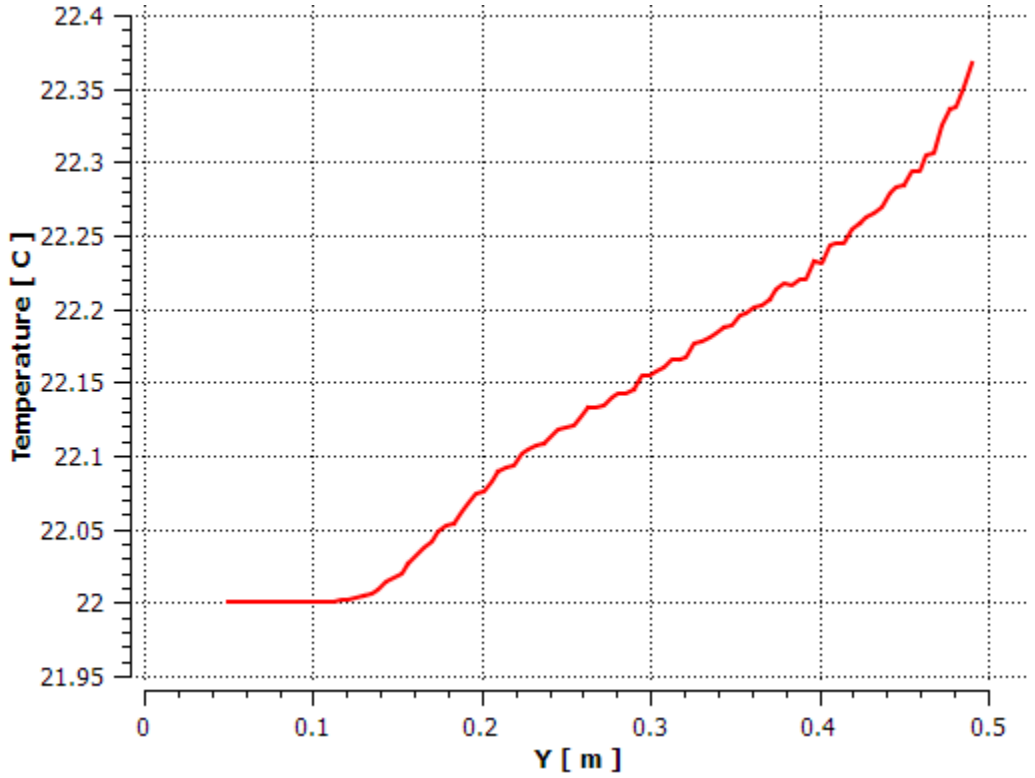
Further Steps

- Optimize water channel in order to reduce the velocity of water to 2 m/s
- Make smoother (90°) turns of water channel
- Calculate the transient/dynamic increase of temperature when beam is moving on target during one cycle/turn
- Stress-strain curves for tungsten at different temperatures are required for correct estimations of thermal stress
- Consider other target materials (W26Re,…)

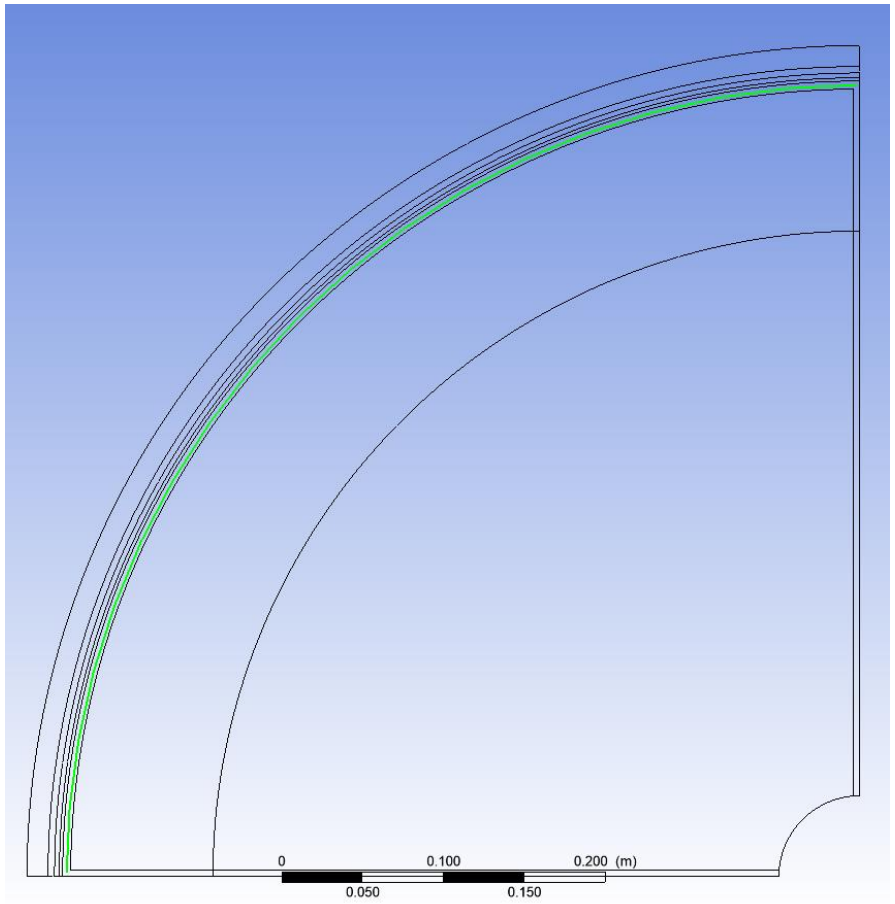
Backup Slides

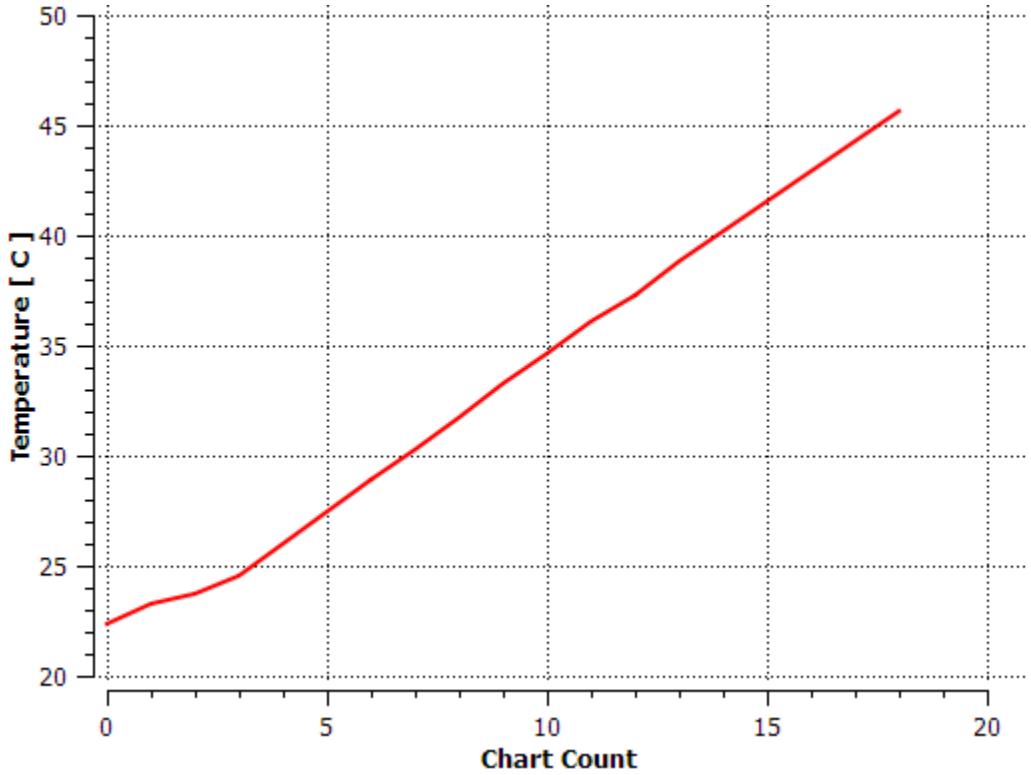
Temperature of Water in the Middle of Water Channel from Inlet to Top





Temperature of Water in the middle of Water Channel along Circular Path from Top to Bottom-Left





Circular path of 90° was split in 19 equal intervals (5°) shown as “Chart Count” (X-axis on the chart)

Temperature of Water from Outlet to End of Circular Path