SECOND
TARGET
STATION

Core Vessel 4/2025 Preliminary Structural Analysis

T. McManamy

4/7/25

U.S. DEPARTMENT OF ENERGY

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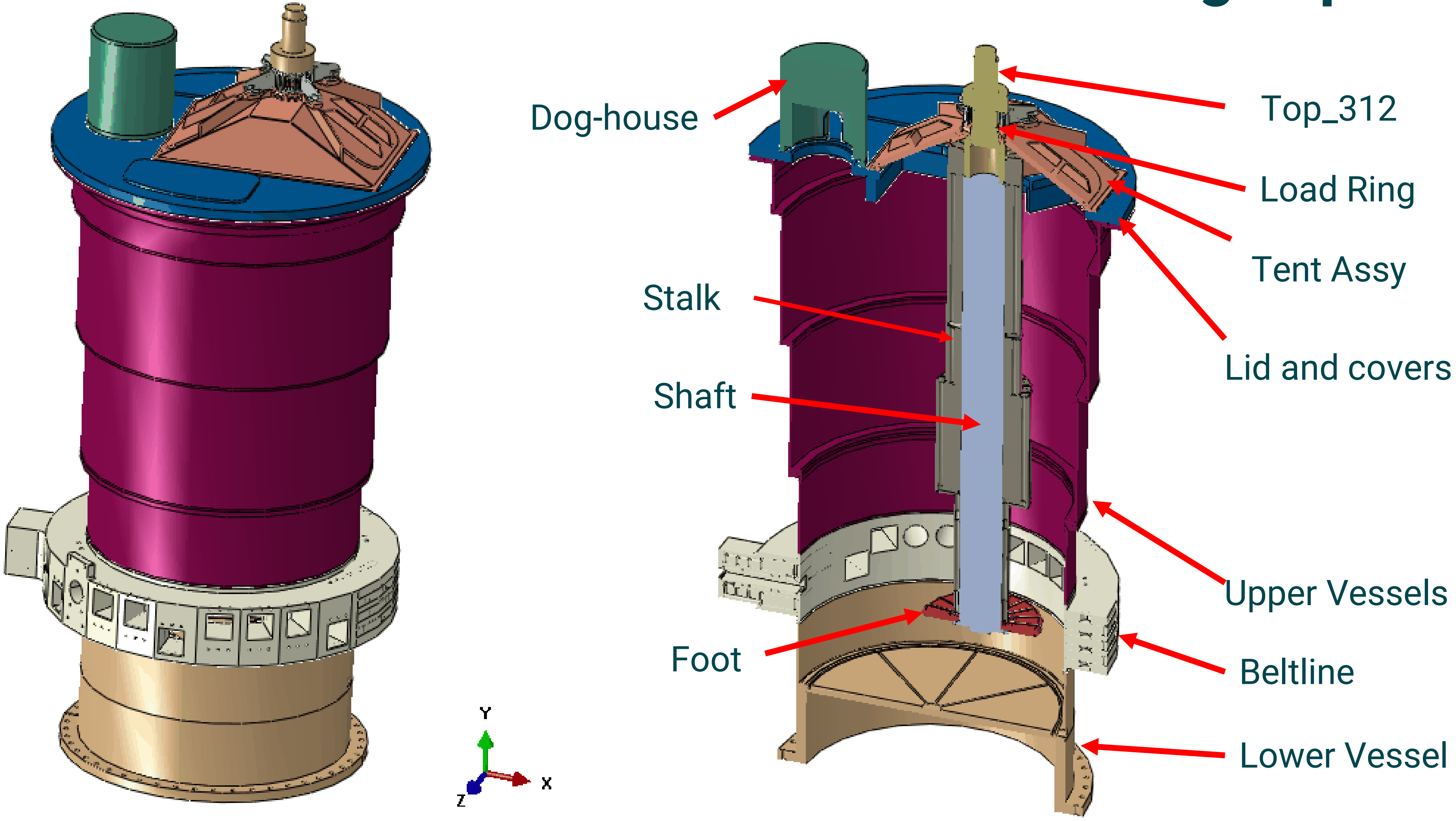
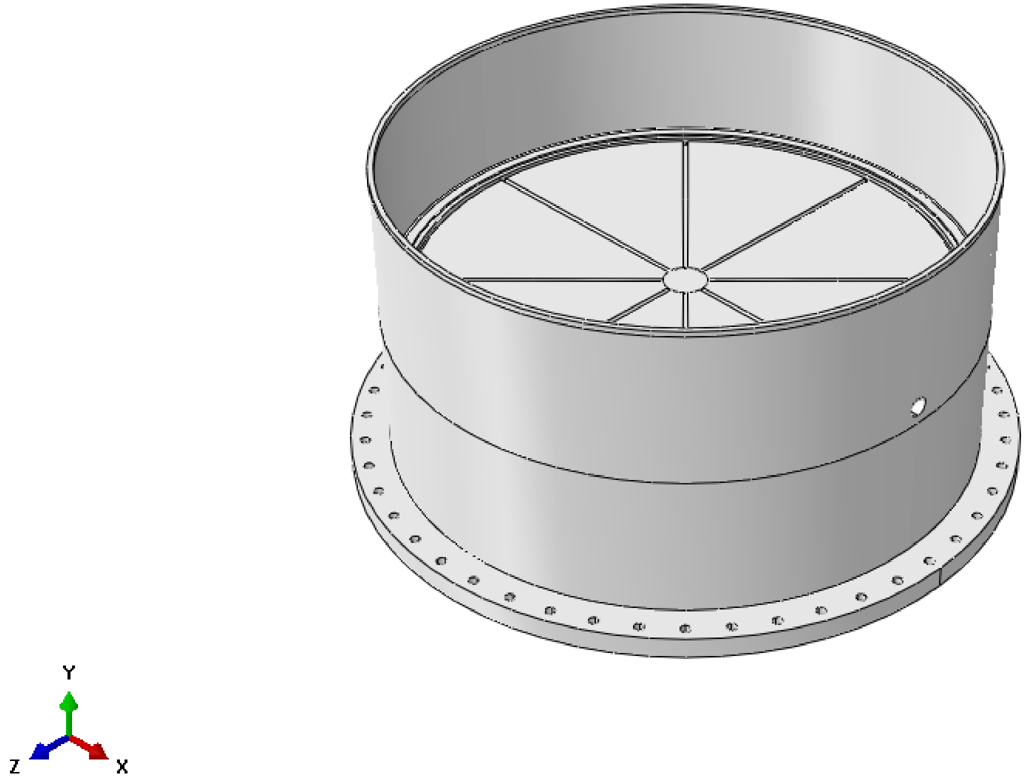
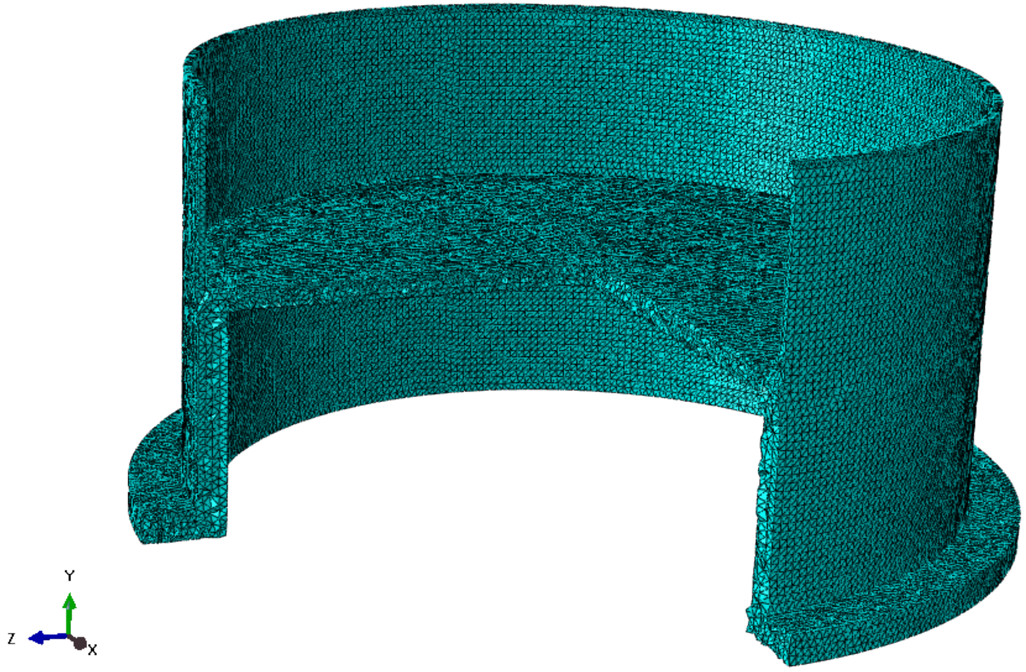
Overall Core Vessel Seismic model with merged parts



Internal Shielding and nozzle extensions not included

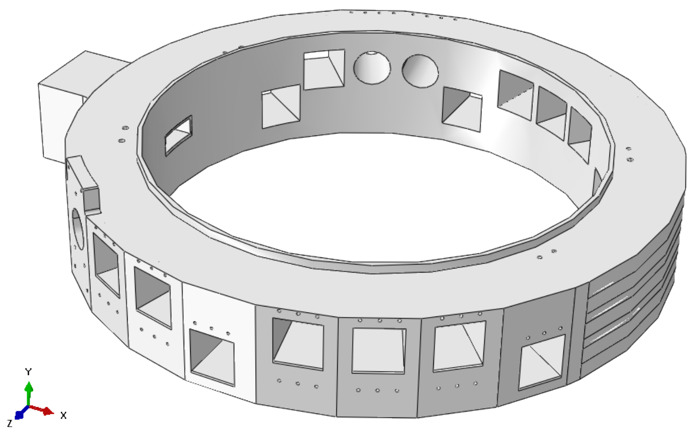
Lower Vessel part and mesh



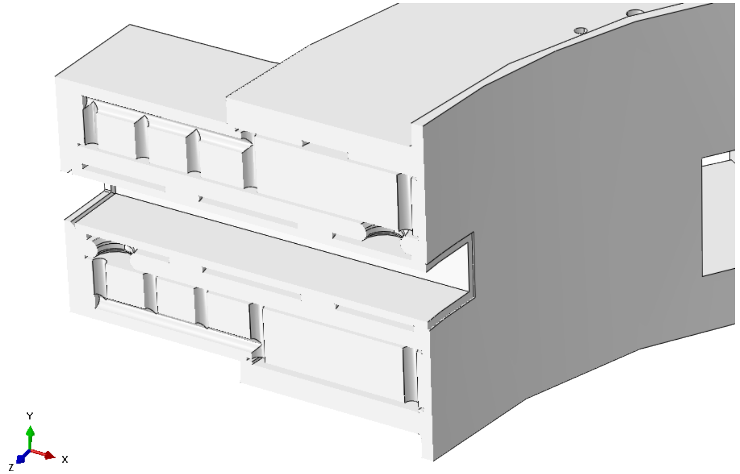


Beltline Part and mesh

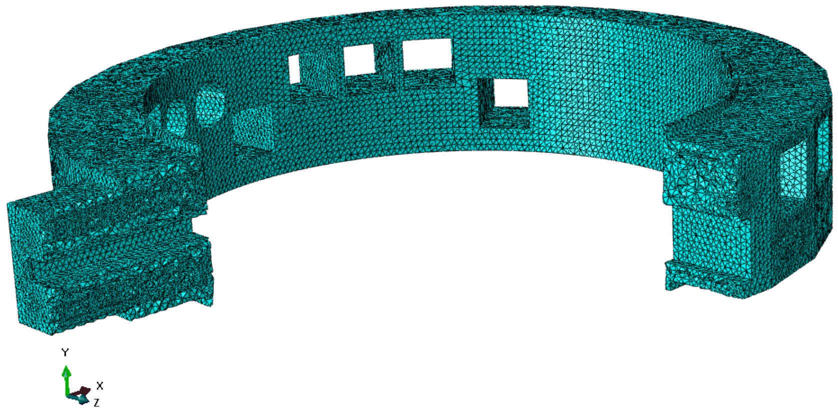
Part



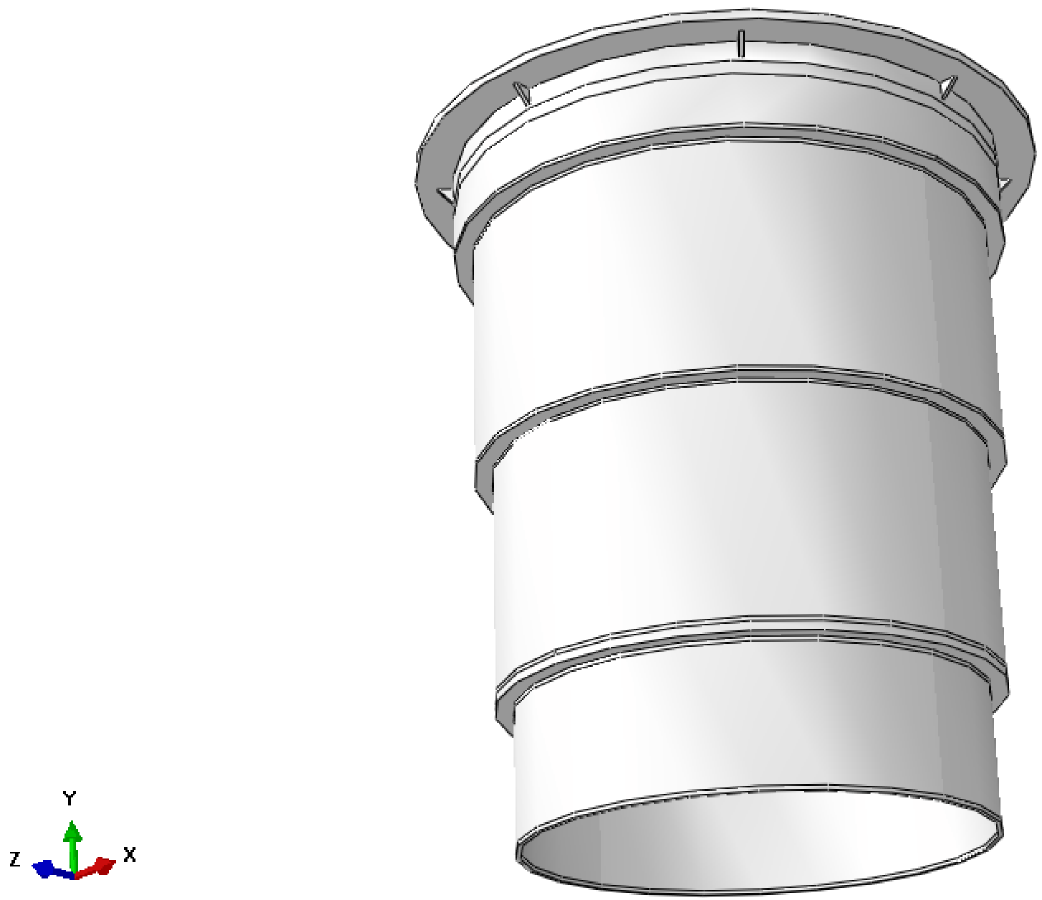
PBW zone with cut

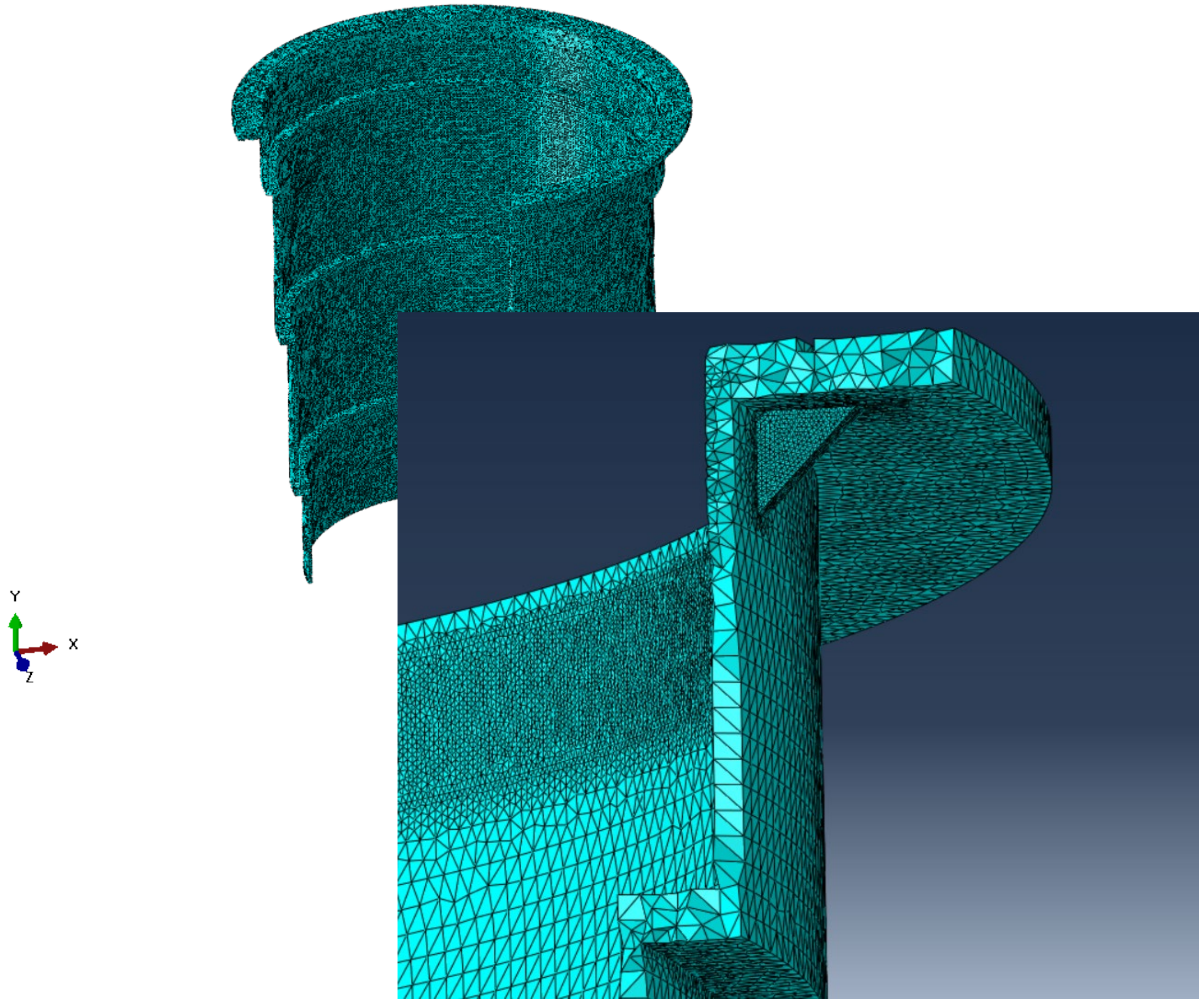


Mesh

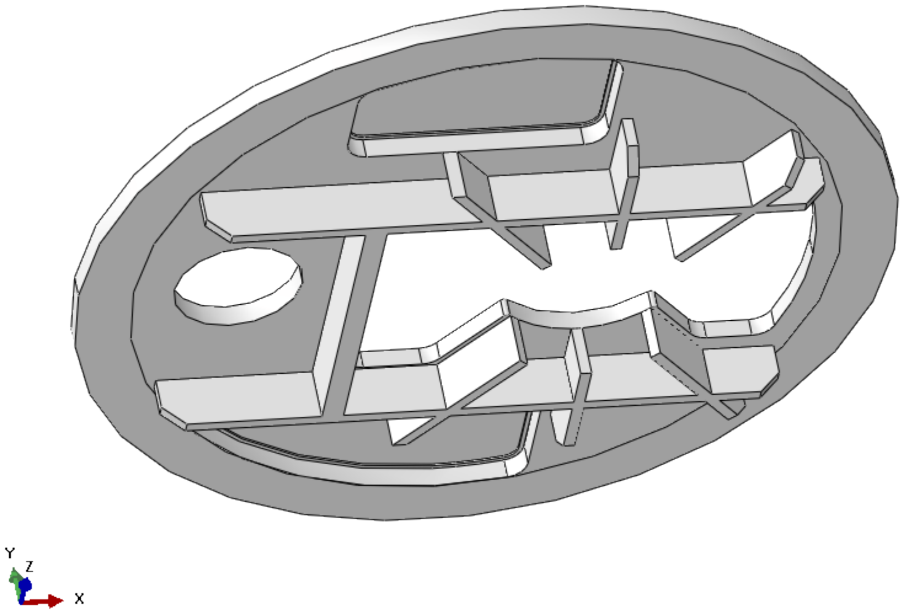


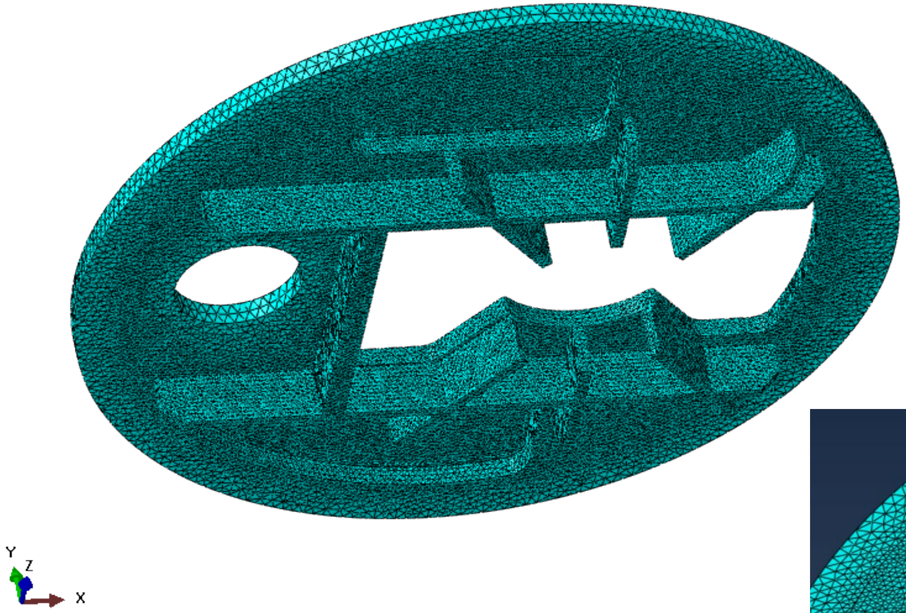
Upper Cylinder Part and mesh

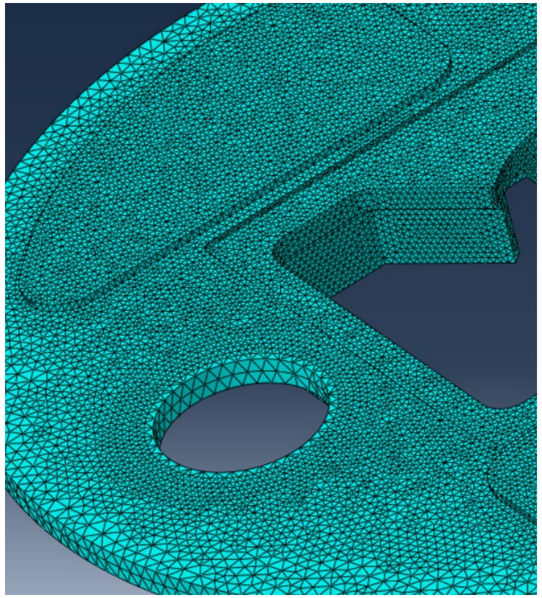




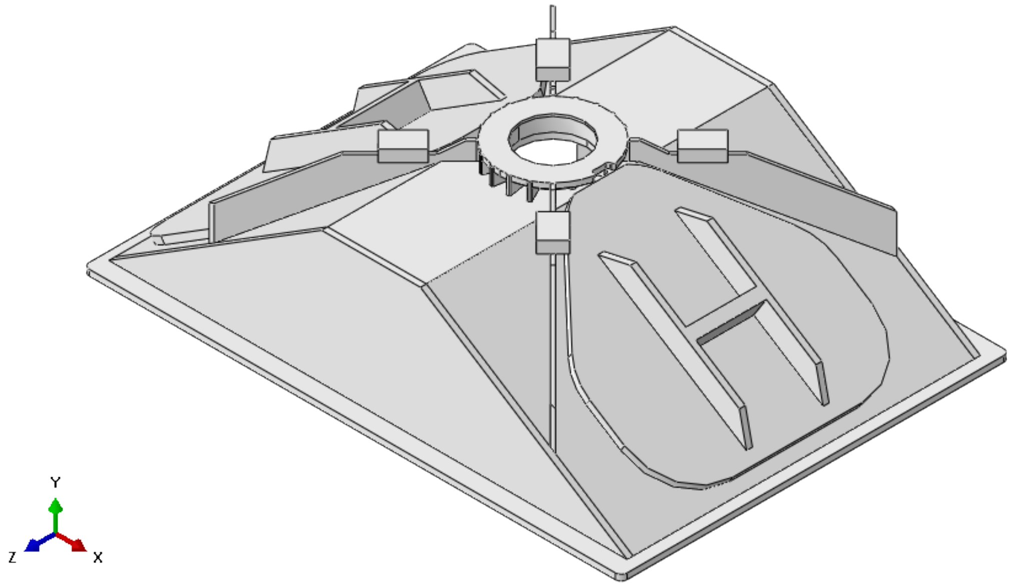
Lid and covers part

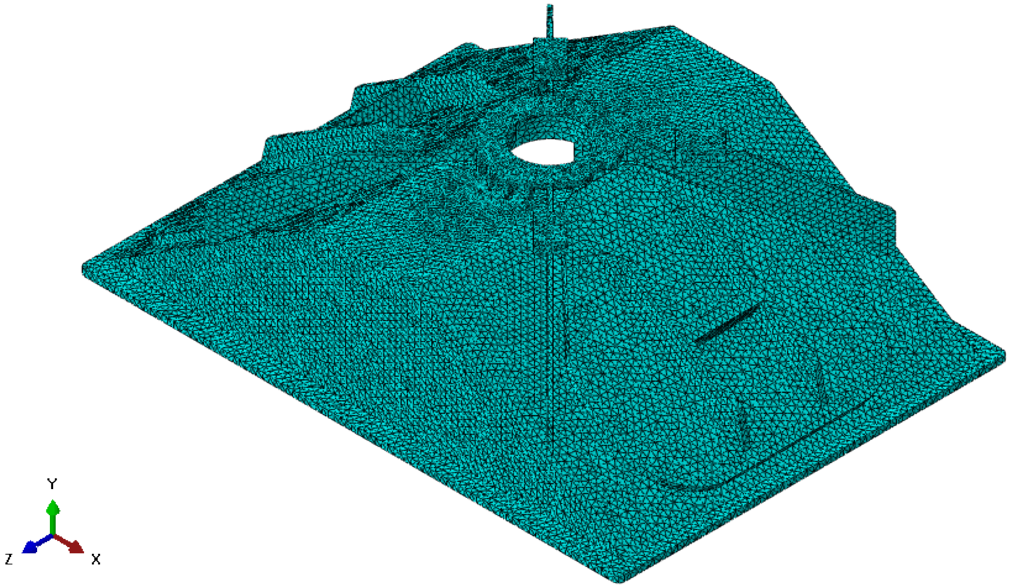




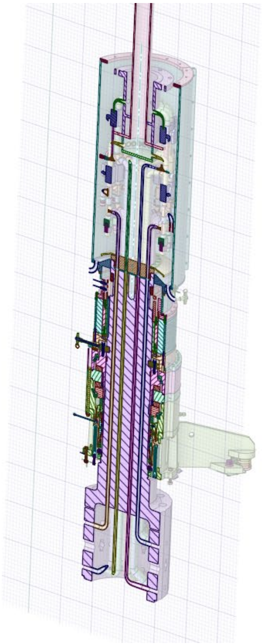


Tent Assembly

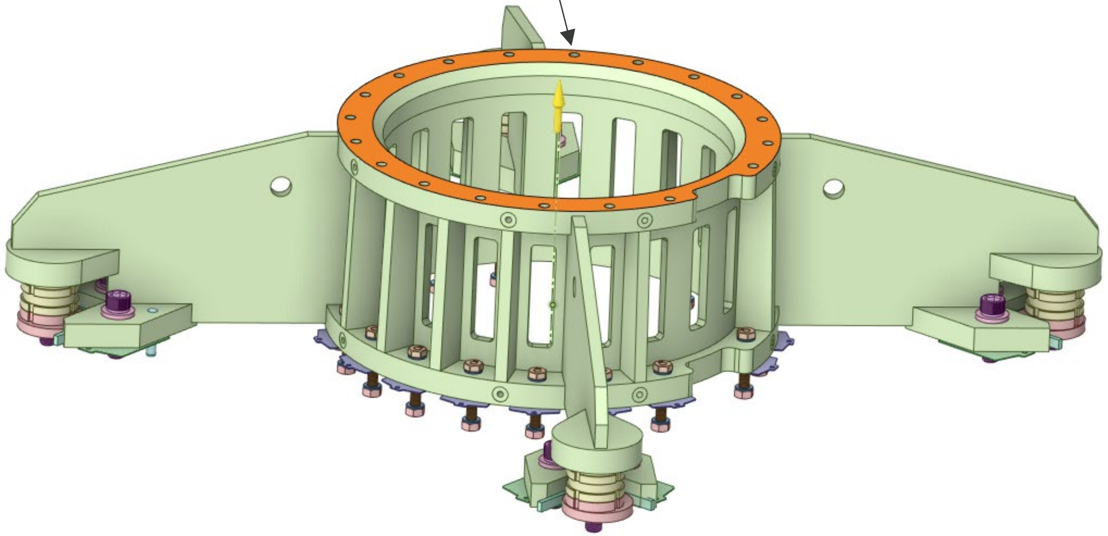




SpaceClaim Upper Shaft model

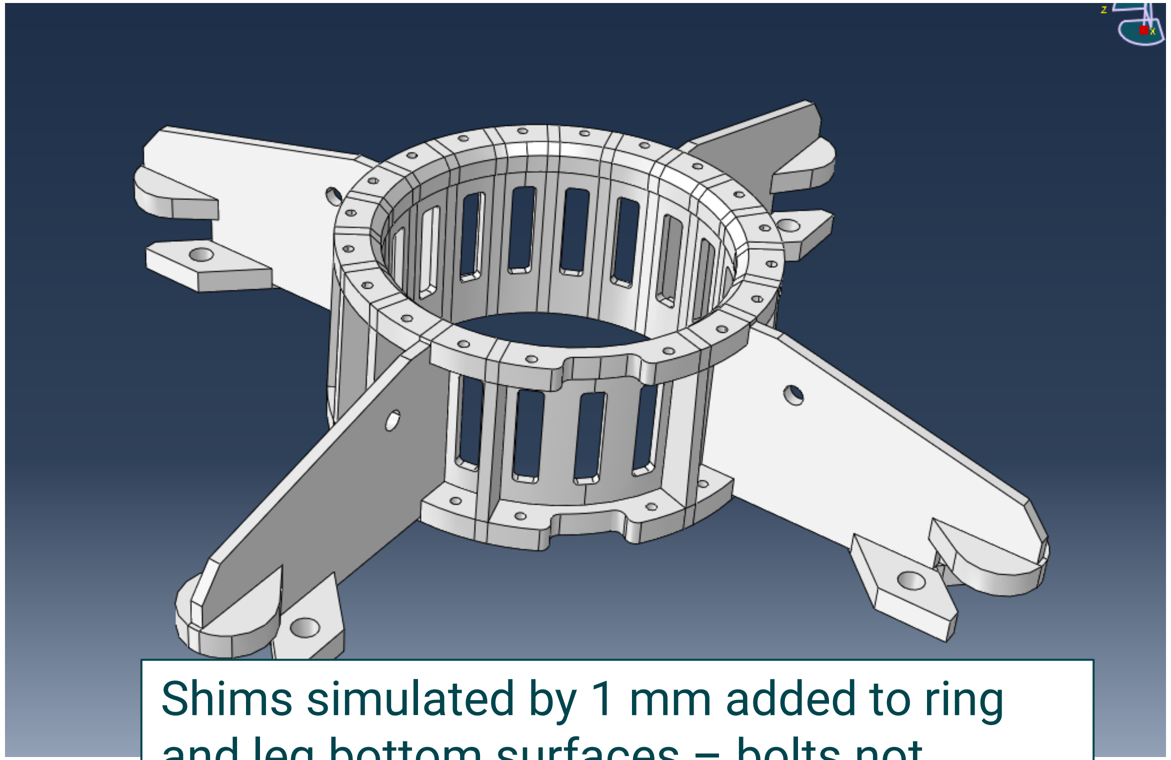


All target and shaft vertical loads go through upper ring surface



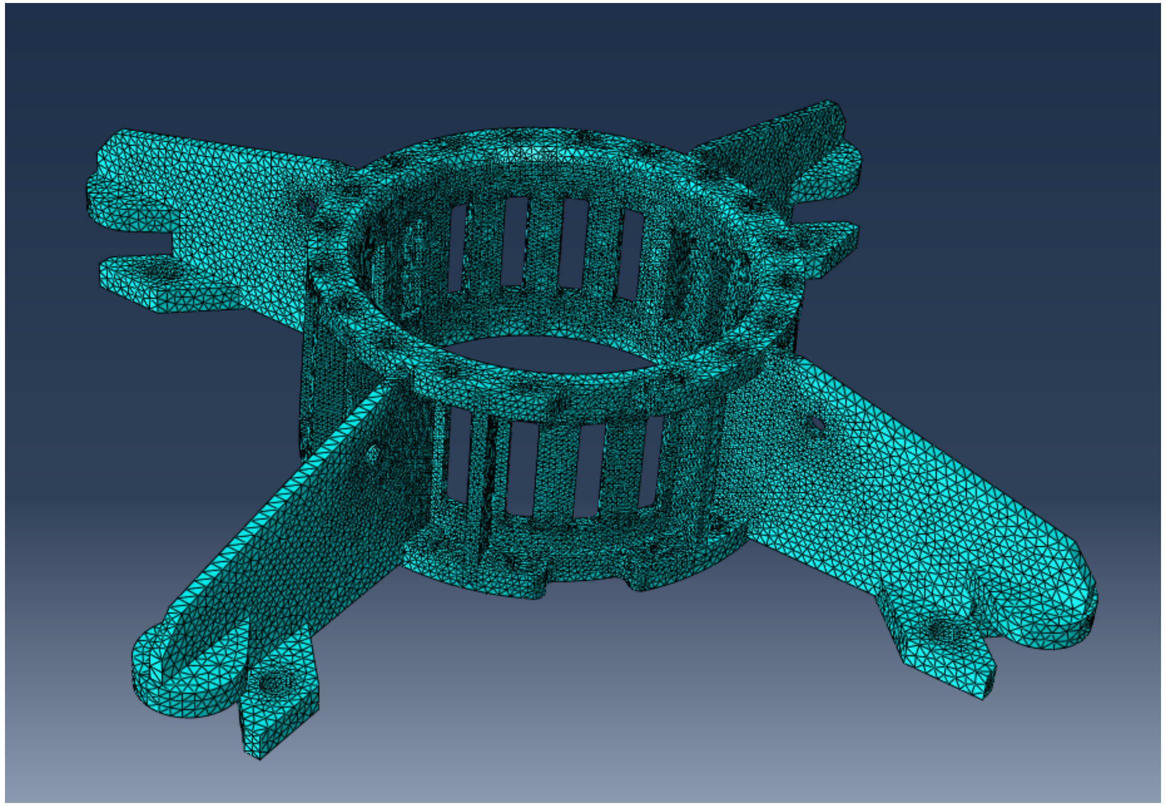
Shaft load ring model in Abaqus

Simplified Abaqus model

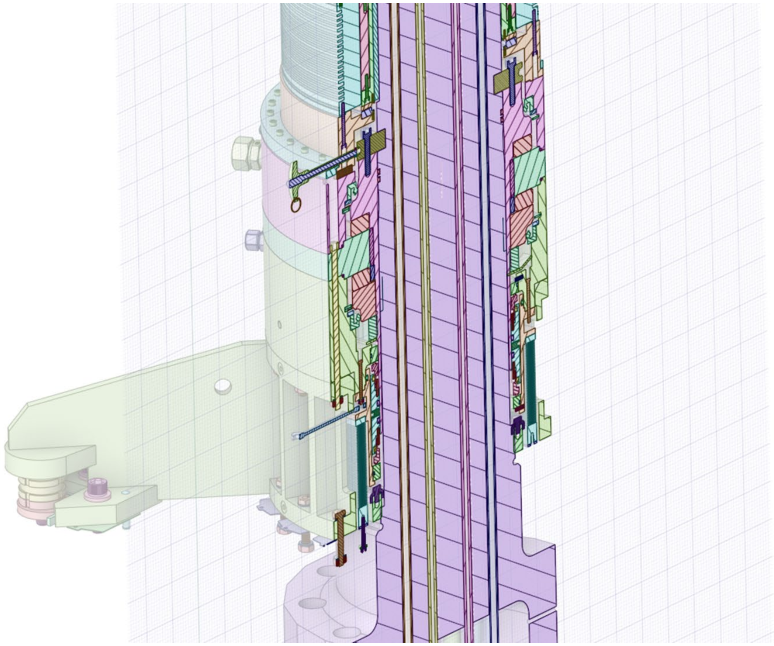


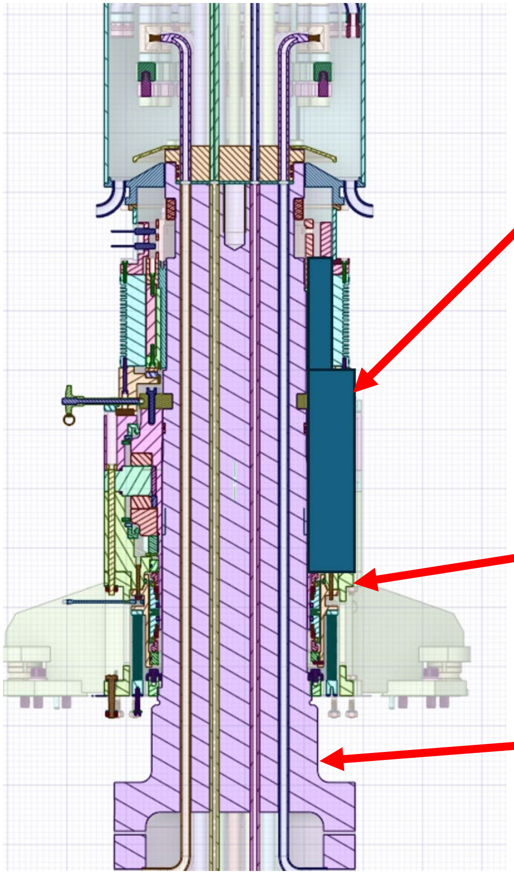
Shims simulated by 1 mm added to ring and leg bottom surfaces – bolts not included

Mesh model with C3D10 elements



Upper Shaft and Crown SpaceClaim model and approximation



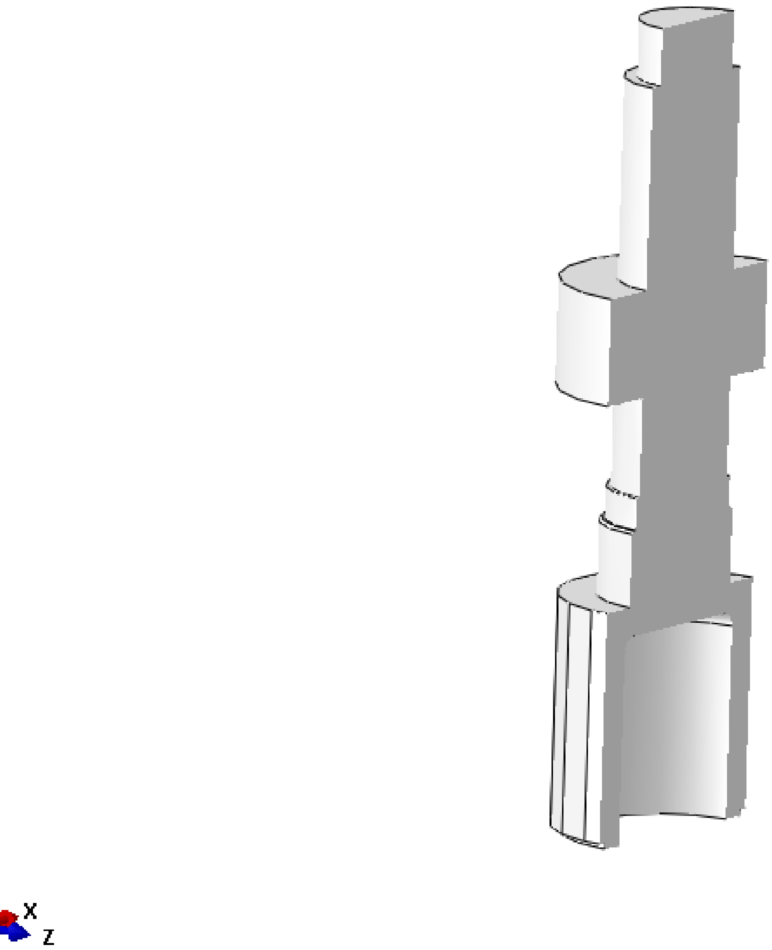


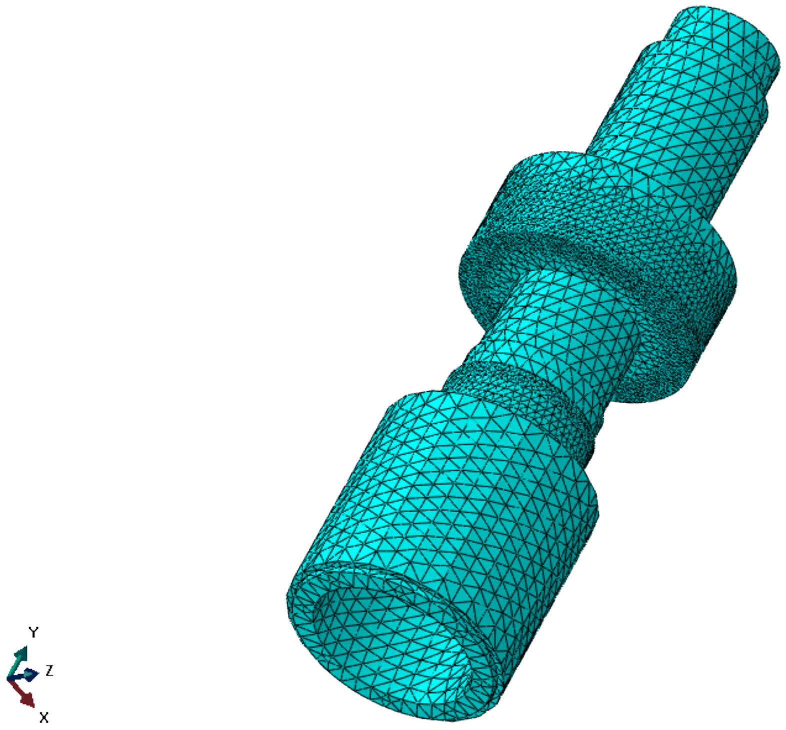
All the bearings and drive components above load ring assumed to be a merged, stiff structure with the crown piece

Load Ring interface

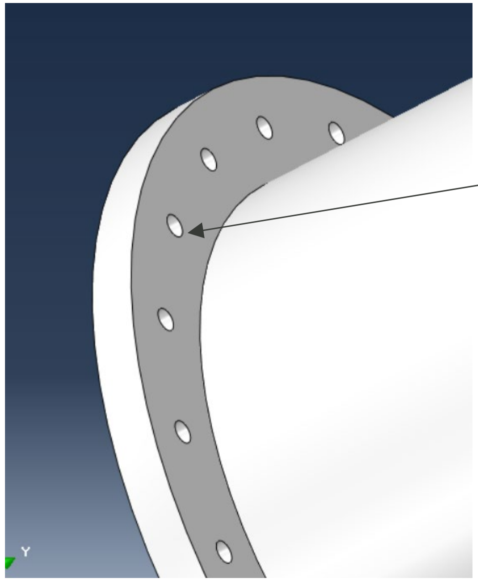
Crown Piece

Top 312 Part which includes crown for segment attachment with all holes and cooling tubes suppressed

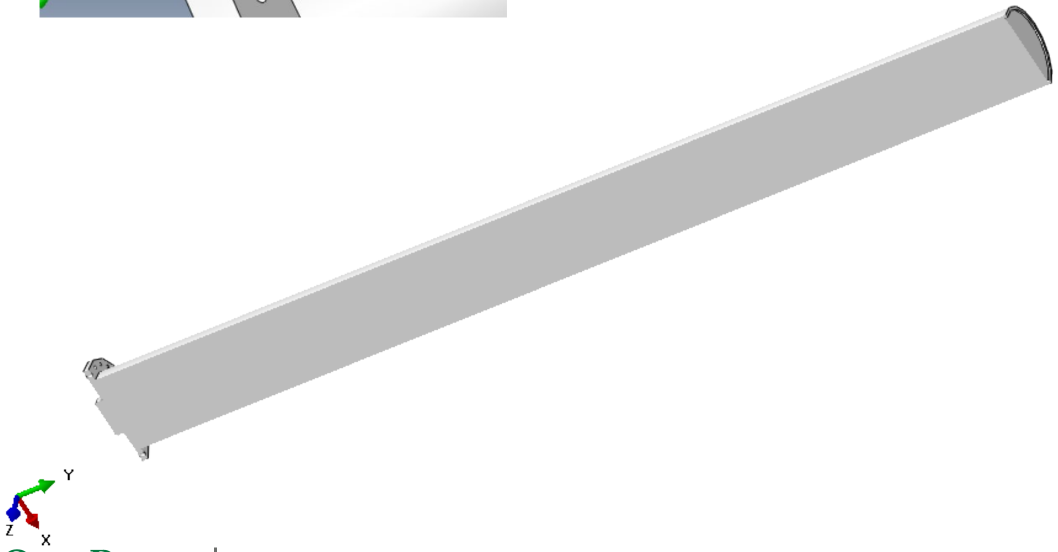


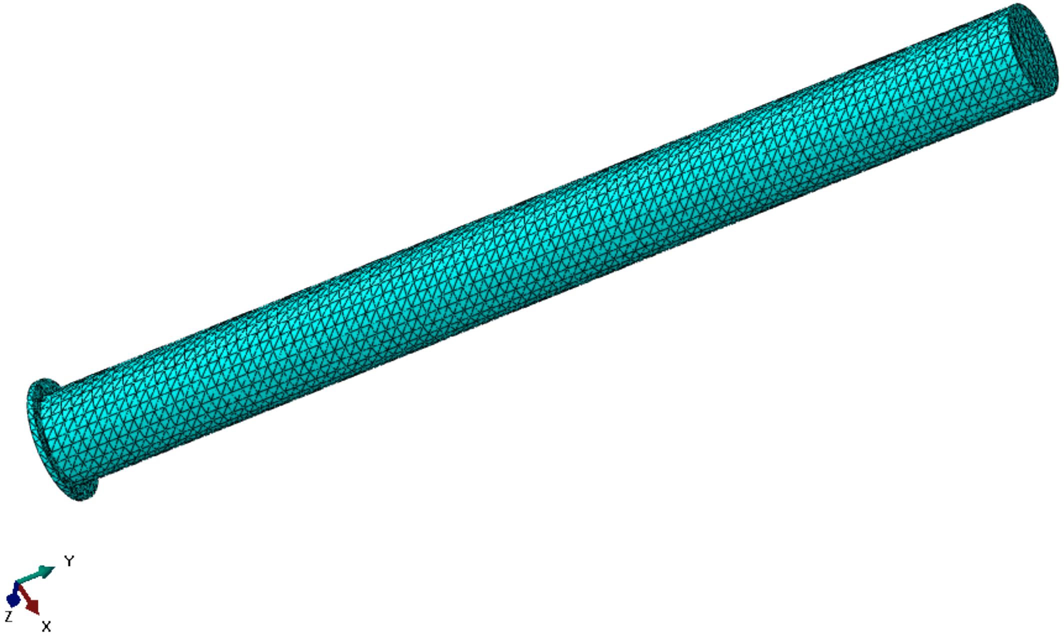


Shaft model as a solid



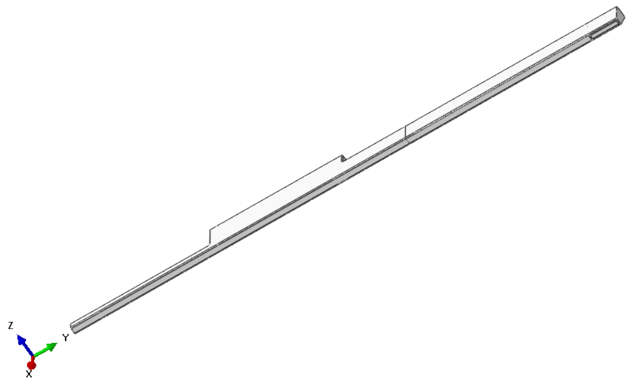
14 mm diameter holes added for target pin interfaces





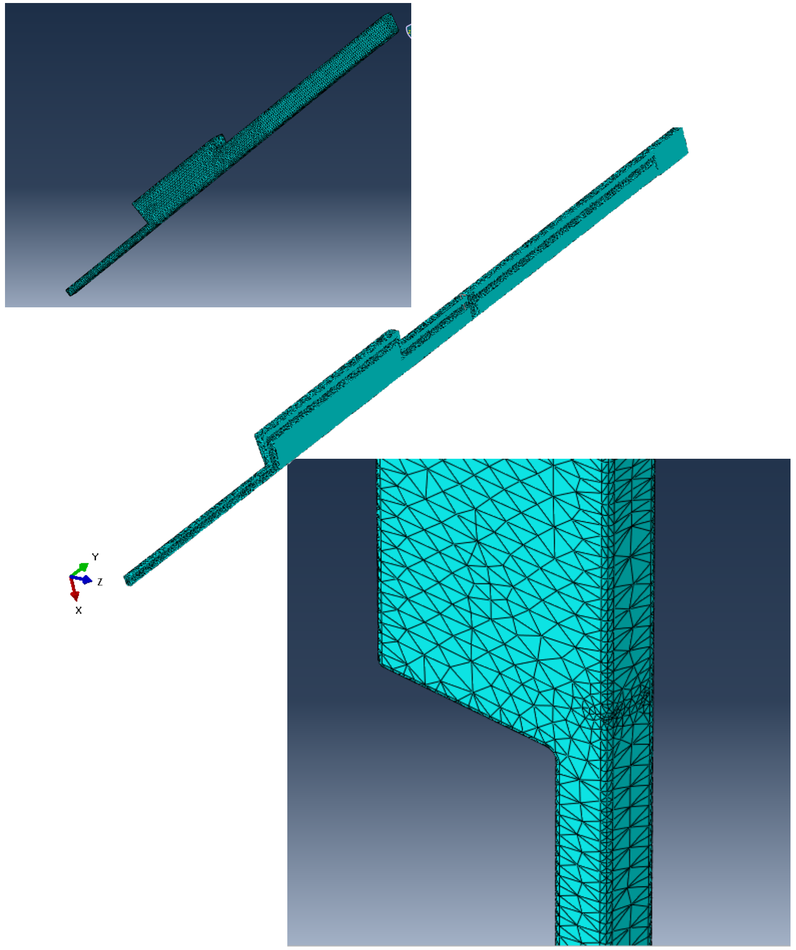
Segment stalk simplified with merged parts and only main coolant channel and remote handling thinning included

Stalk part



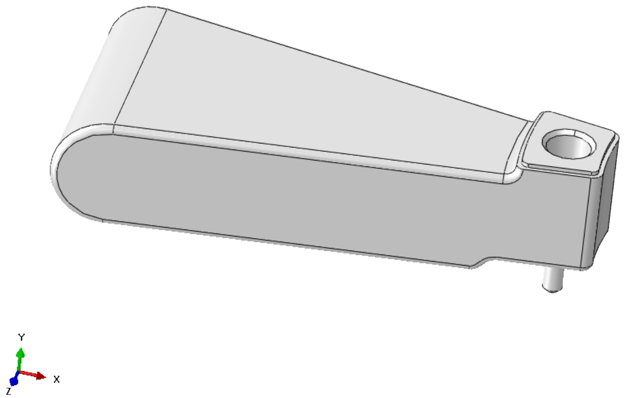
Cut to show channels included

Mesh

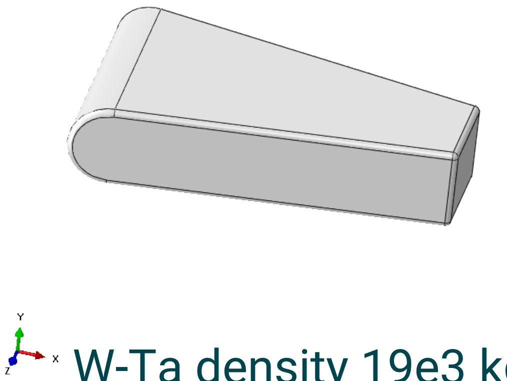


Simplified foot

Foot simplified part

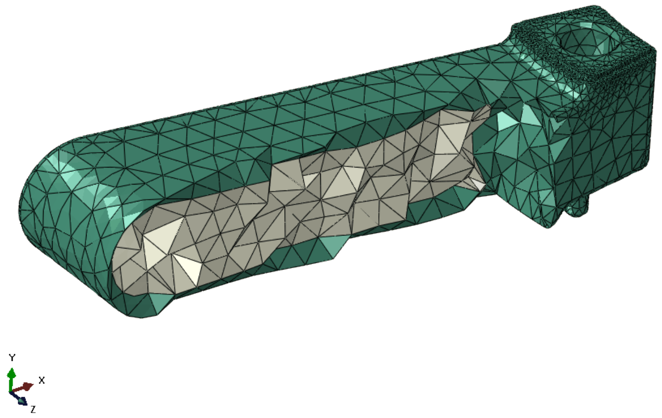


Tungsten and tantalum region

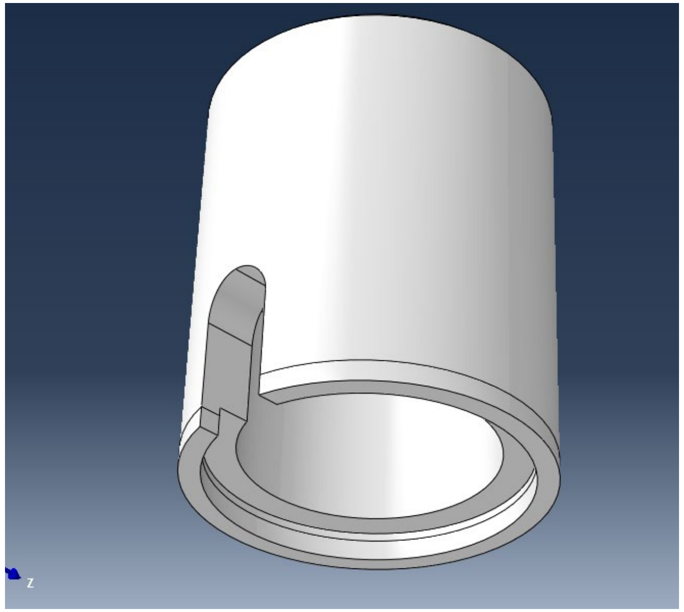


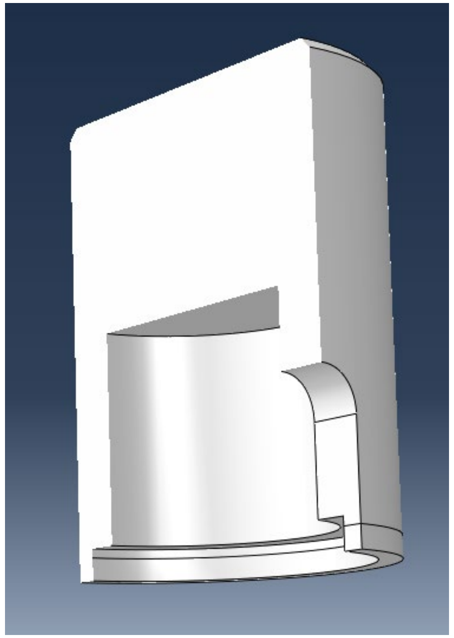
W-Ta density 19e3 kg/m^3

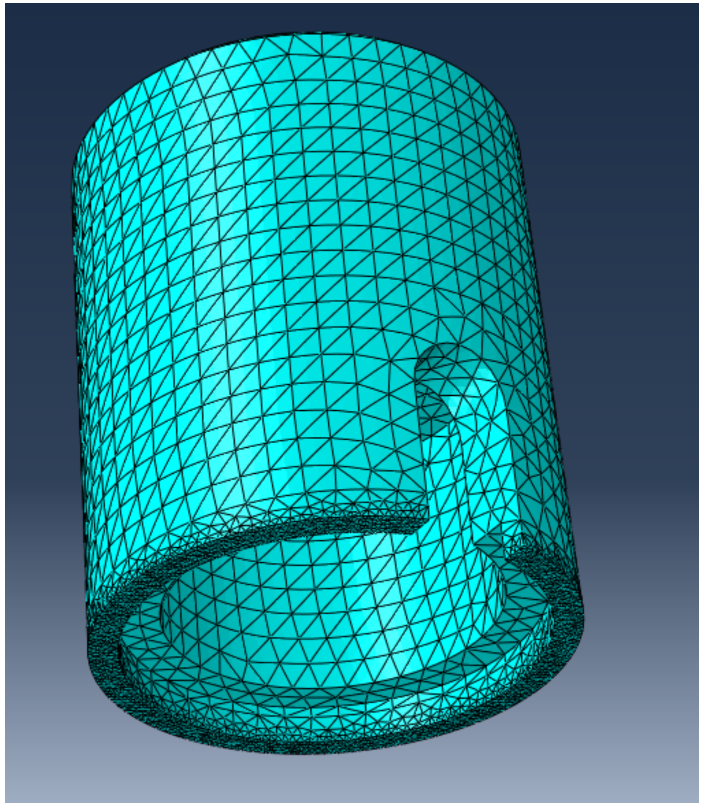
Mesh with materials



Doghouse part



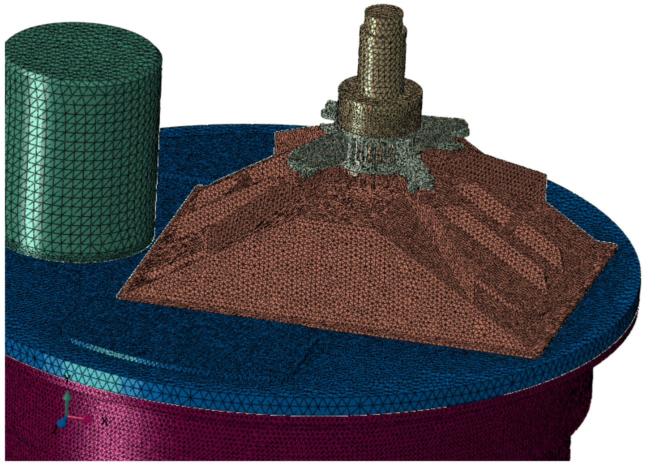




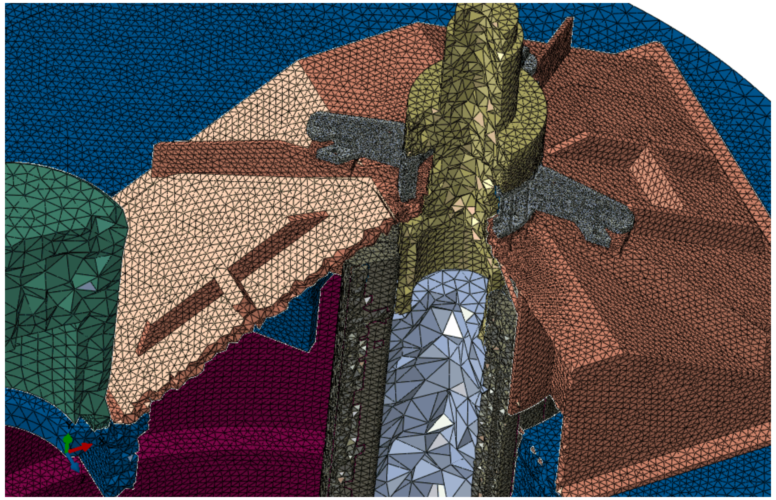
Density assumed 12.3 e3 kg/m3
Mass 5,000 kg

Assembly Mesh model examples

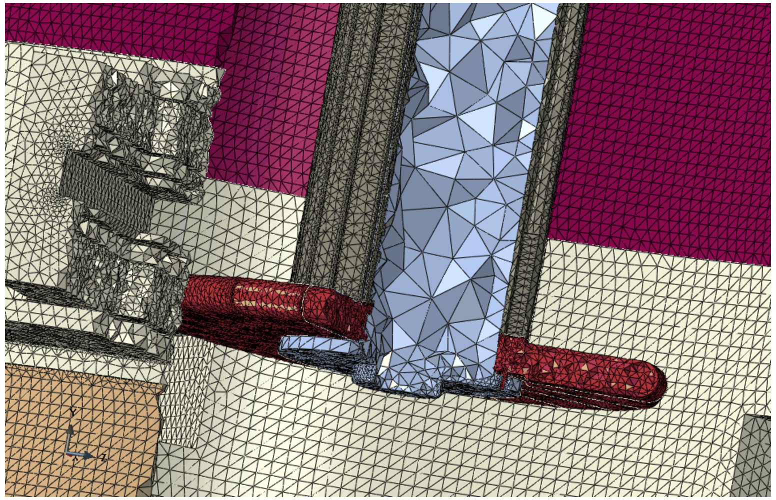
Upper region



Upper region with cut

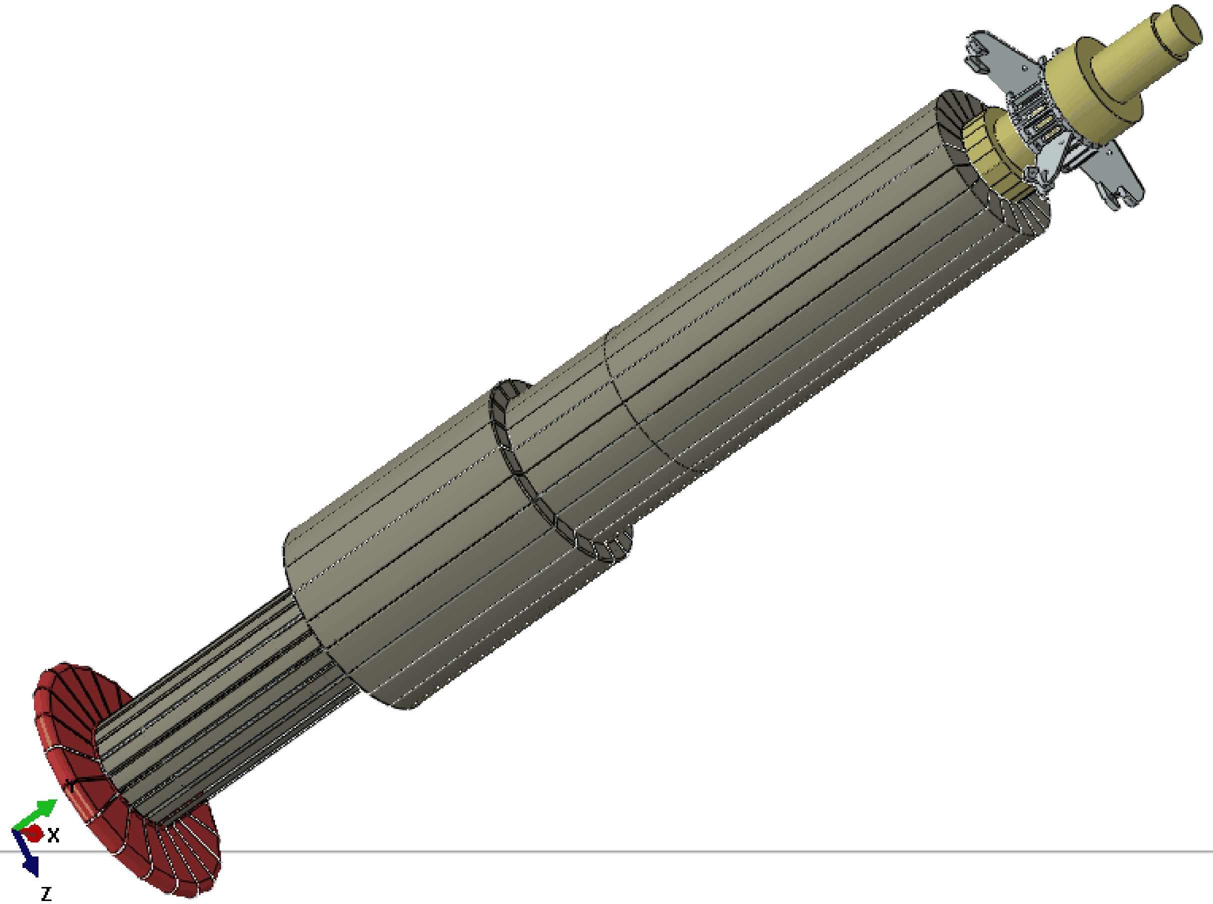


Lower shaft region with cut



Total 6.9 x 10^6 C3D10 elements

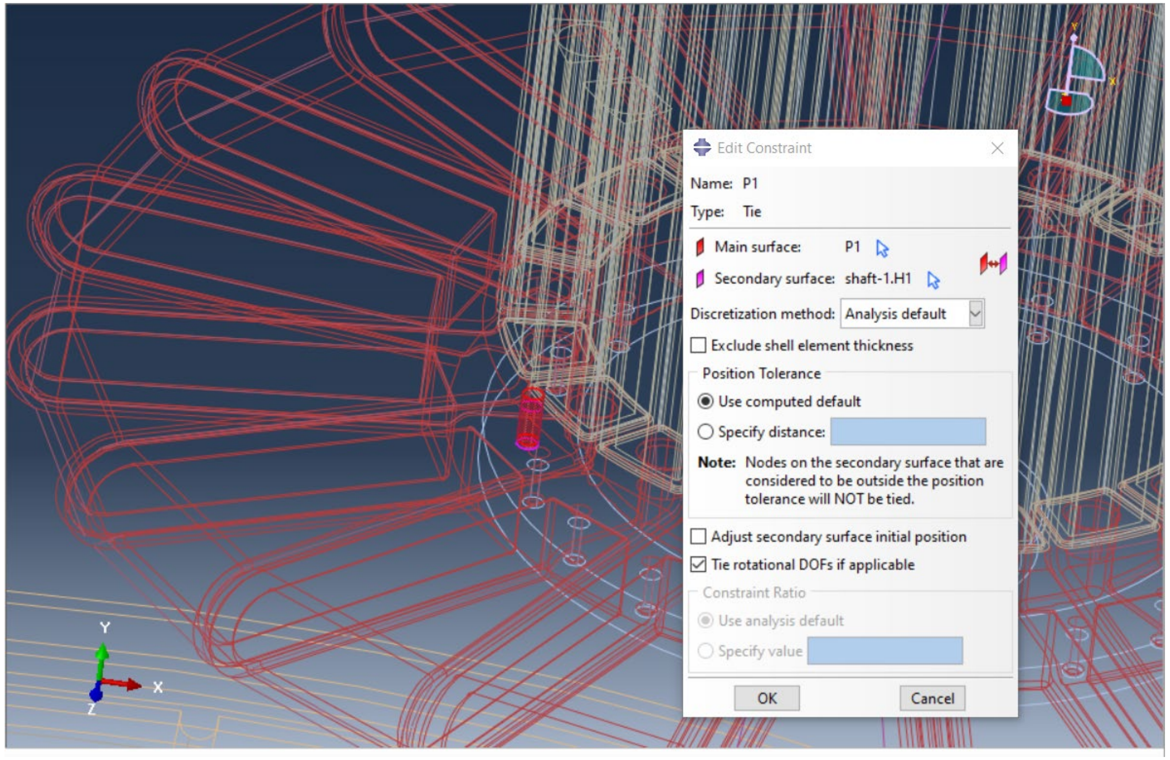
Mass of target components - 17,022 kg



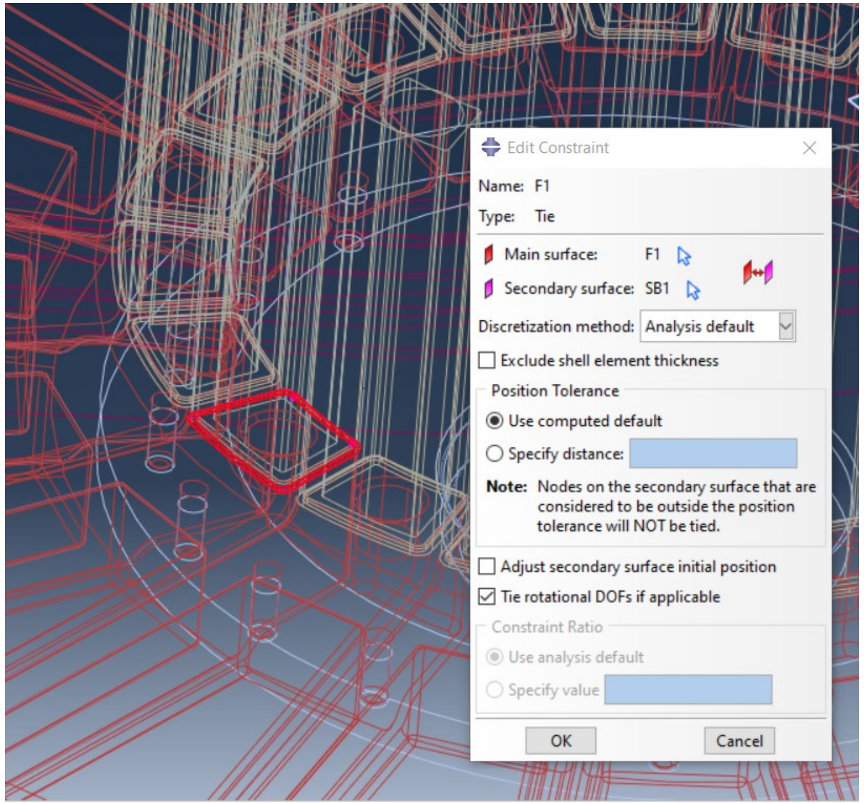

```
Mass properties:
  Volume: 2.07
  Volume centroid: 0.483,2.65,-3.51e-10
  Mass: 17022.18
  Center of mass: 0.483,2.59,-3.43e-10
  Moment of inertia about the center of mass (Ixx, Iyy, Izz, Ixy, Iyz, Izx): 37851.52,1385.02,37851.45,1.00,3.24e-04,-3.69e-05
```

Constraints

Typical target pin tie to shaft flange

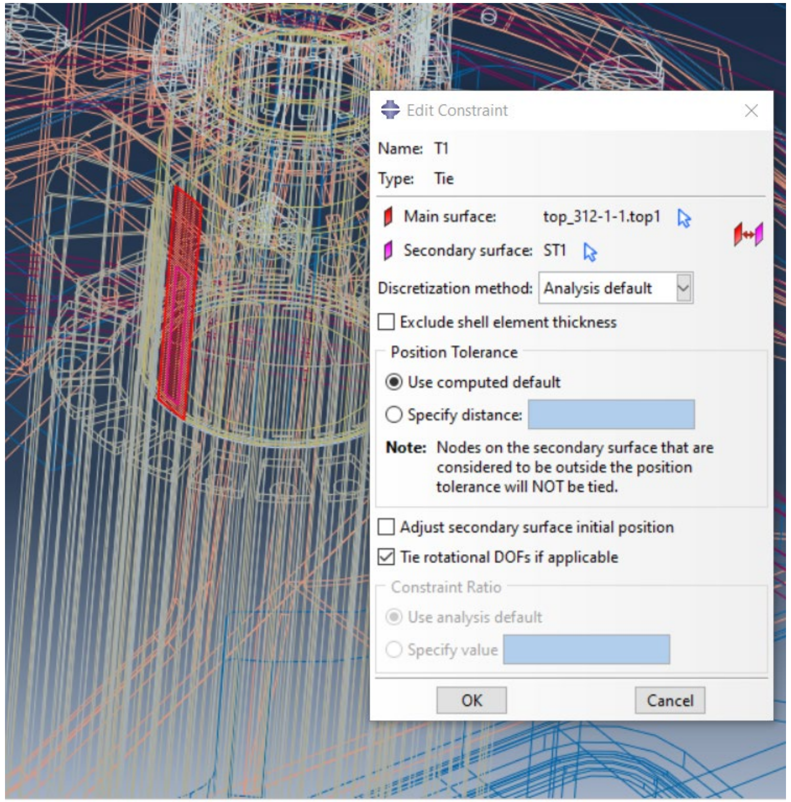


Typical foot to stalk tie

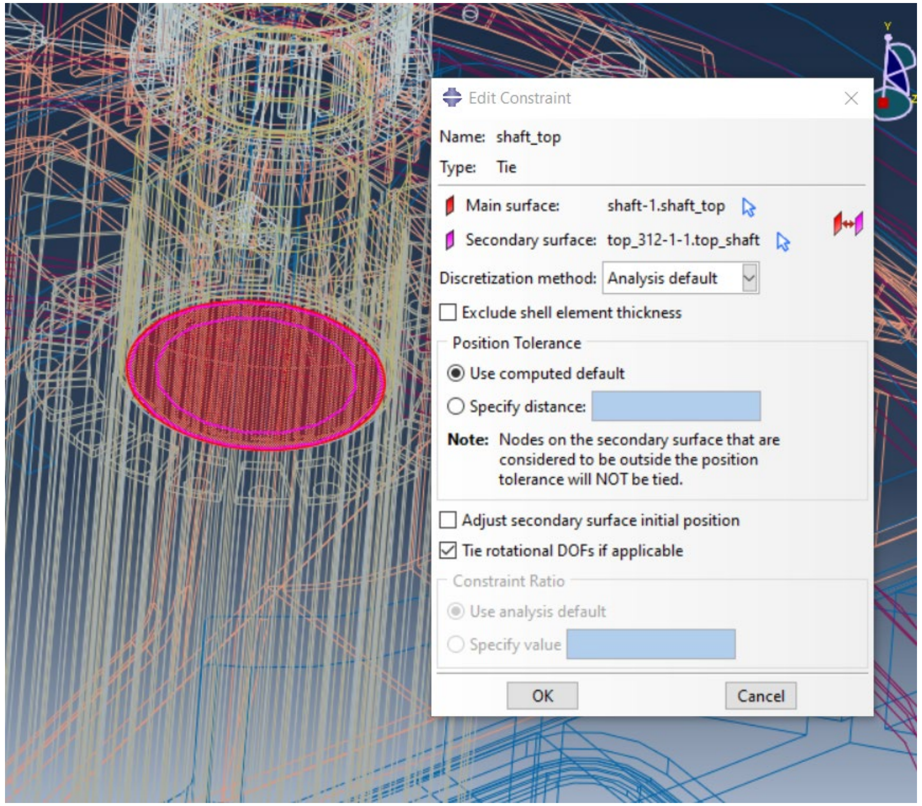


Constraints

Typical stalk to top (crown) tie

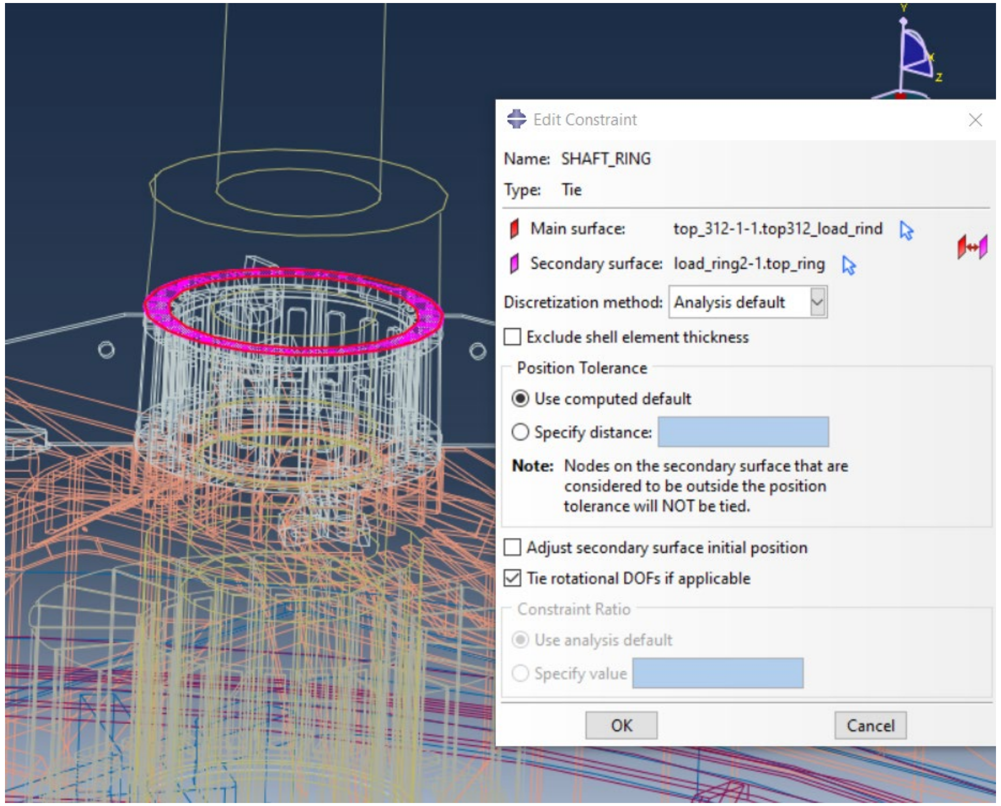


Shaft to top tie

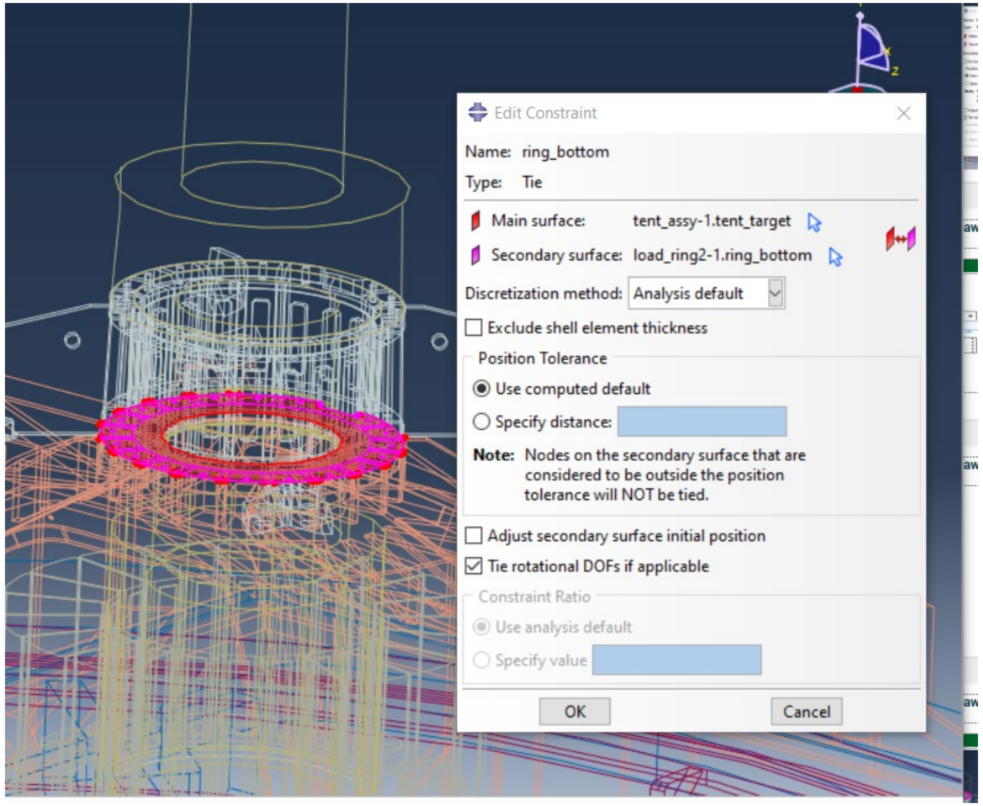


Constraints

Top tie to load ring

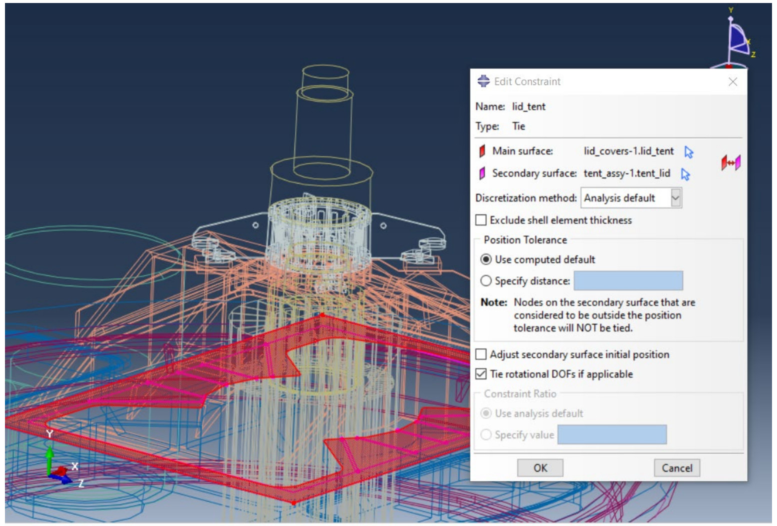


Load ring to tent assembly tie

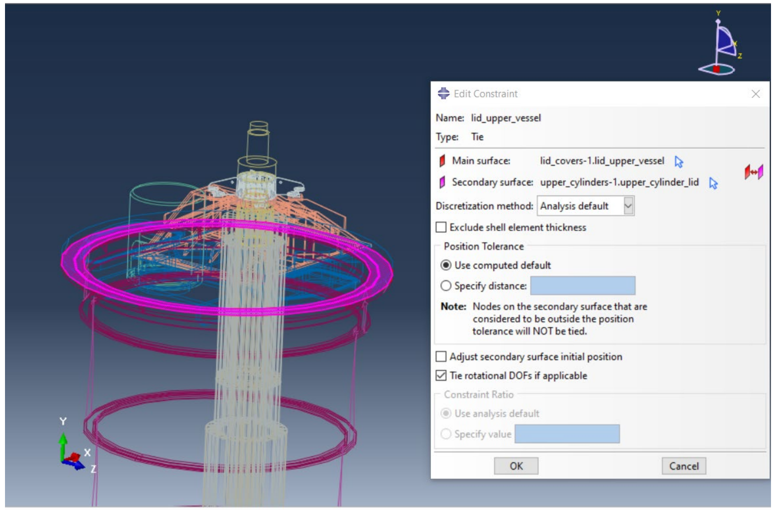


Constraints

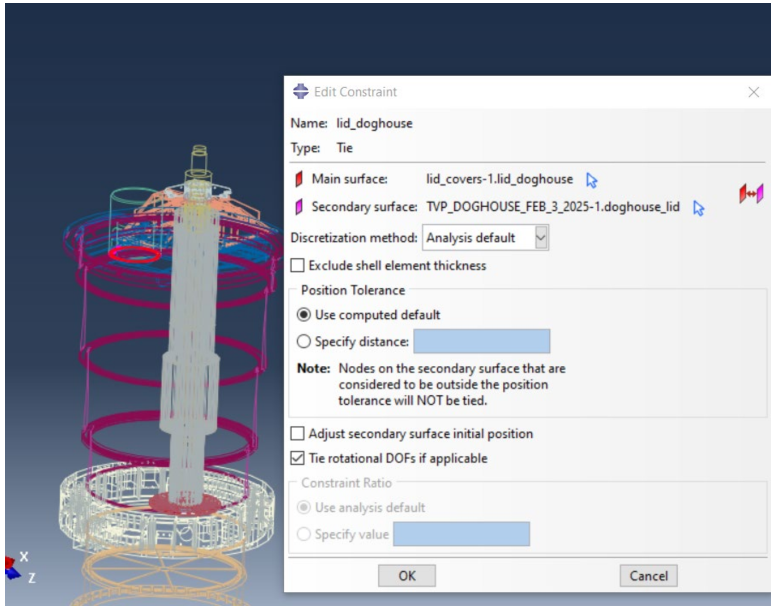
Tent assy to lid tie



Lid to upper cylinders

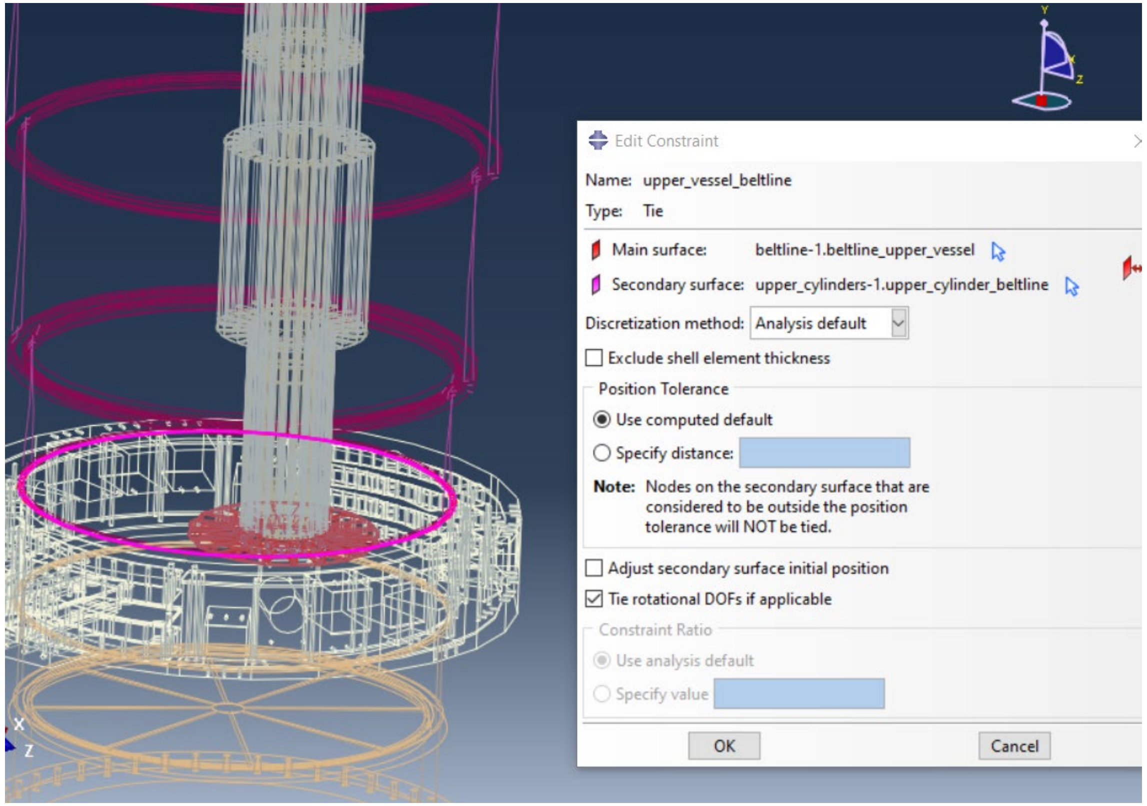


Lid to Doghouse

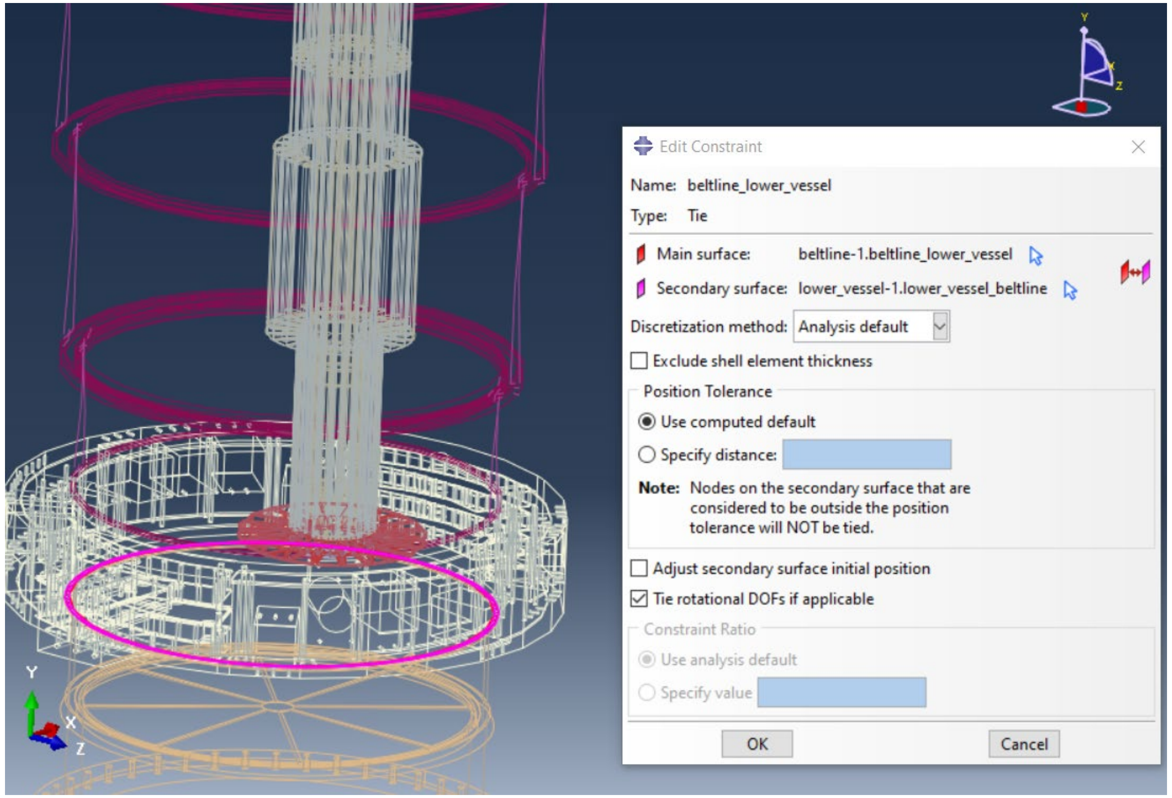


Constraints

Upper Cylinders to beltline



Beltline to Lower Cylinders



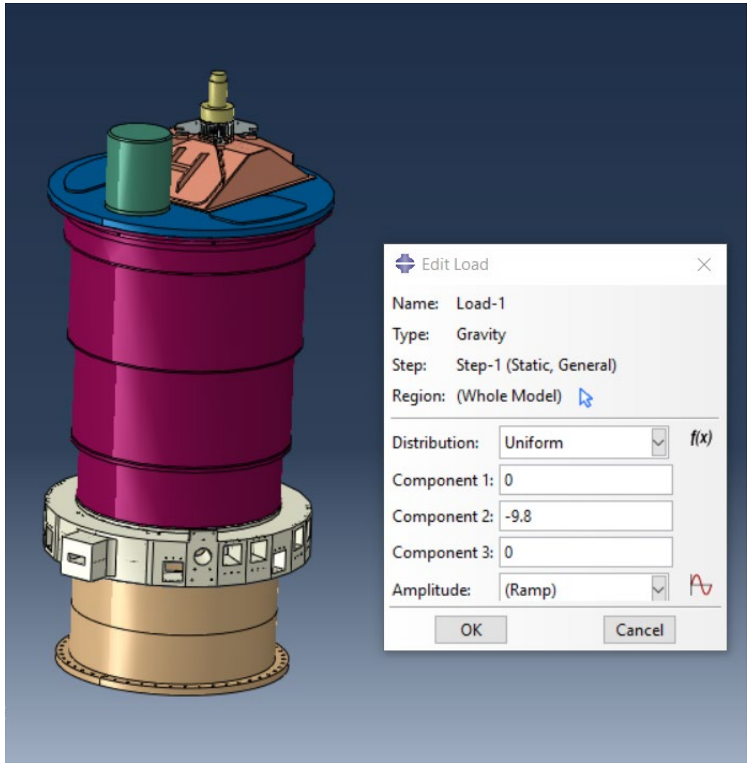
Analysis sequence

- Step 1 – Gravity only with internal shielding weight simulated with a pressure on the core vessel lip
- Step 5 – Added Seismic side load of .072 G to give approximately 5 mm lateral displacement at shaft bottom
- Step 6 – Added Seismic side load of .39 G for a total of .46 G with a 5mm displacement boundary condition applied to nodes at the bottom of the shaft near contact area with snubber ring
- Step 2 – Vacuum pressure loads added
- Step 3 – Internal water pressure load added
- Step 4 – Core vessel CFD temperatures added with all model nodes assumed initially at 36 C stress free and the Core vessel CFD temperature applied to the lower cylinders, beltline, upper cylinders and lid. The results for this step then included all loads

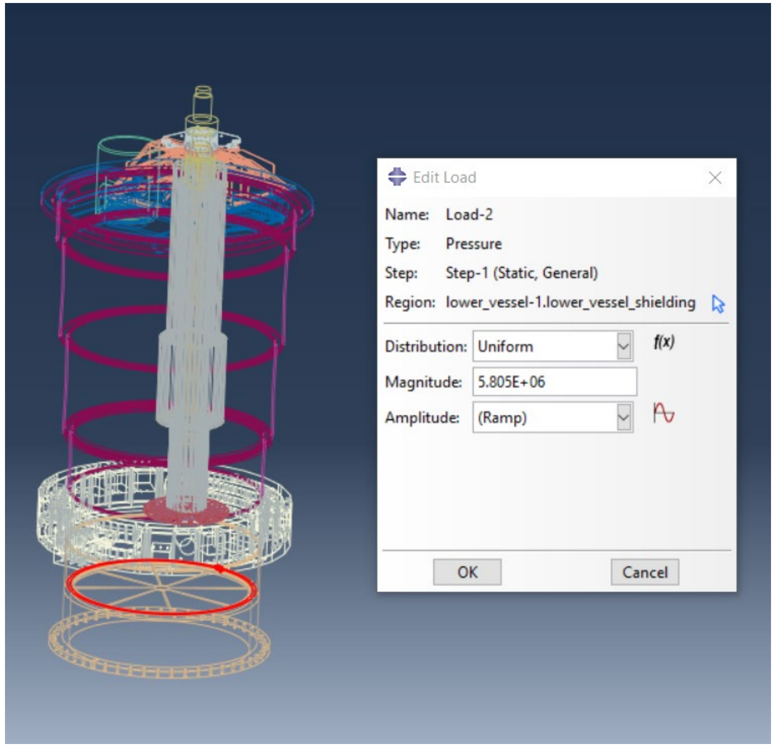
- Seismic analysis assumes the shaft is centered in the snubber ring attached to the core vessel shielding with a 5 mm gap all around
- If the shaft is offset within the ring or if the ring can move under the seismic load, allowing a greater shaft displacement in one direction, the stresses could be significantly increased

Step 1 Gravity only

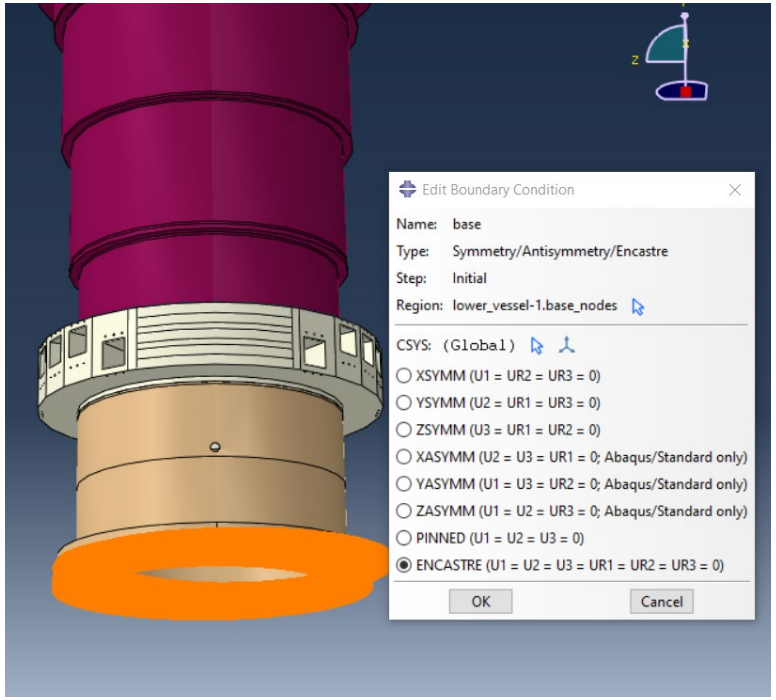
Gravity load



Simulated weight of internal shielding

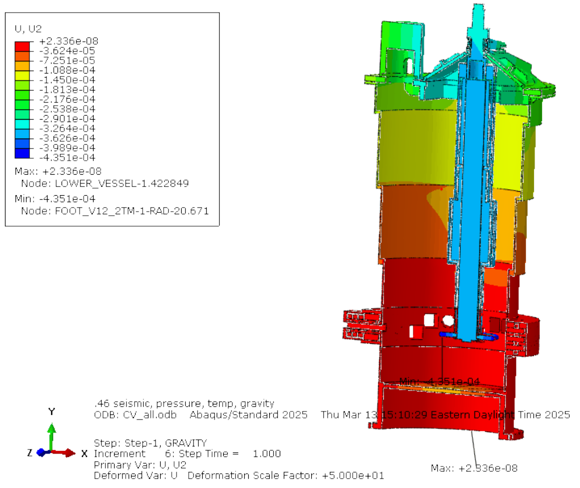


BC Fixed nodes on base

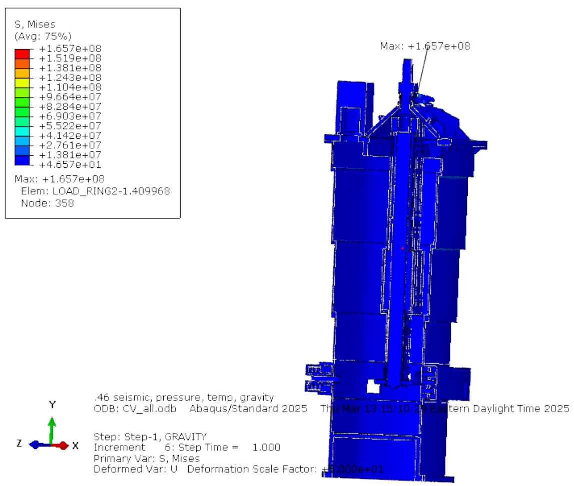


Step 1 Gravity loads Results

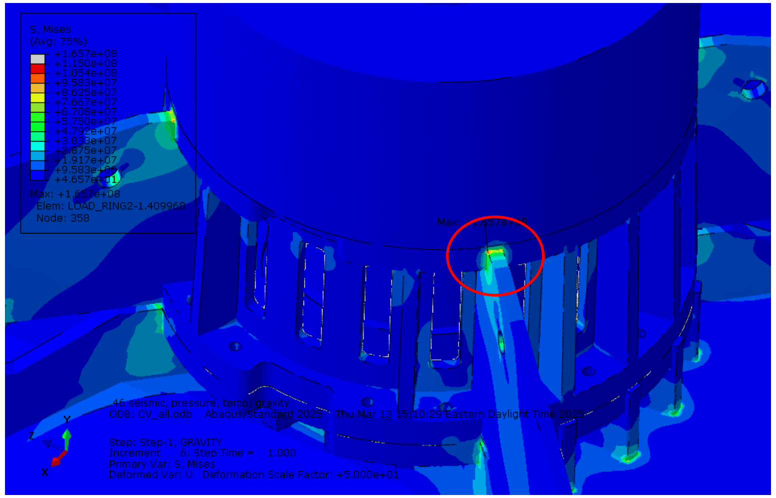
Vertical deflection 0.4 mm max downward



Von Mises Stress



Peak Stress 166 MPa



115 MPa scale max

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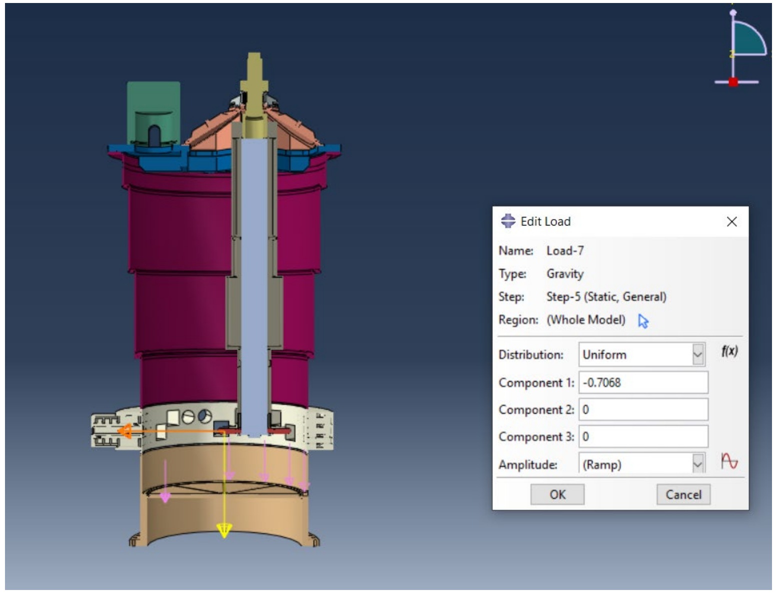
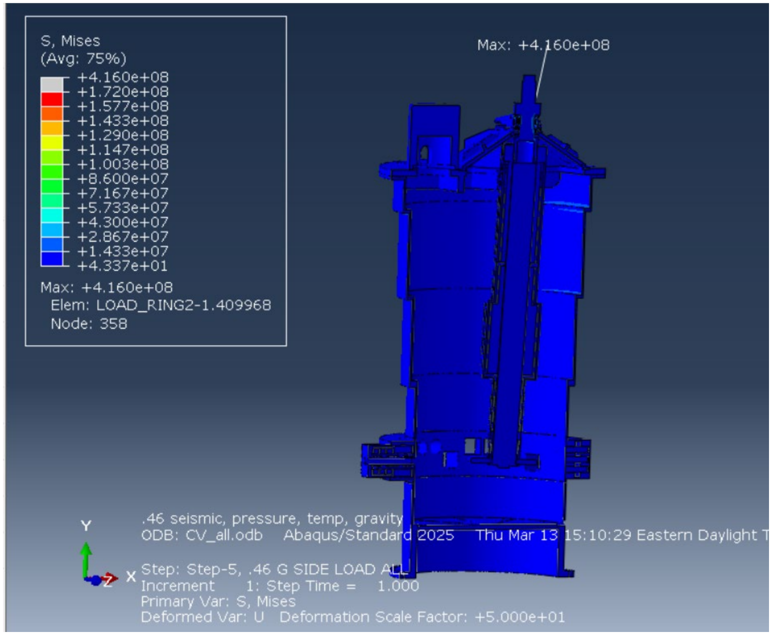
Step 5 Side load to give approximately 5 mm displacement

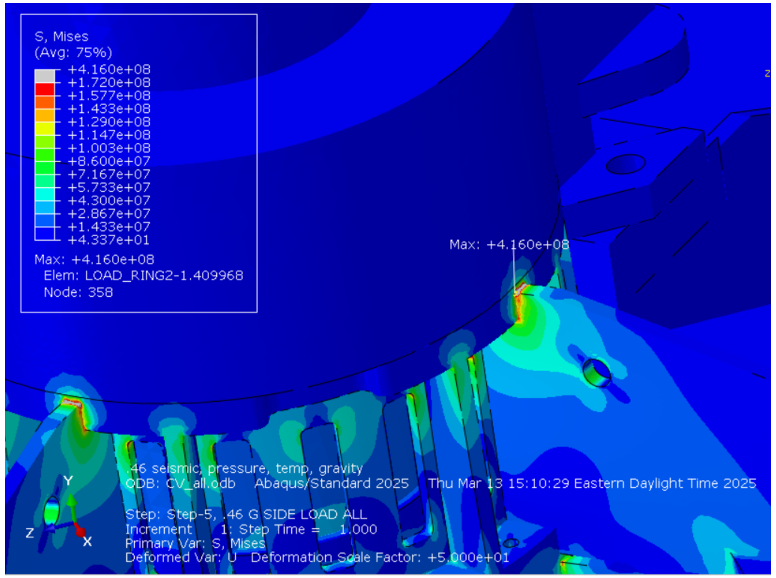
Side load .15 g



Peak stress 416 MPa



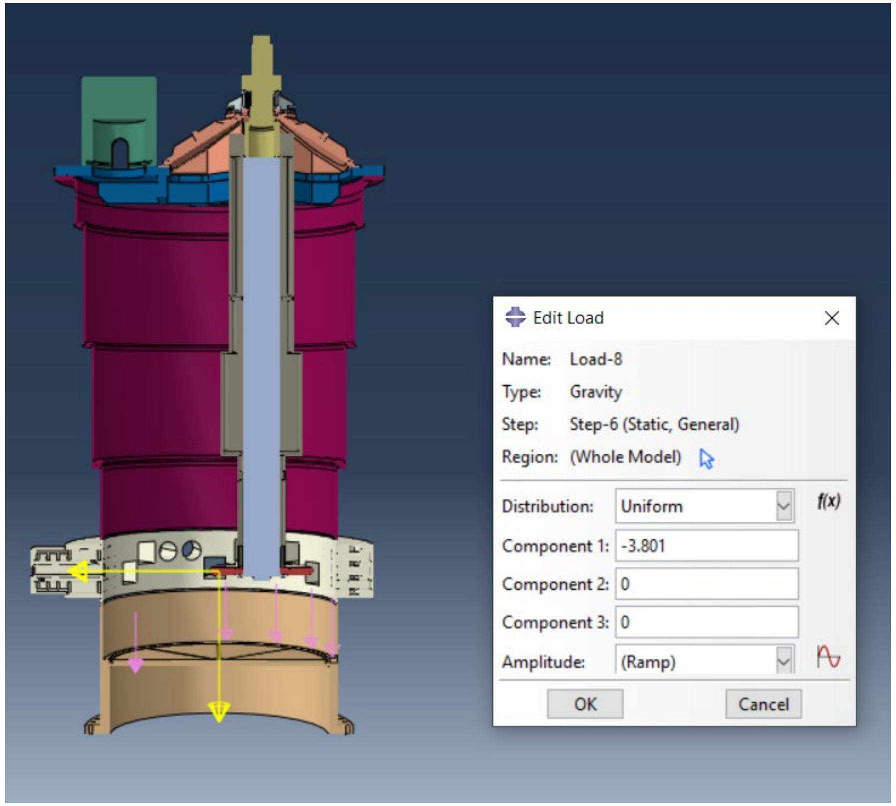
Peak at sharp corner and localized



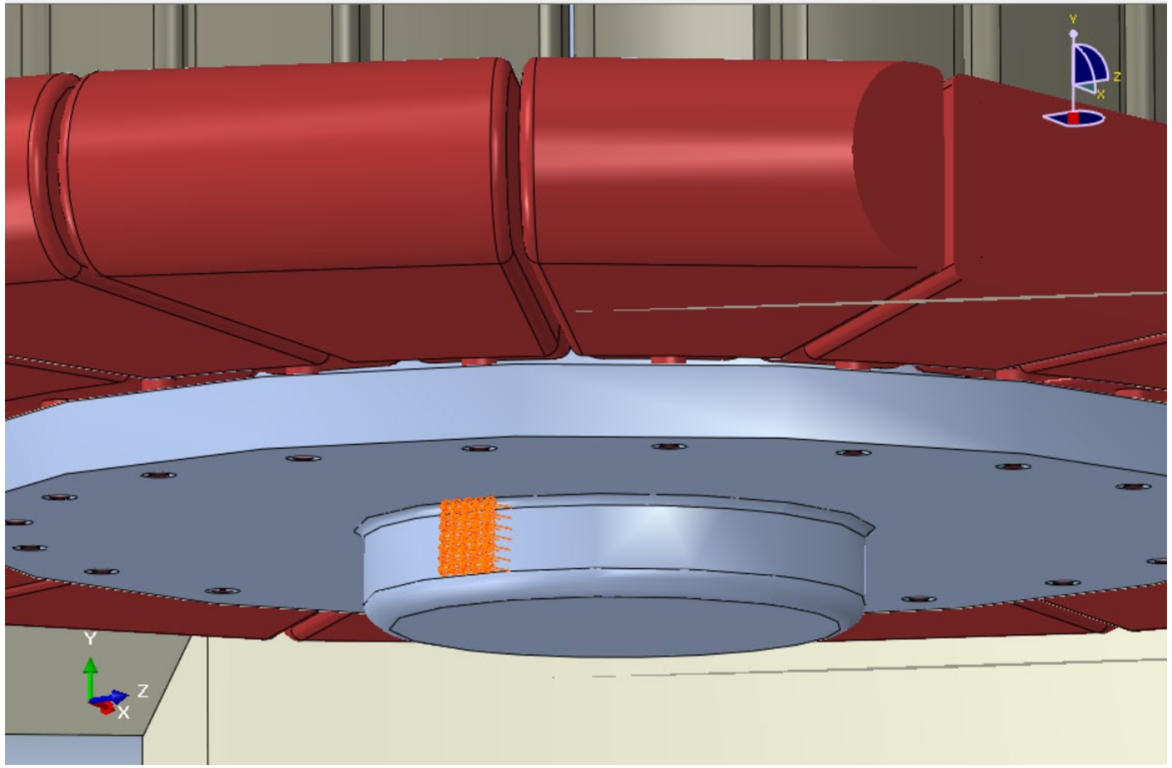
Scale max 1.5 Sm – 172 MPa

This step was included to distinguish stresses incurred from shaft angular deflection from full .46 G side load

Step 6 – side load added to give a total of 0.46 g and 5 mm displacement boundary condition at shaft bottom added

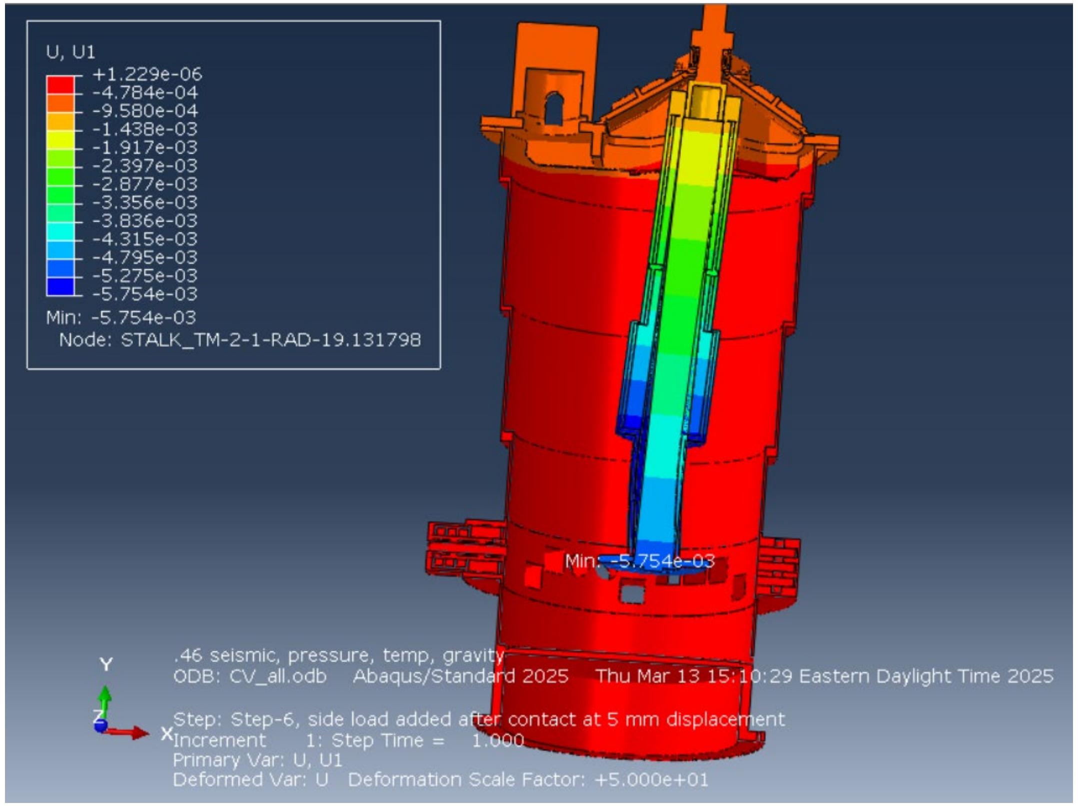


5mm displacement boundary condition

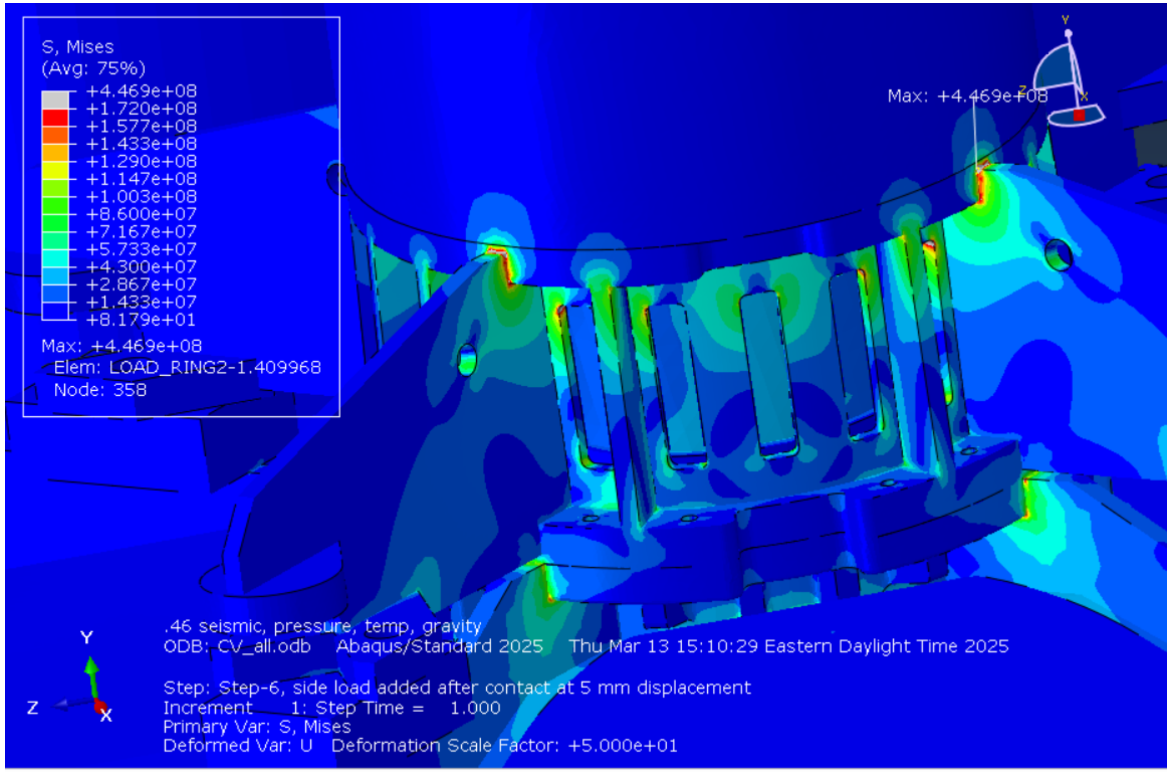


Step 6 gravity plus .46 seismic side load

U1 horizontal displacement peak 5.7 mm

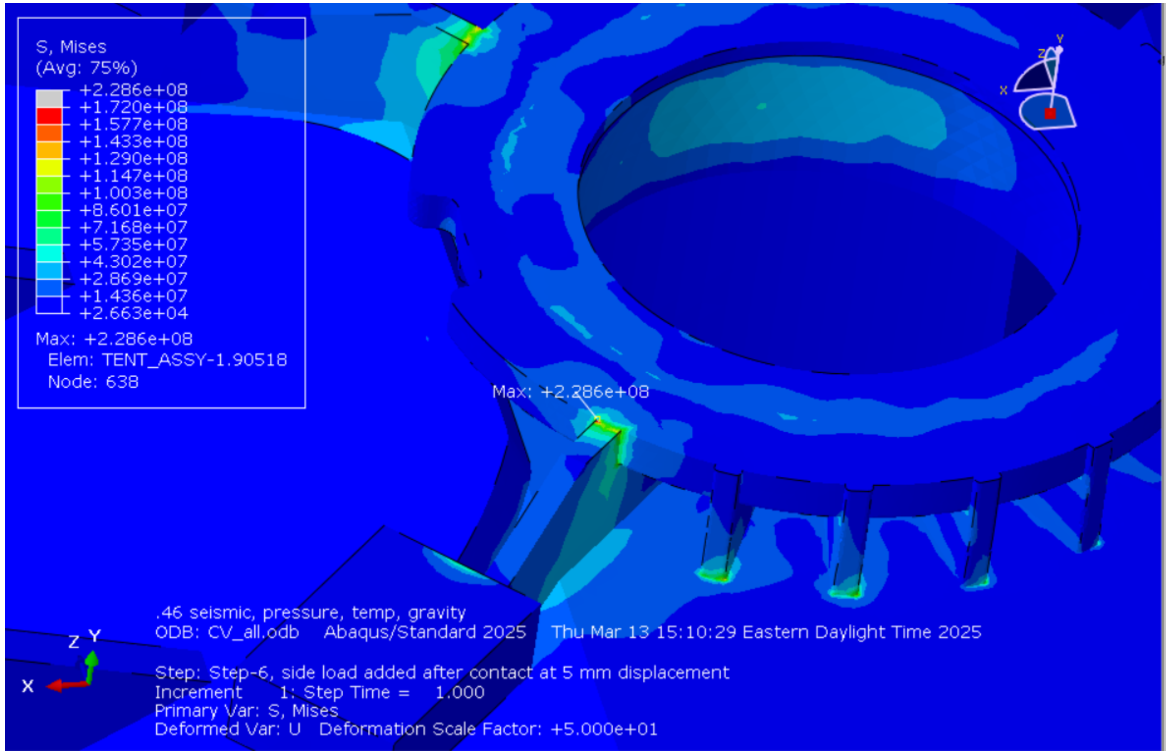


S peak 447 MPa on load ring sharp corner

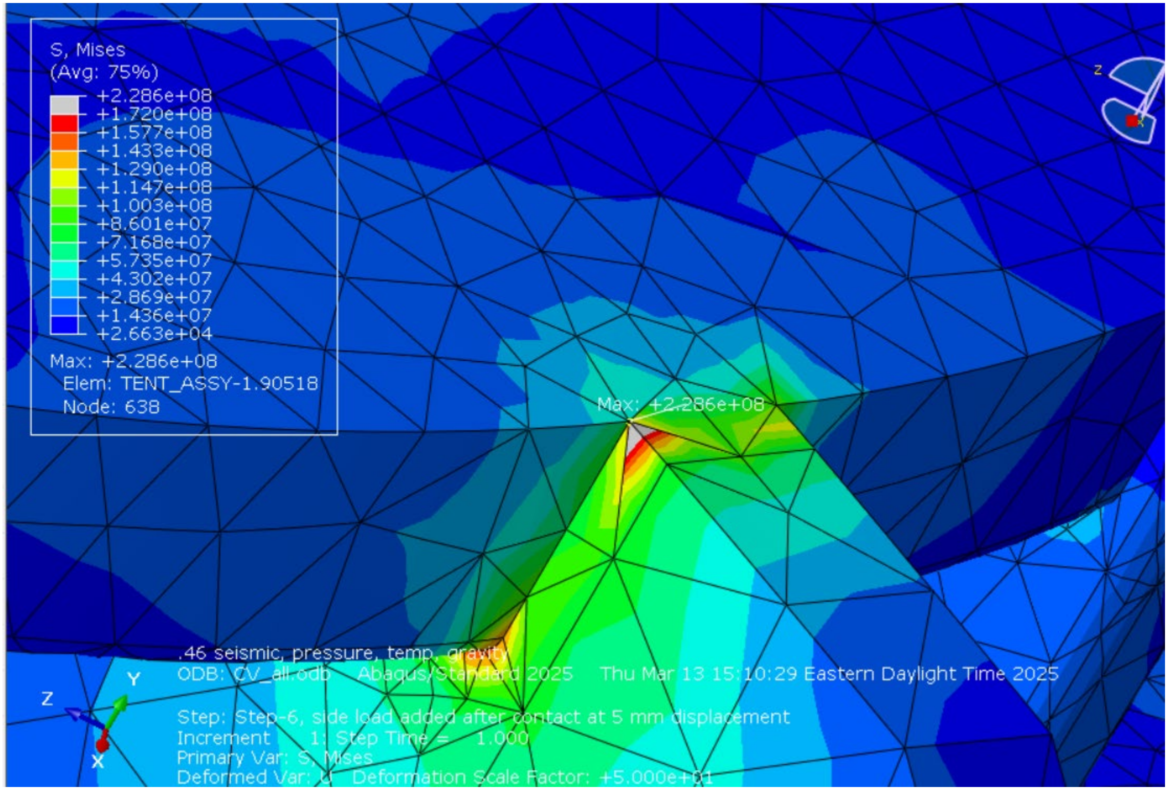


Step 6 Peak stress 226 MPa in core vessel structure by tent

Peak Core Vessel stress 226 MPa

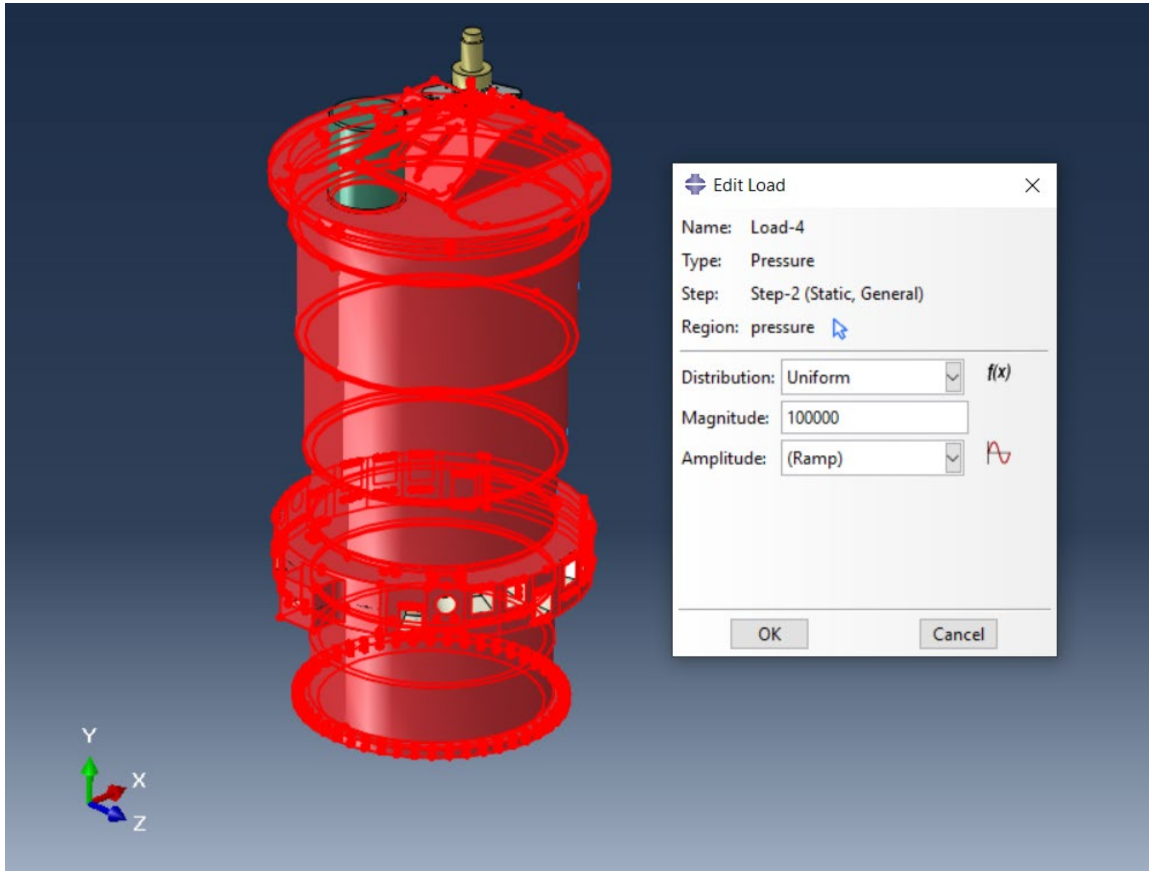


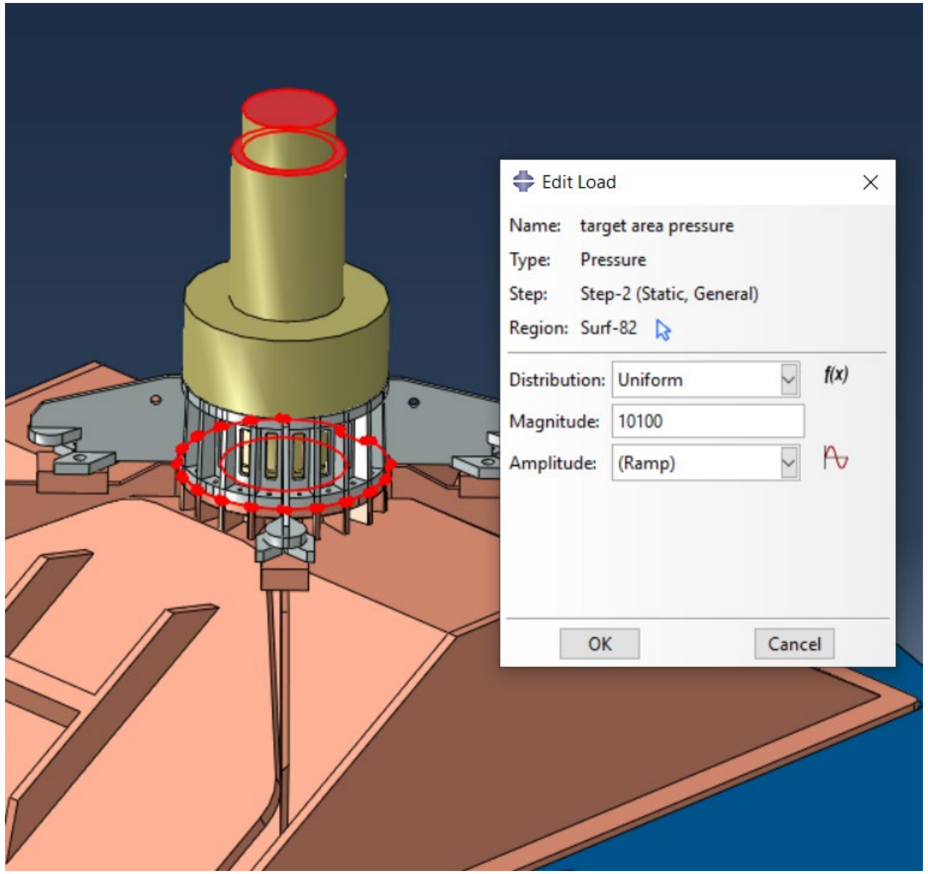
Peak at singularity average below 172 MPa



Analysis for Vacuum Pressure, Water Pressure and Thermal loads added to gravity and Seismic loads

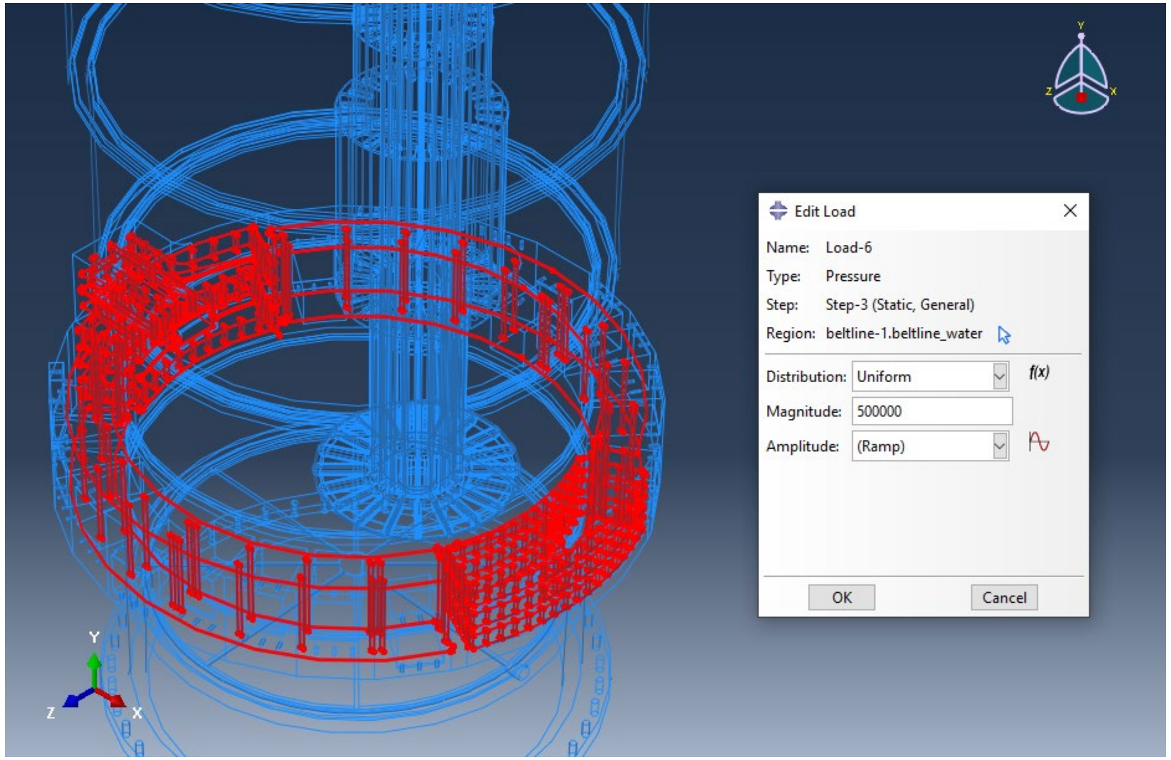
Vacuum pressure loads



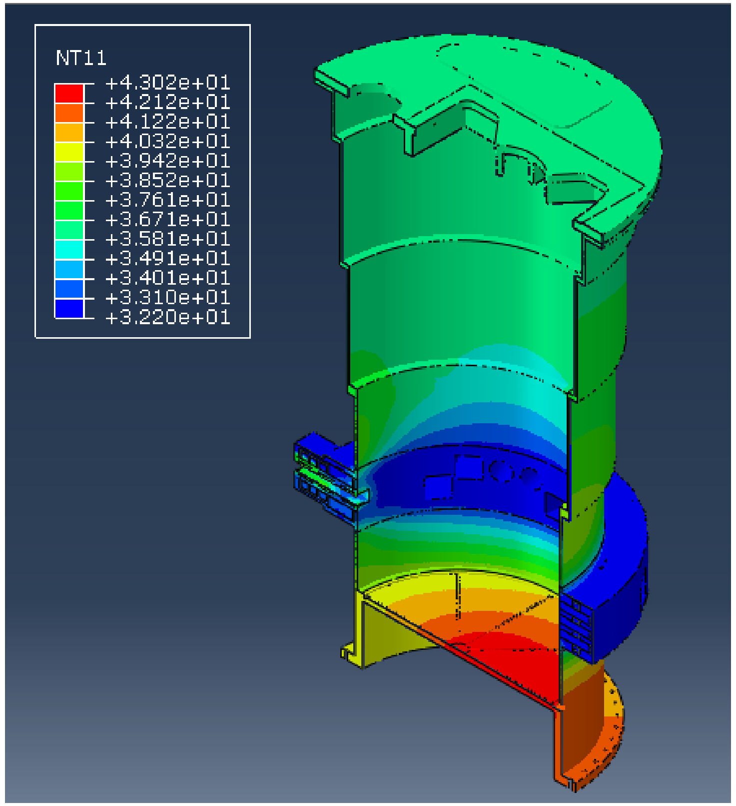


5 Bar water pressure and CFD temperatures added in Steps 3 and 4

Water Pressure

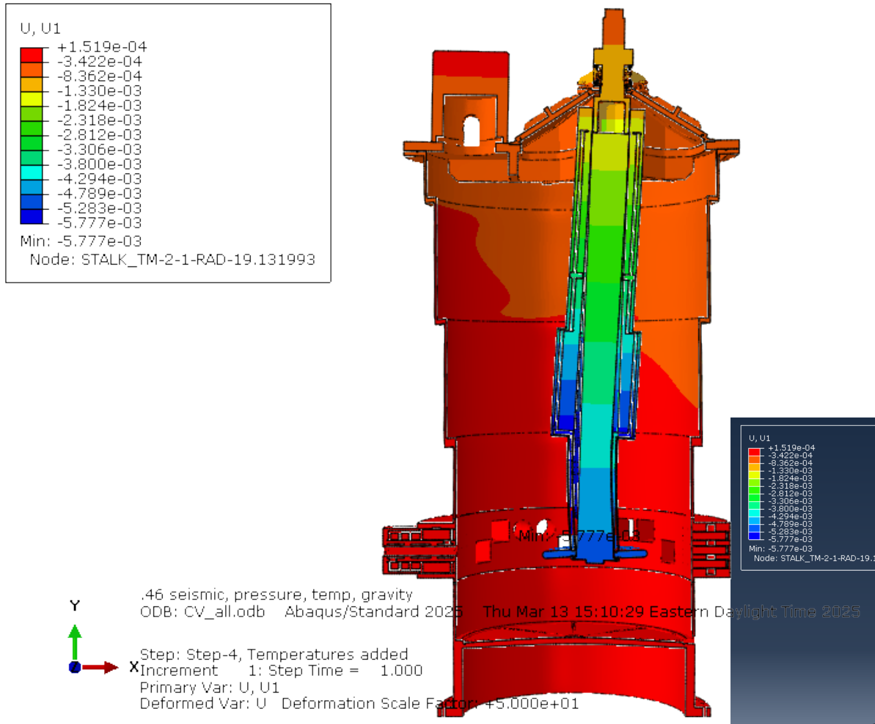


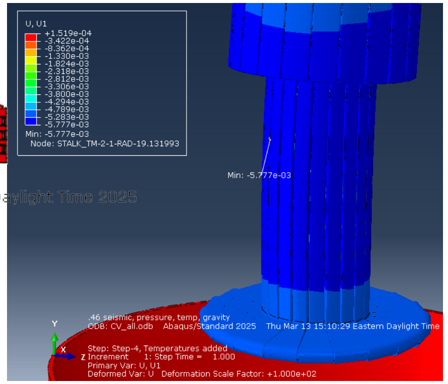
CFD Temperatures applied - all other parts fixed at 36 C



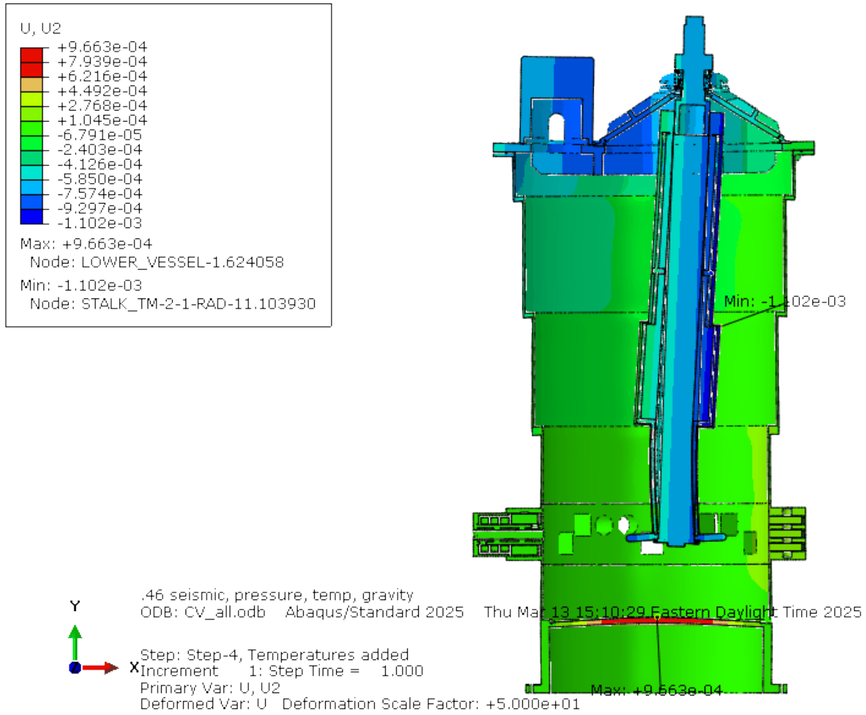
Step 4 Results – Seismic and operational loads

U1 peak 5.8 mm



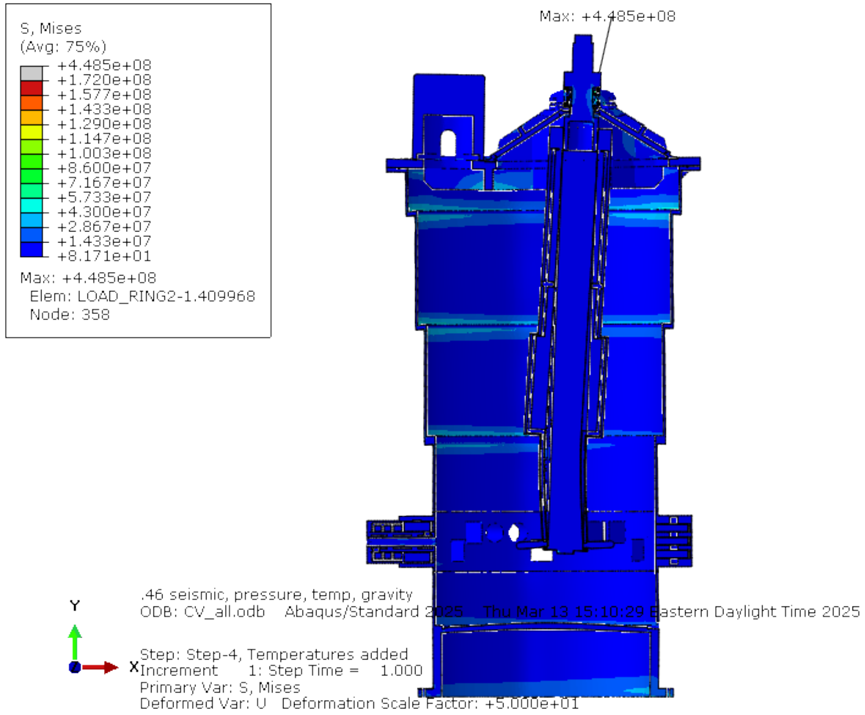


U2 peak 1.1 mm down and 1 mm up at bottom plate

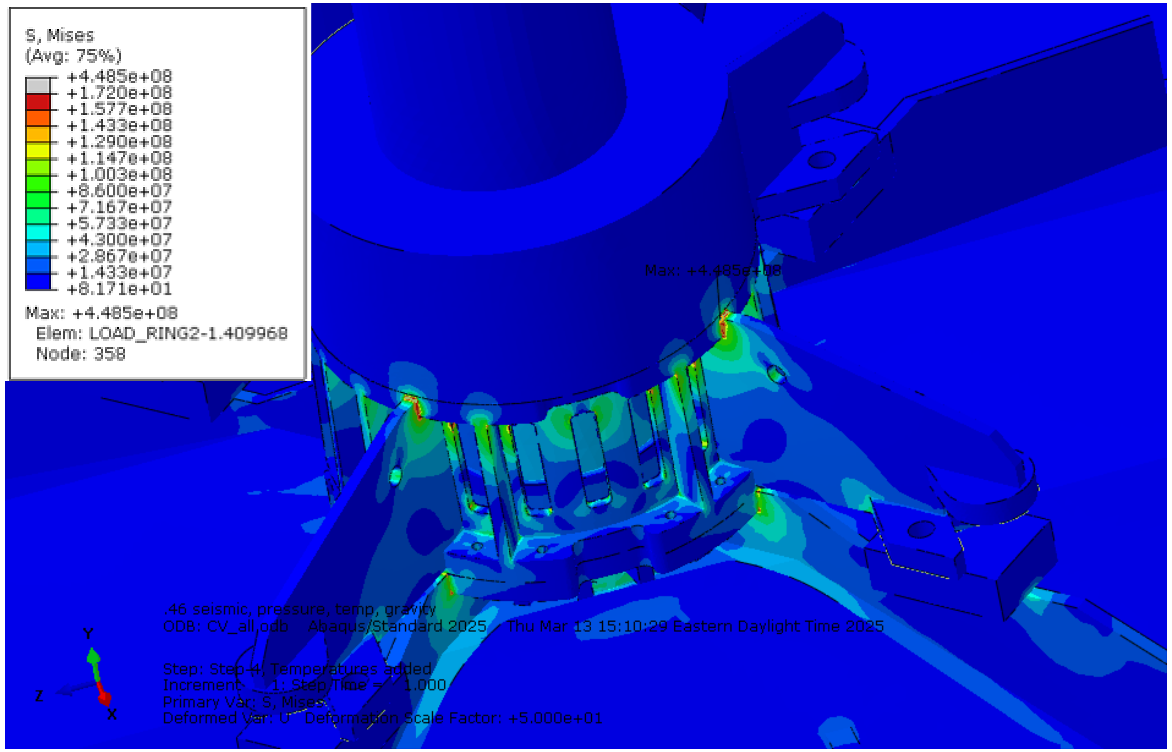


Step 4 Stress Assembly

Stress peak 448 MPa



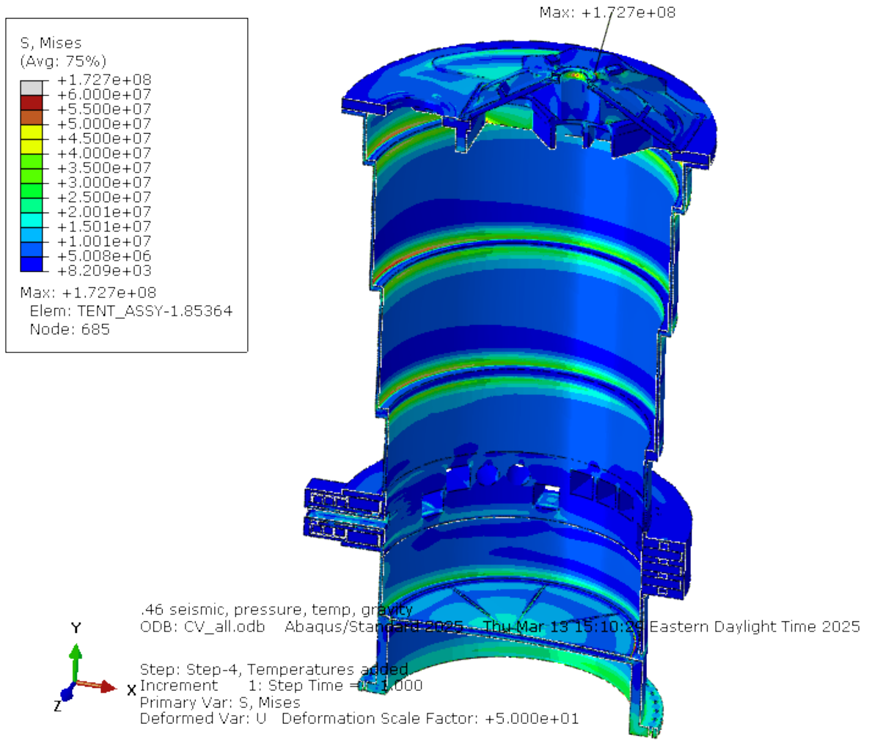
Stress top region – 172 MPa scale max



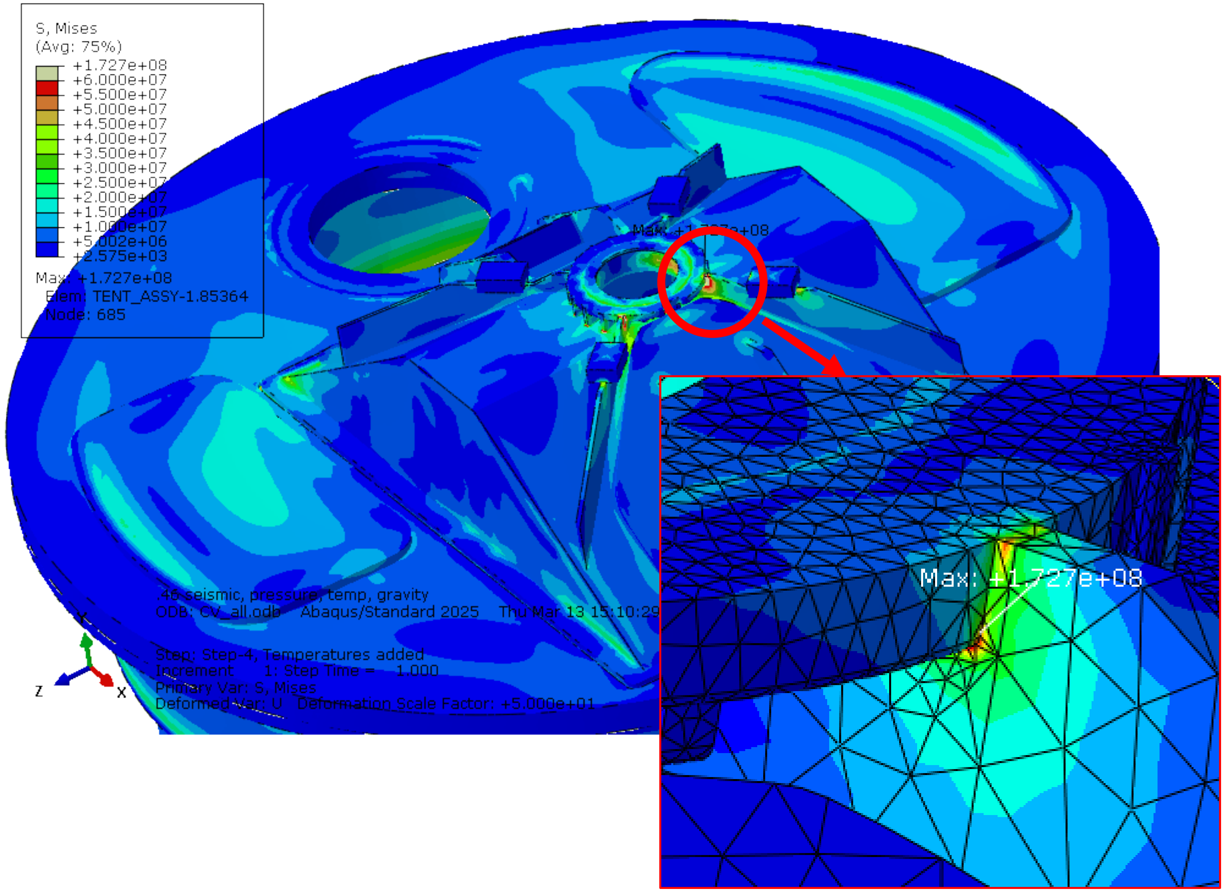
448 MPa Stress peak is where a load ring leg connects to a ring on the side opposite to the load direction

Step 4 Core Vessel Stress Results – Seismic and operational loads

Core Vessel Stress – 172 MPa peak – 60 MPa scale

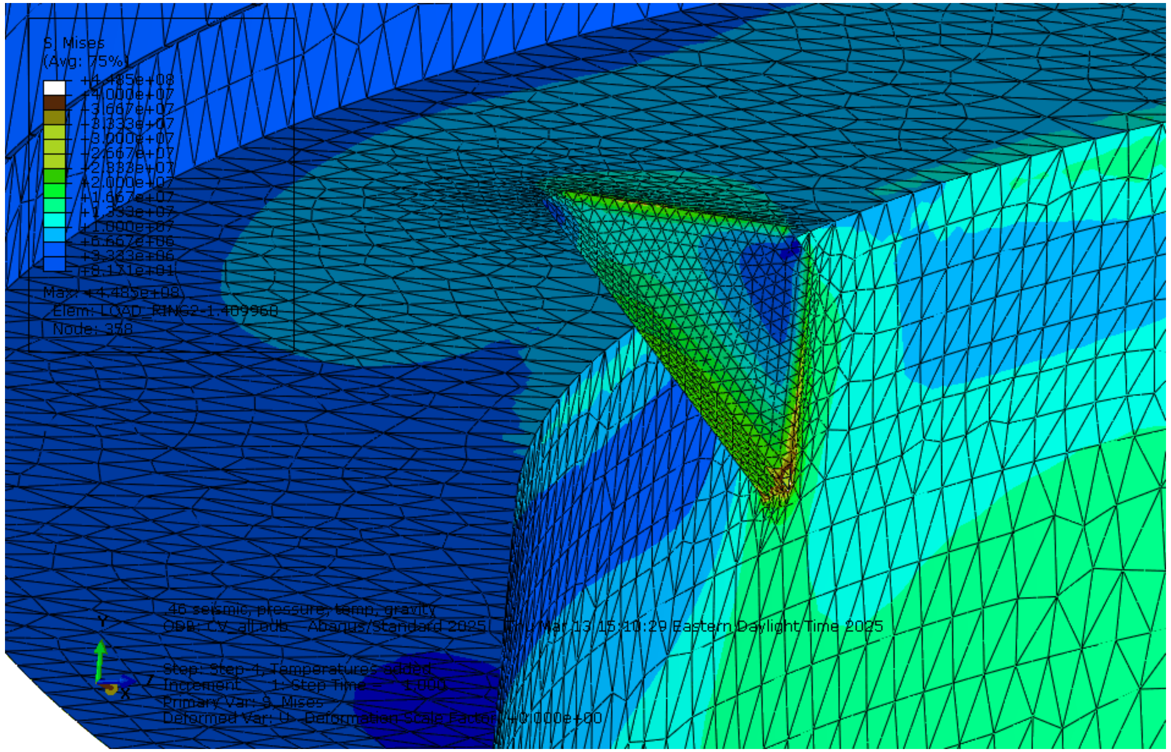


Peak stress 172 MPa by "tent" leg connection

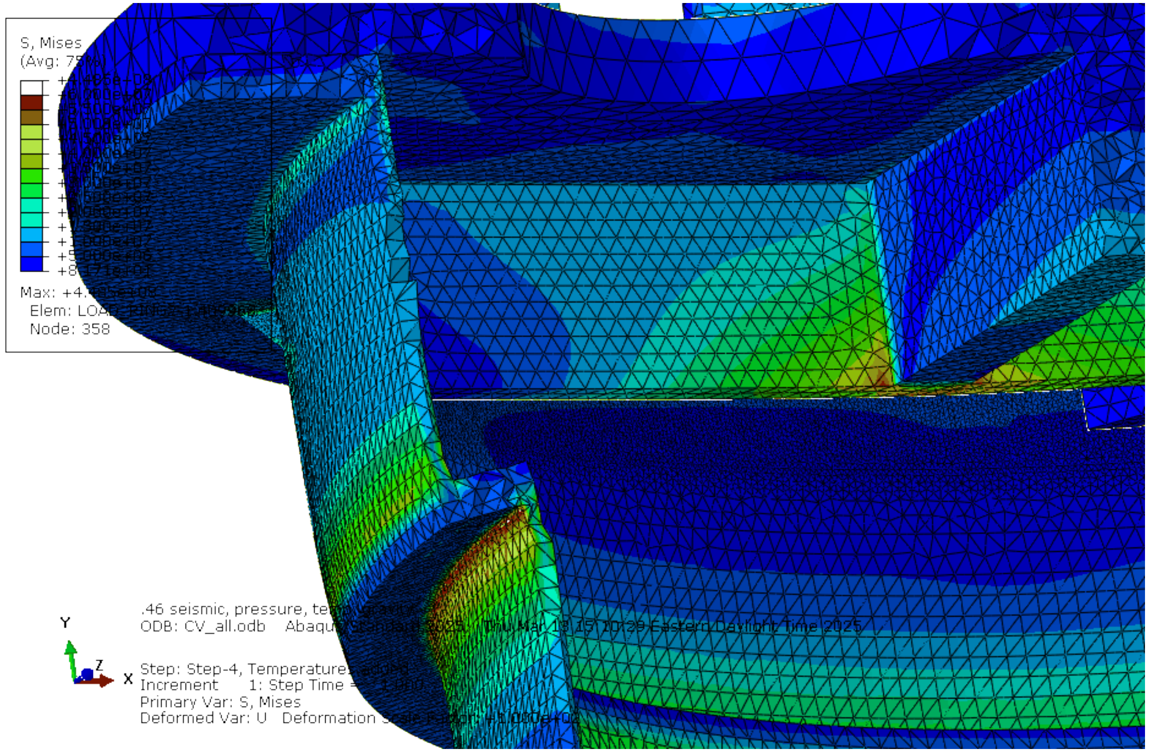


Step 4 Stress Results – Seismic and operational loads

Lid gusset – 40 MPa scale maximum

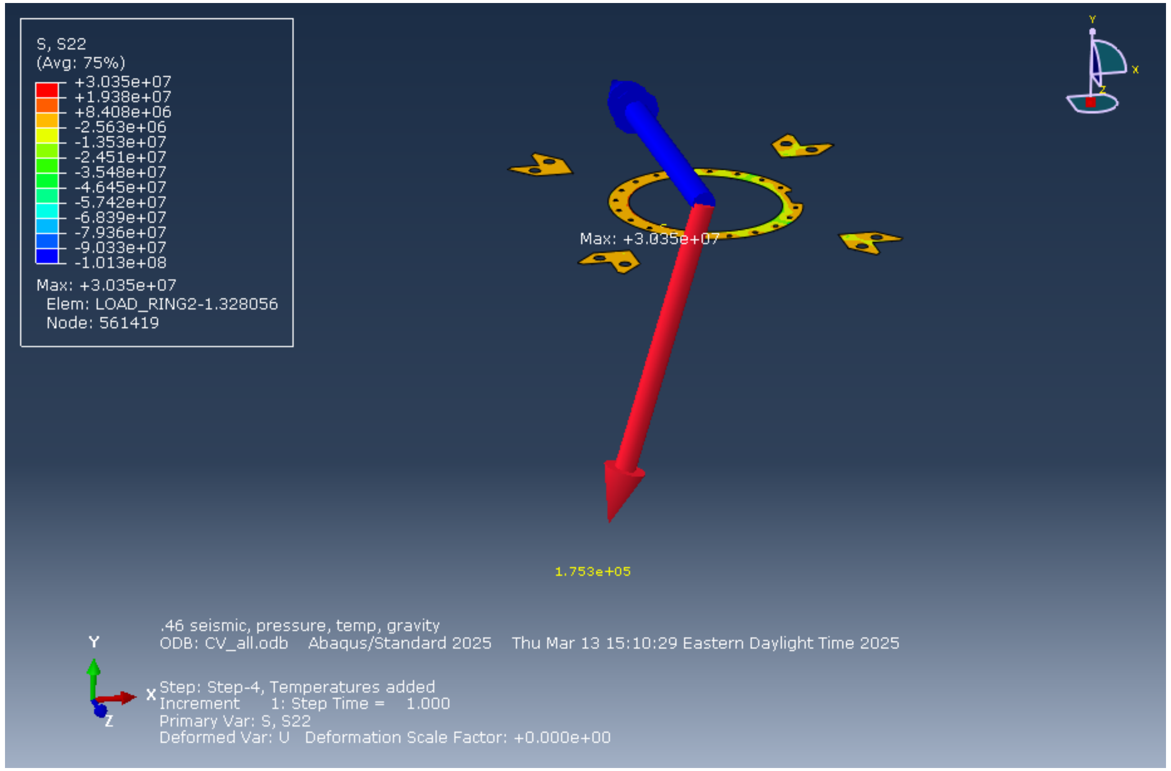


Vessel Stress 60 MPa scale - mesh

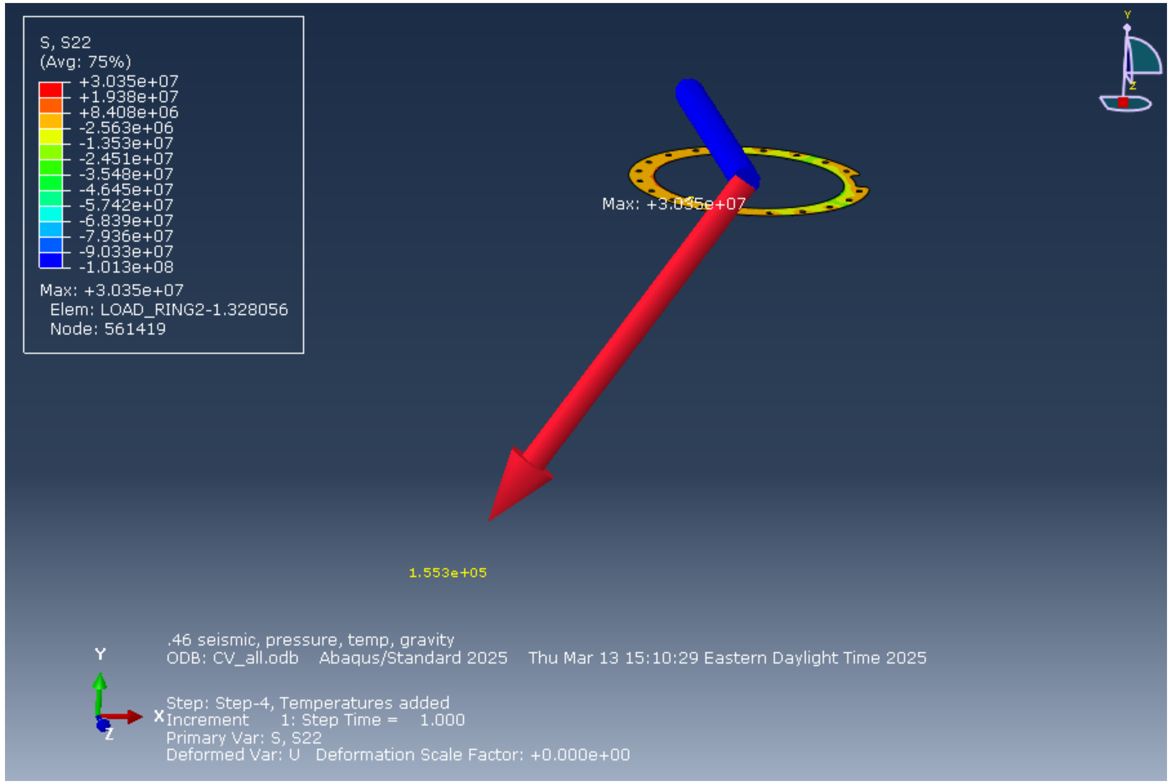


Step 4 results with a cut 1 mm above the load ring tie to the tent assembly

Vertical stress and loads at bottom of load ring and legs



Vertical stress and load in central ring



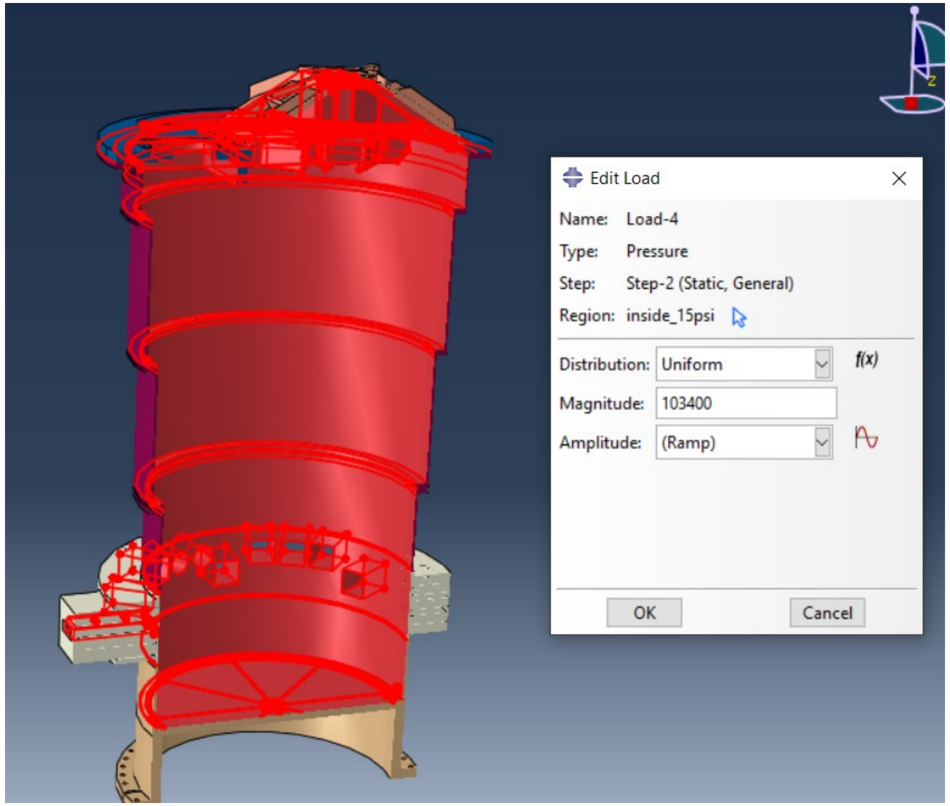
Approximately 88% of the vertical load is transmitted to the central ring

The overpressure case with 15 PSIG internal pressure was evaluated

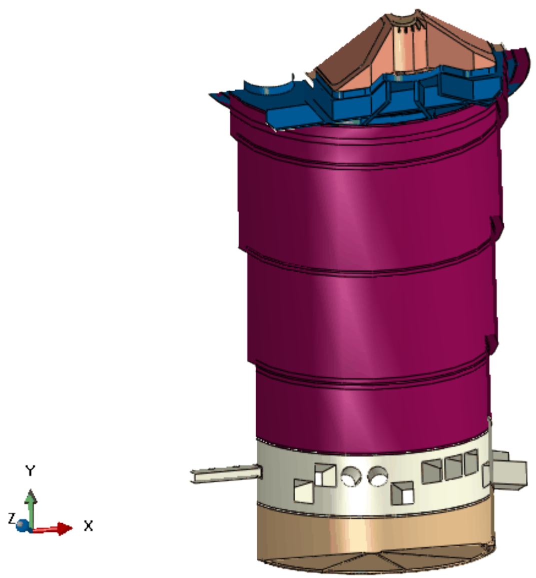
- The external pressure of 1 bar in step 2 was replaced with an internal pressure of 103400 Pa (15 PSIG)
- All other loads were applied as previously done including seismic displacement and imported temperature profile

External 15 PSIG case added for Step 2

Internal 15 psig on core vessel

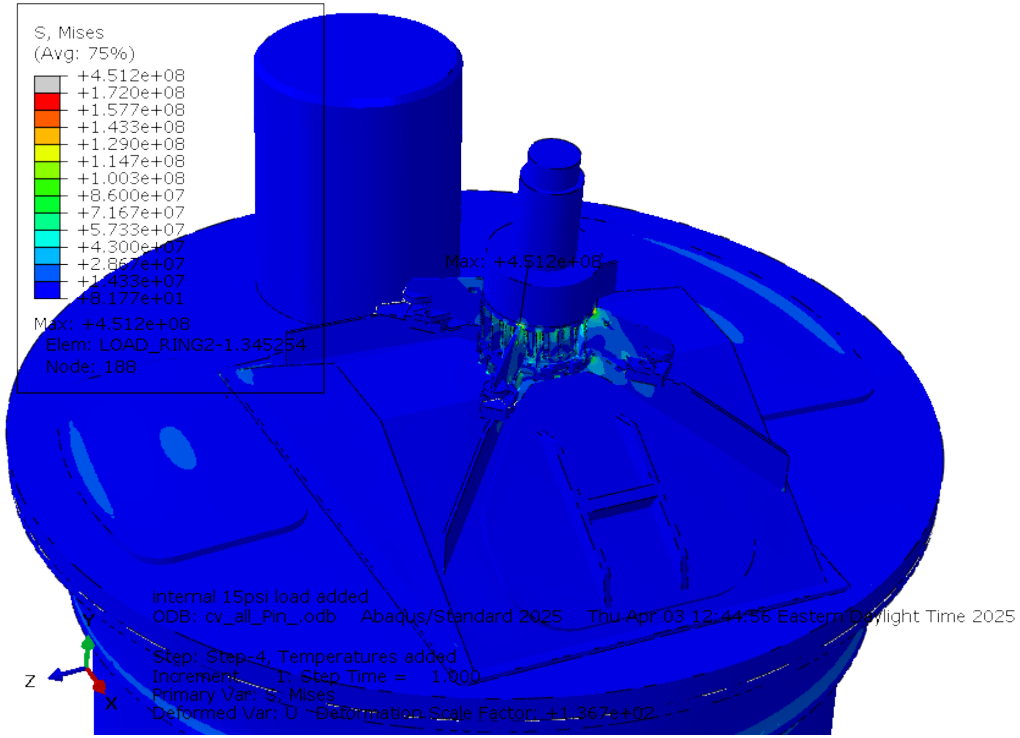


Surfaces with 15 PSIG applied

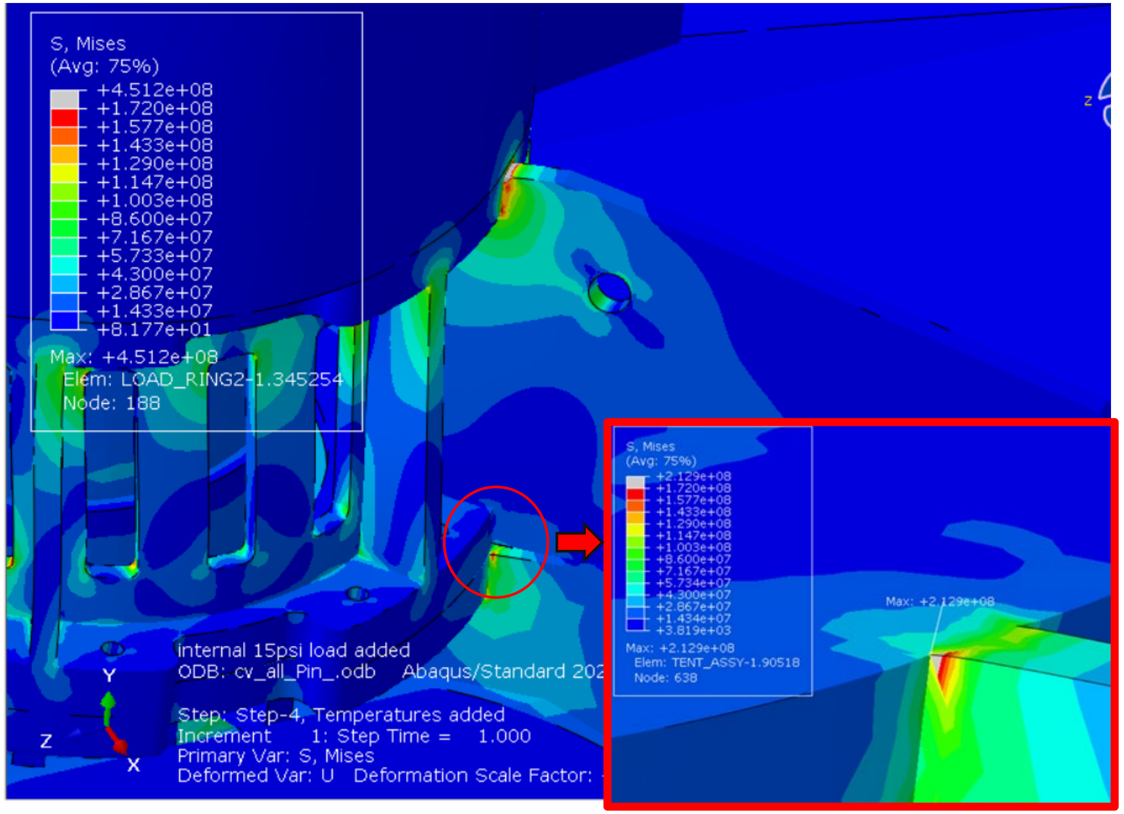


Mises stress with combined loads including internal pressure

S Mises = 172 MPa scale maximum

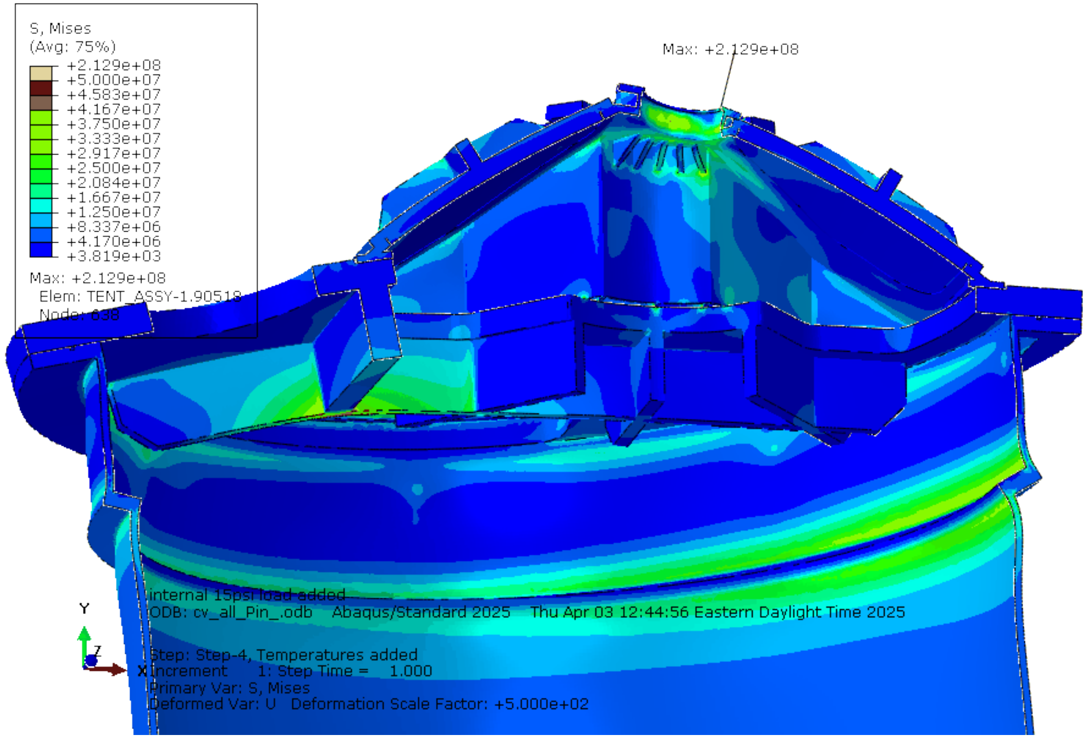


Peal stress 213 MPa in core vessel

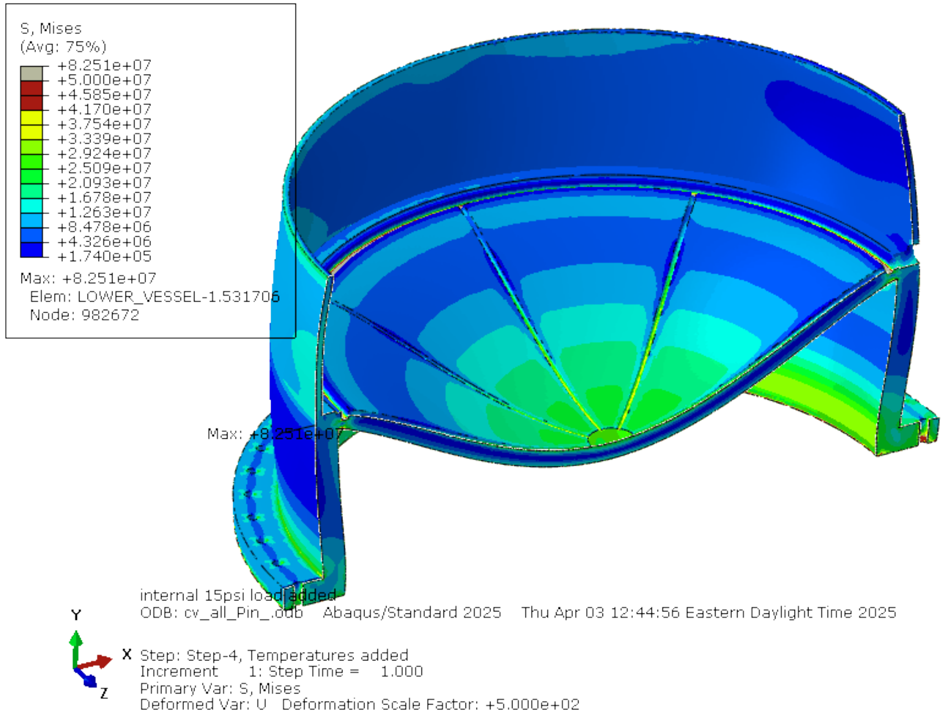


Peak core vessel stresses with all loads still driven by shaft displacement with a peak of 213 MPa at a corner singularity

Von Mises stress with 50 MPa scale maximum

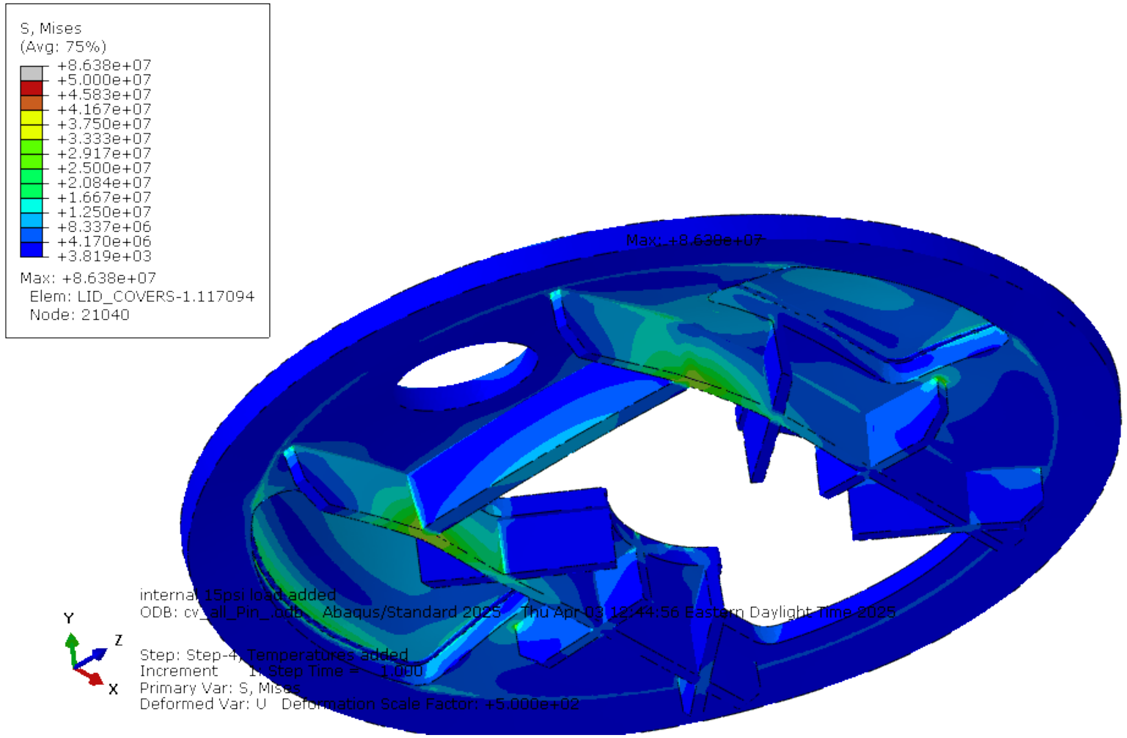


Peak stress in lower cylinder of 82 MPa in drainage groove – 50 MPa scale

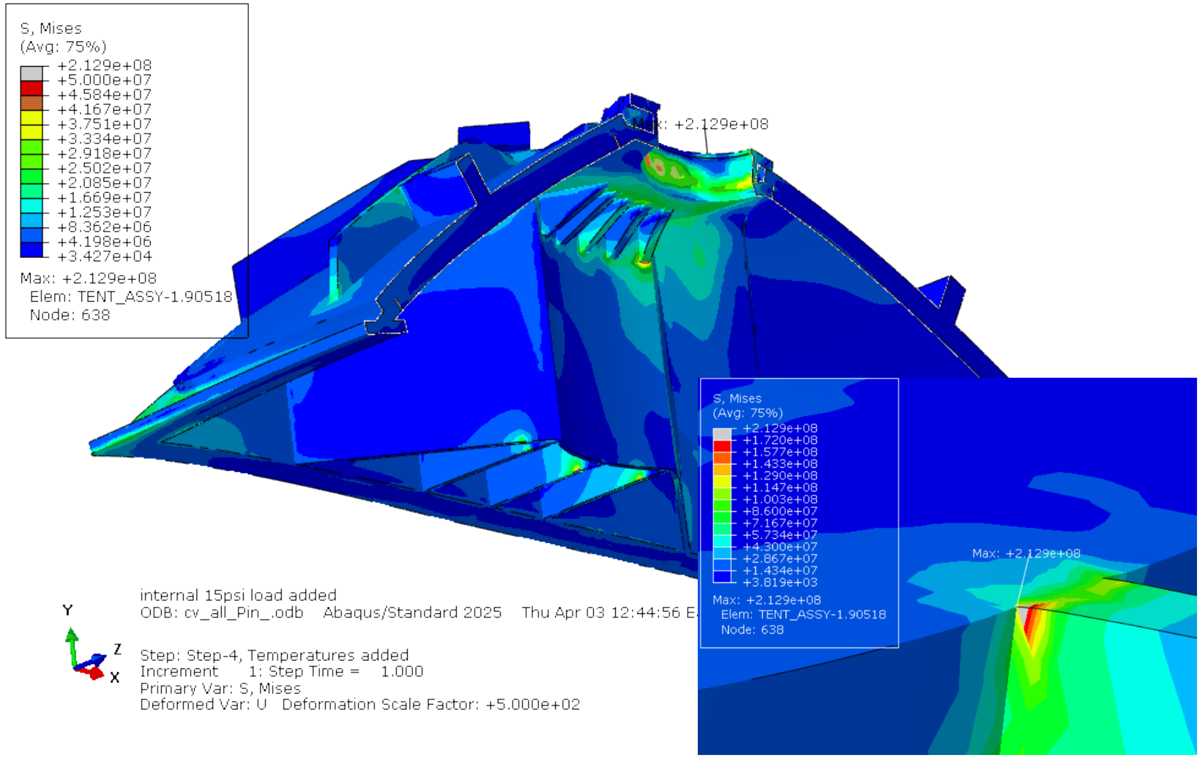


Component Stresses with all loads including internal pressure

Lid and Covers – peak 86 MPa



Tent Assembly 50 MPa scale – peak 213



Summary

- Results are preliminary and do not include any bolt analysis
- Elastic material properties assumed
- Mesh refinement in some high stress locations would be desirable
- Lower Vessel thermal stresses assume a 36 C base plate temperature
- Loads do not include nozzle extensions
- Approximately 88 % of the vertical gravity loads from the target assembly go through the central ring structure and only approximately 12 % is carried by the “legs”
- Calculated Core vessel stresses all are at or below the 172 MPa limit for 1.5 Sm on membrane plus bending including a .46 G seismic load in the beam upstream direction and vacuum operation
- The target shaft load ring and core vessel peak stresses are driven by the angular deflection of the stiff shaft
- The peak stresses are very sensitive to the amount of deflection at the base of the shaft within the nominal 5 mm gap from the restraint ring

Summary (continued)

- An internal pressure of 15 psig instead of vacuum increased the peak stress at the tent leg connection corner singularity from 172 MPa to 213 MPa including a 5 mm seismic displacement at the bottom of the shaft
- Stresses from the internal pressure were generally below 90 MPa except at the singularity by the leg connection
- Cover plate stresses from internal pressure did not consider bolt loads and assumed merged surfaces