Standard problem exercise SPE - 3

Performance of pre-stressed concrete containment vessel under severe accidents

Part – I: Structural Analysis

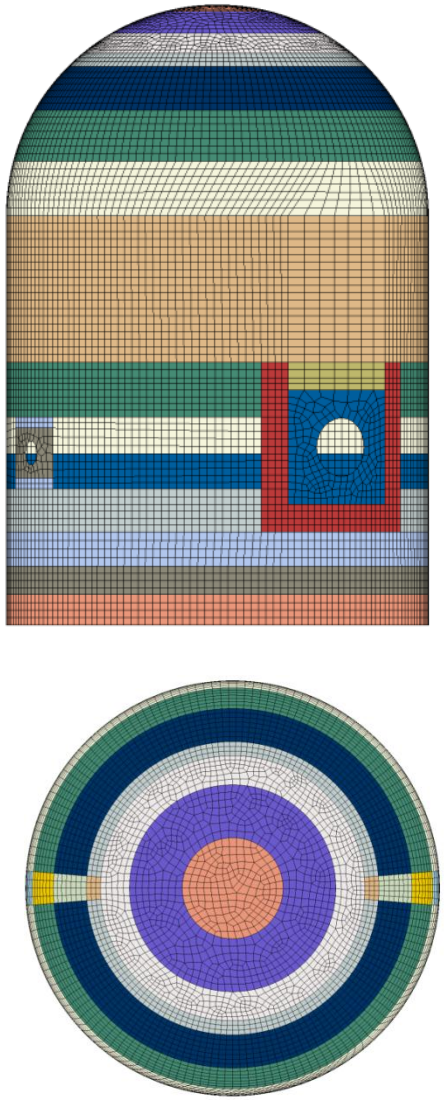
AERB, India

Outline

- Phase-2 analysis: Case – 2
  - Model
  - Failure prediction criteria
  - Results
- Summary

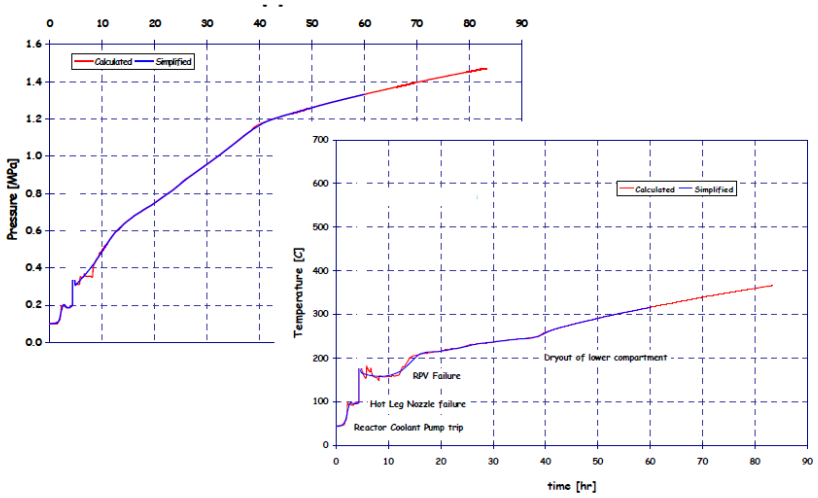
Model

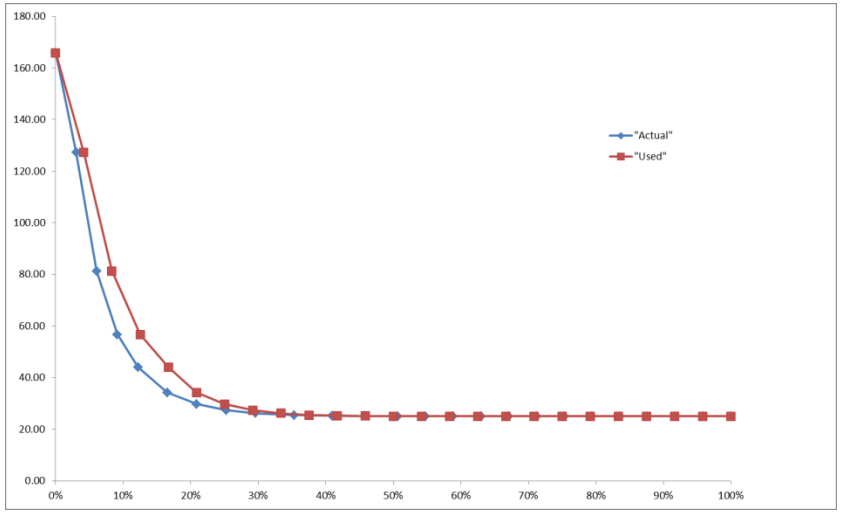
- Calibrated Model-3 from phase-1
- Modification to include temperature loading
  - Number of layers changed from 2 to 4
    - Layer 1: Liner (9 integration points)
    - Layer 2 to 4: Concrete (9 integrations points each)
- Modified model designated as model-4

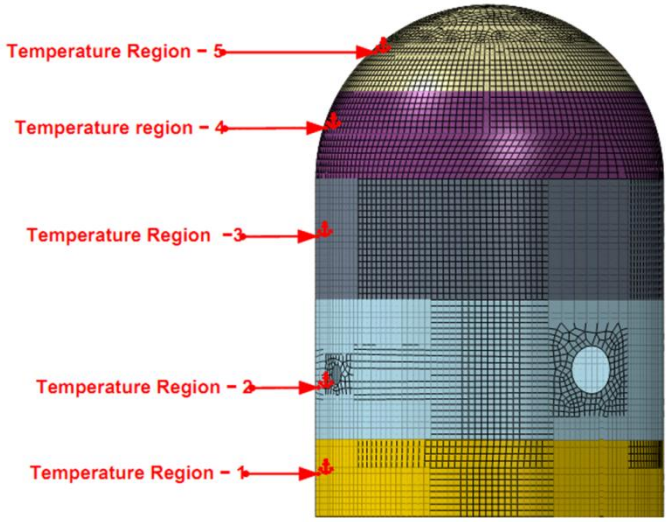


Temperature & pressure variation

- As per problem statement
  - Stress free temperature = 25°C
- Temperature loading regions
- Temperature variation across thickness



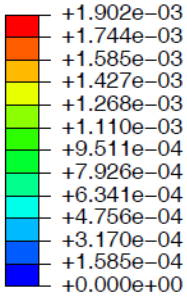


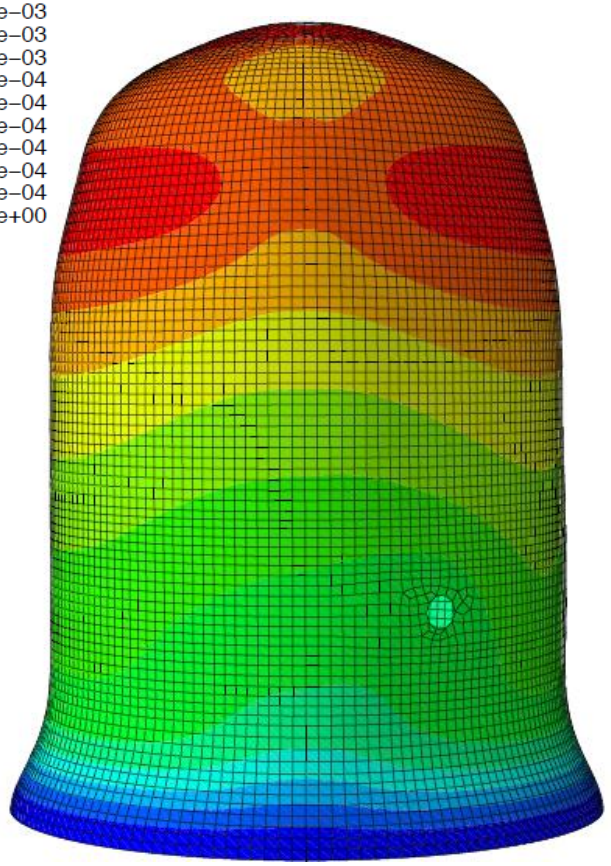


Failure prediction criteria

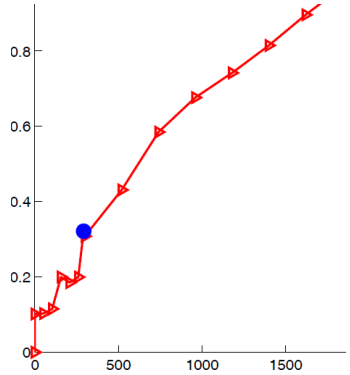
- PCCV model is considered to have reached its ultimate structural failure capacity when
  - Yielding of following occur in any location in the structure
    - Reinforcing steel in both directions
    - Pre-stressing steel in both directions

Case-2 results: Deformed shape

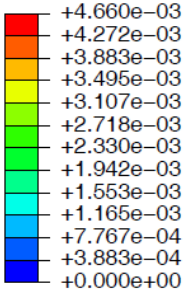


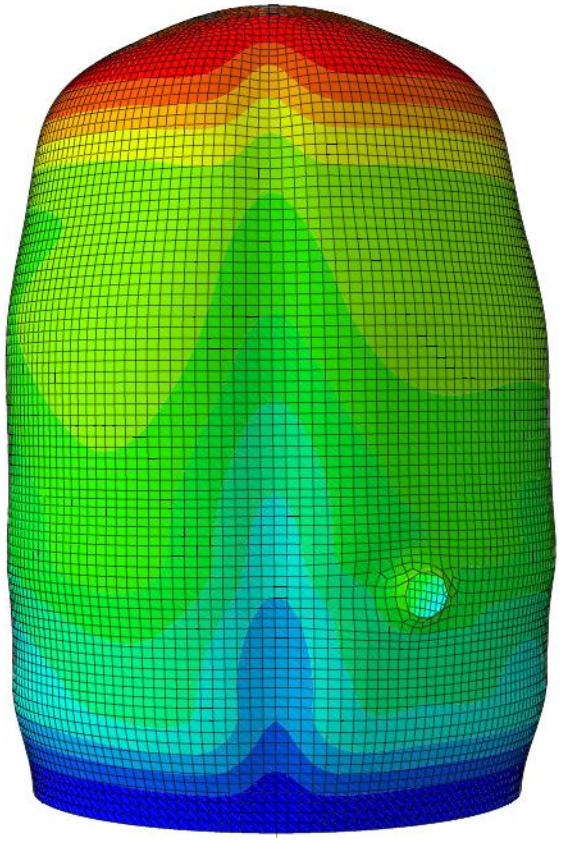


Prestress

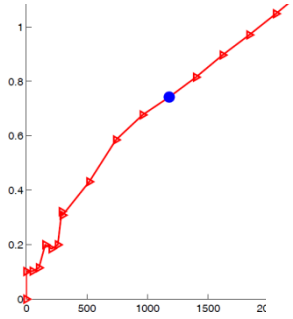


0.82 P_d

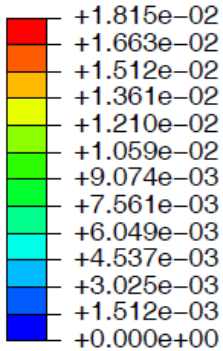


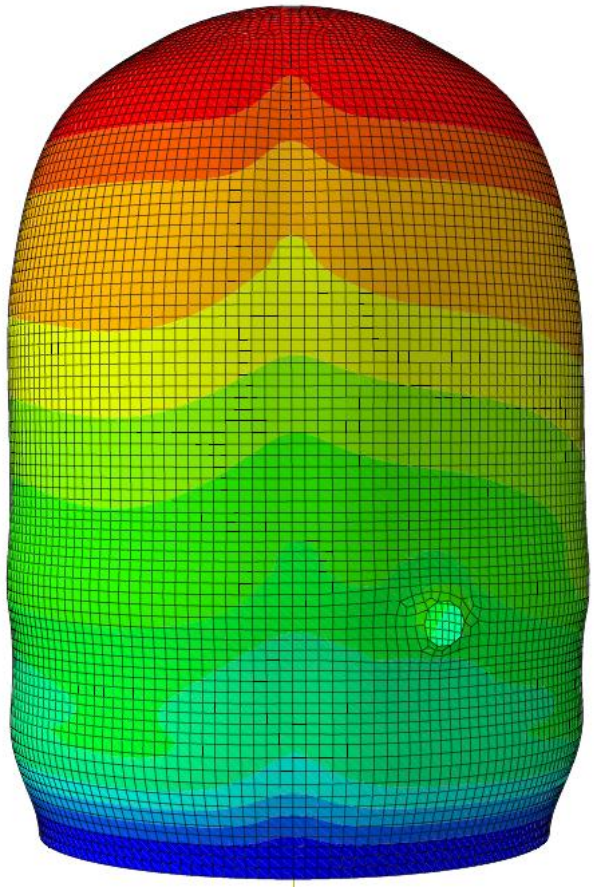


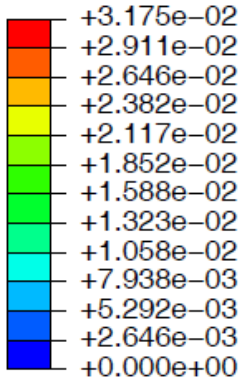
Case-2 results: Deformed shape

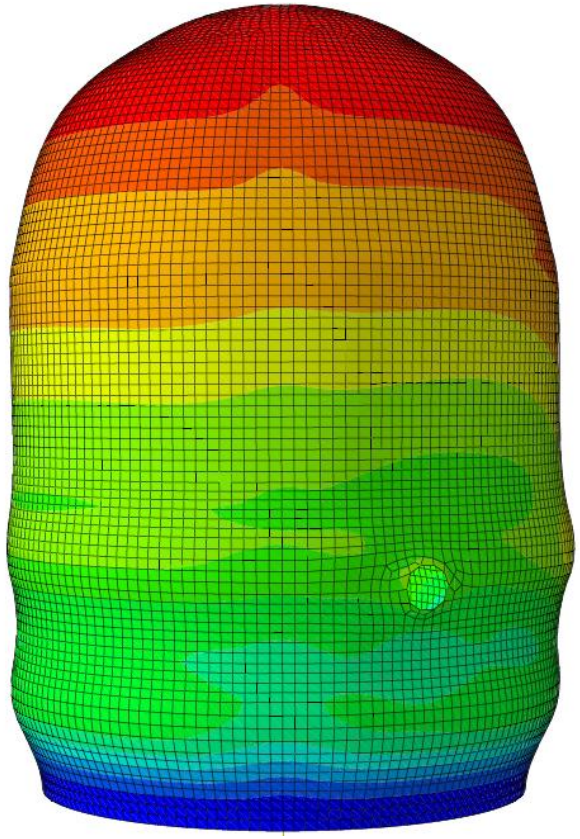


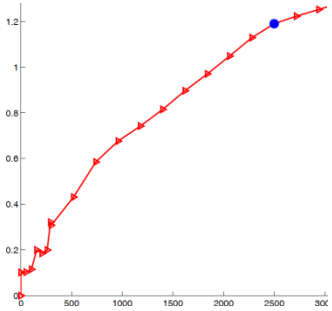
2.0 P_d





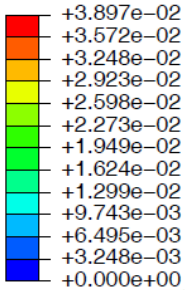




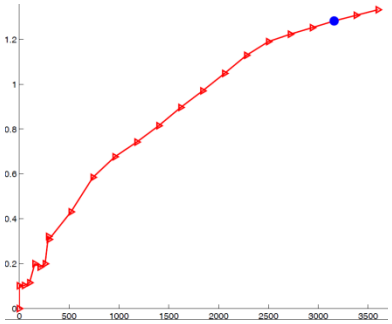


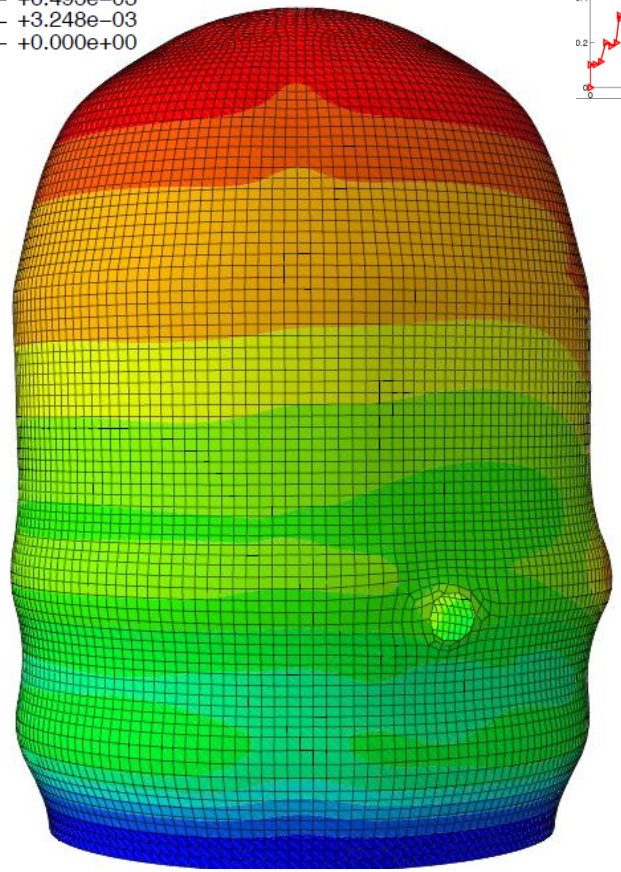
3.0 P_d

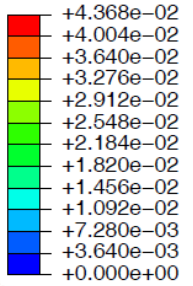
Case-2 results: Deformed shape



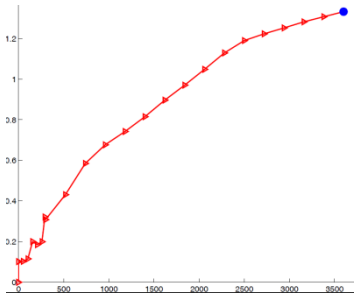
3.30 Pd

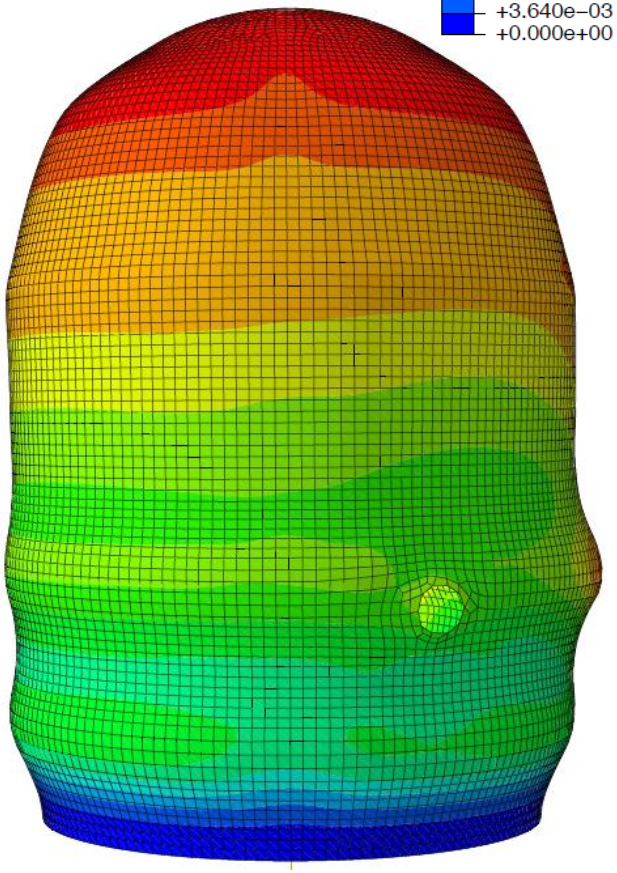






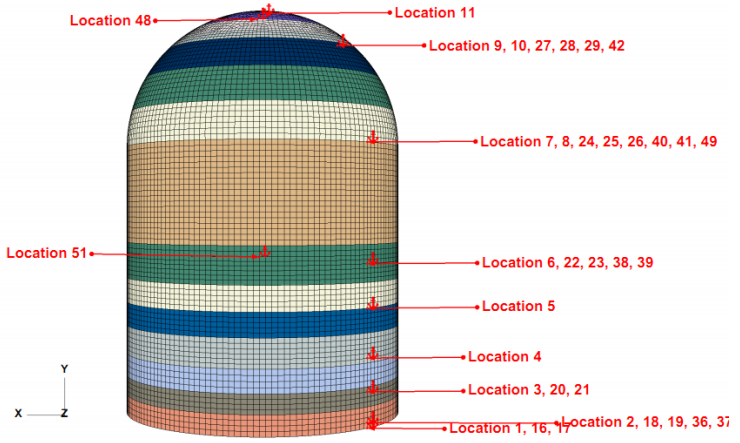
3.41 Pd





Output at 55 standard output locations

- Output provided for 52 out of 55 locations
  - Output at base liner (loc 47) not provided
    - as the base liner is not modelled.
  - Output at anchorage loc. 54, 55 not provided
    - Pre-stressing tendons are modelled as a layer.

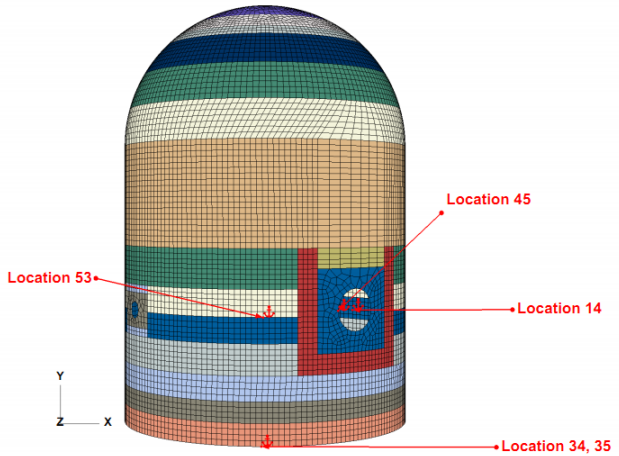


- Rebar strains: Generally provided for the outer layer.

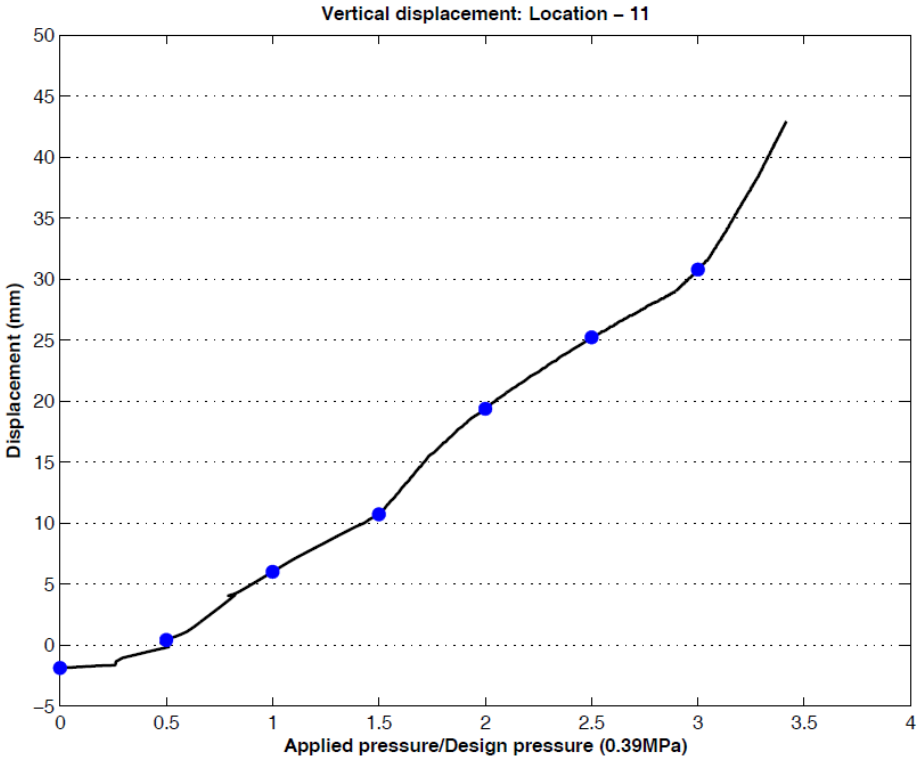
- Liner strain: Integration point at inner surface of PCCV.

- Radial displ. at the centre of E/H and A/L:

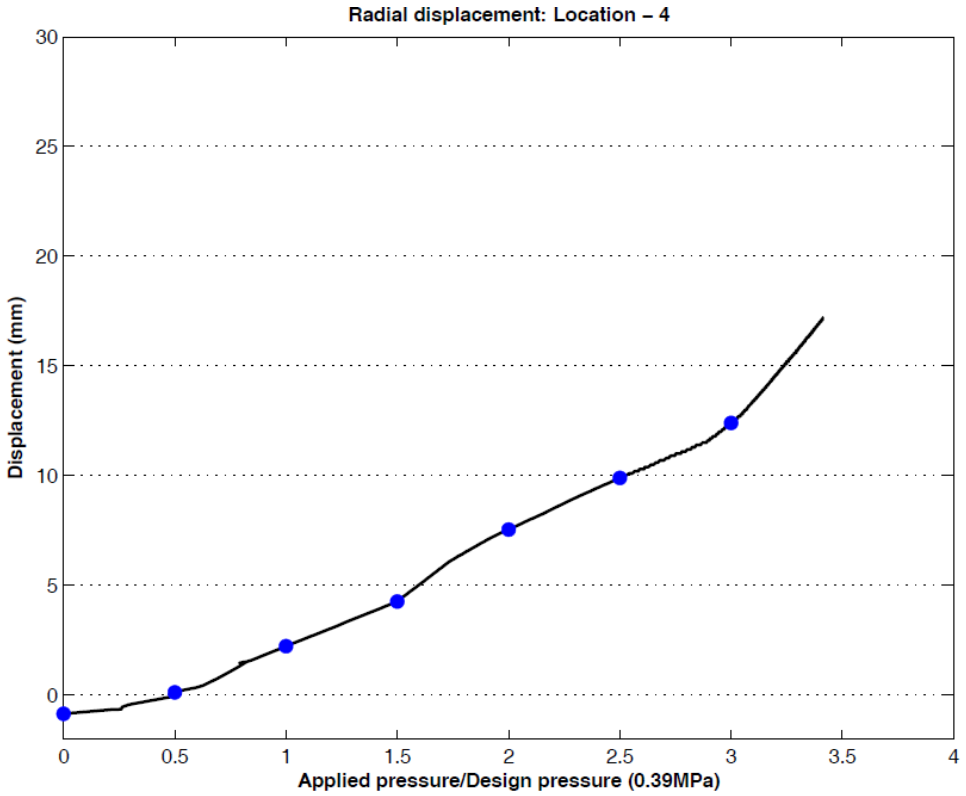
  Mean of displ. at 4 nodes on the edge of E/H & A/L.



Displacement in general area

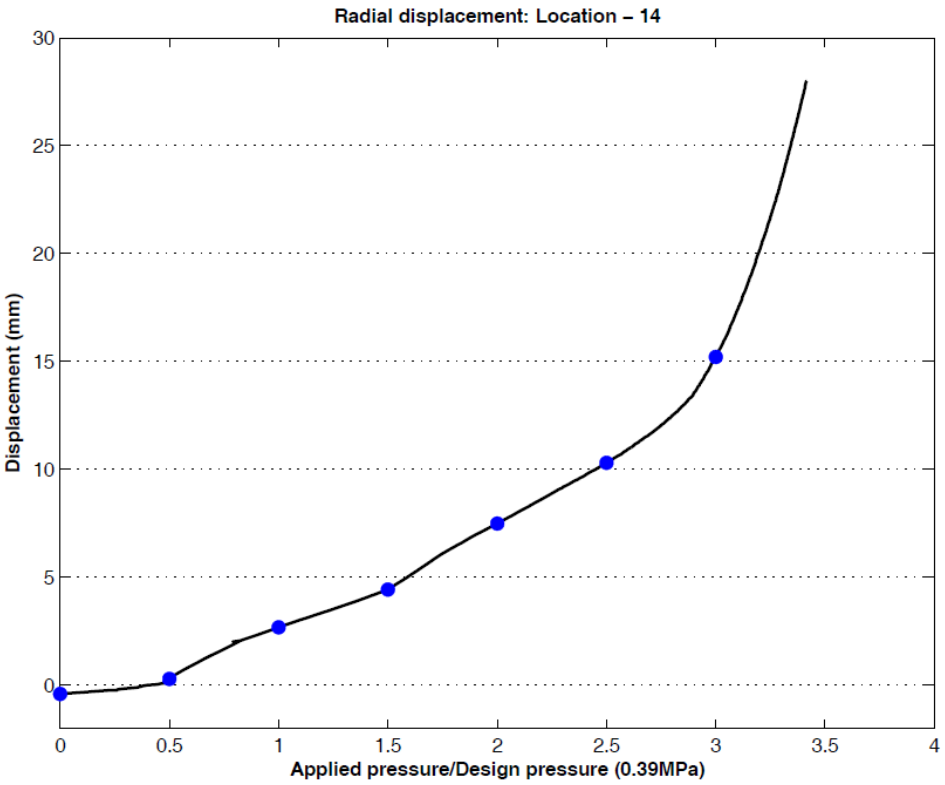


Cylinder general area

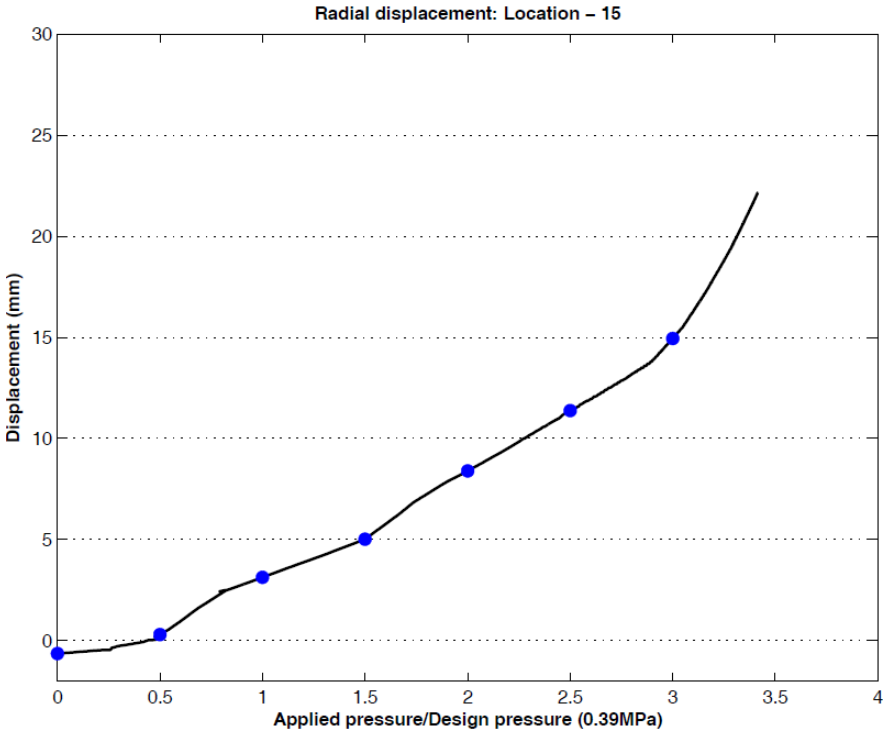


Dome crown

Displacement at openings

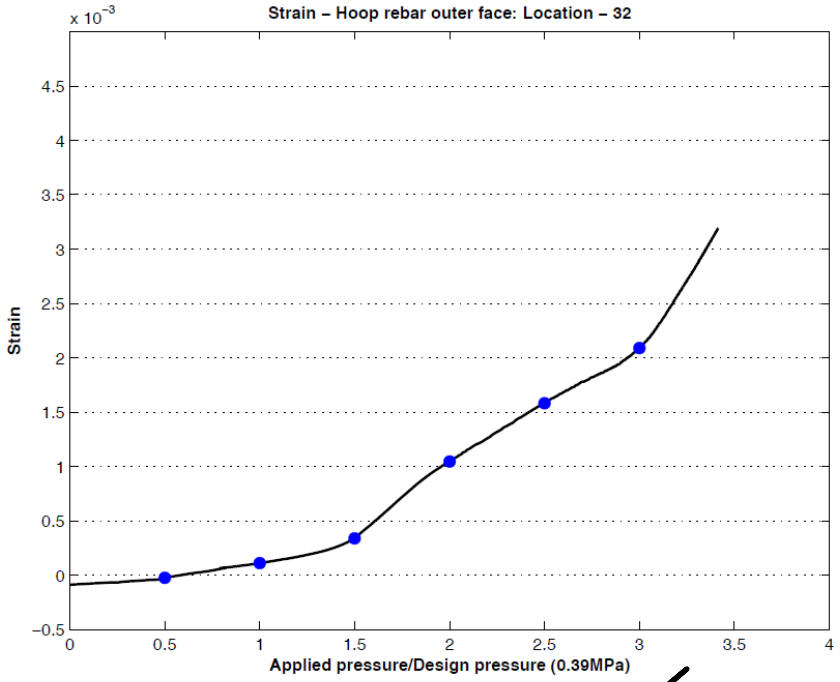


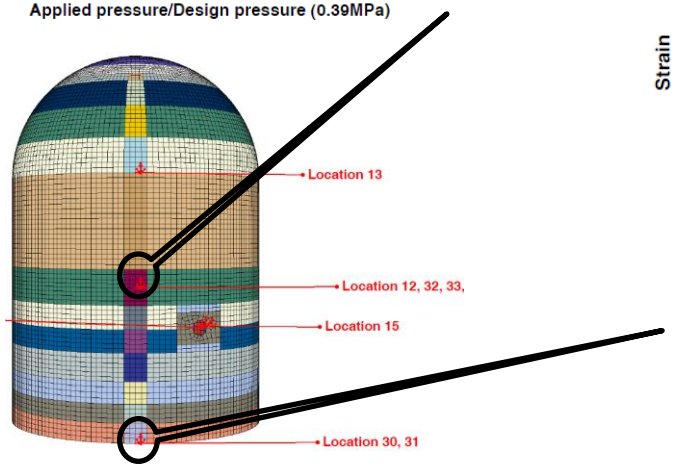
A/L opening

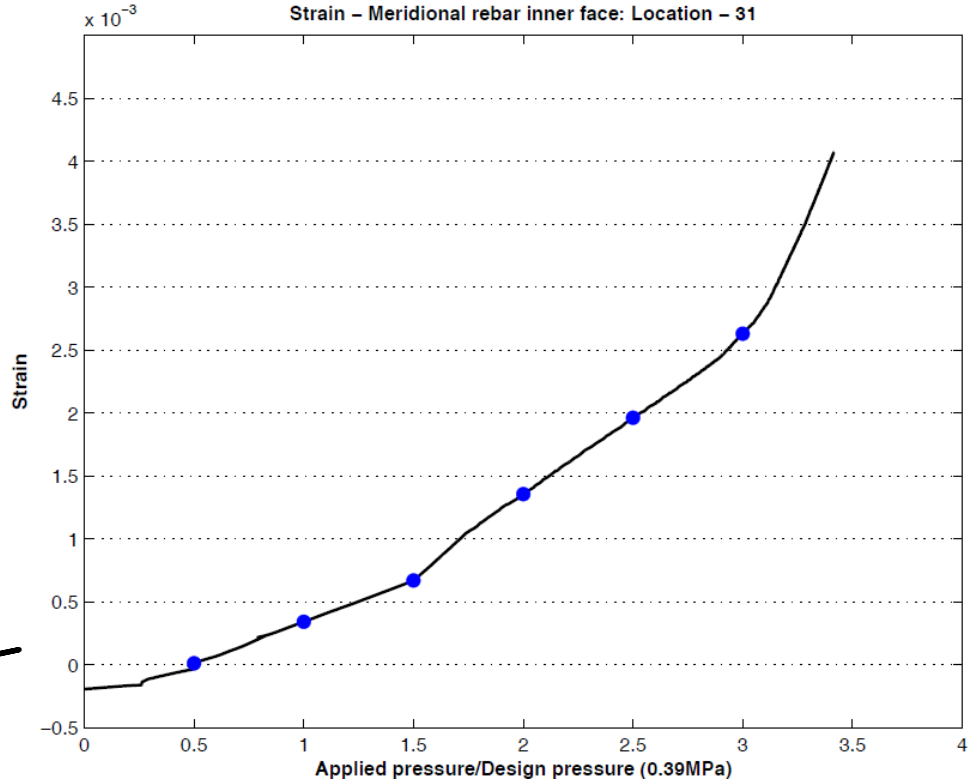


E/H opening

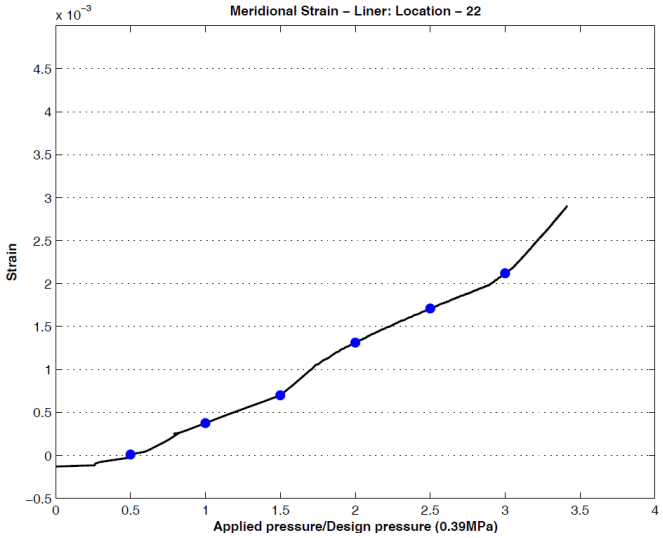
Reinforcement strains

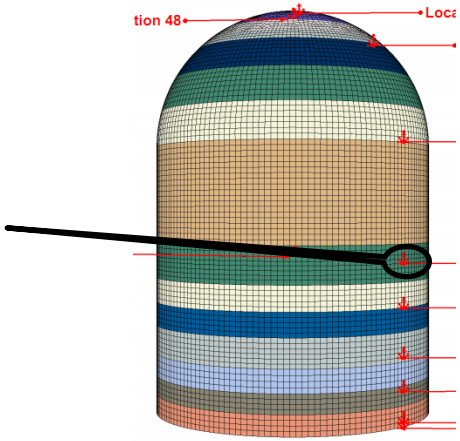


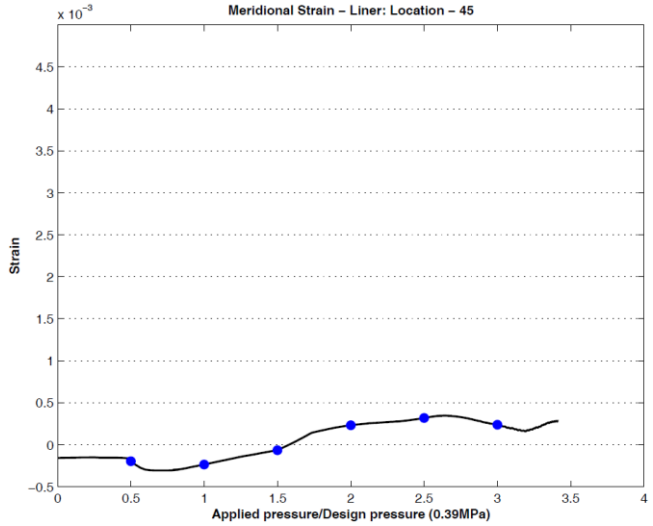


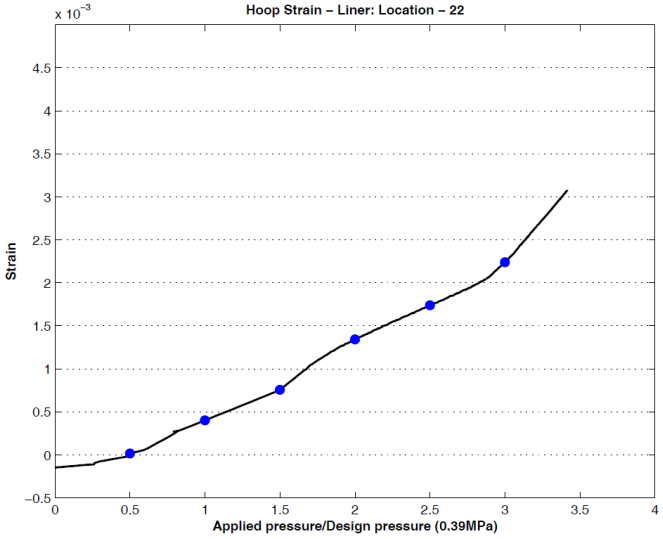


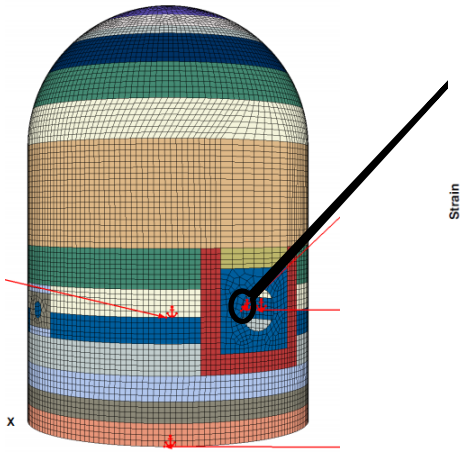
Liner strains

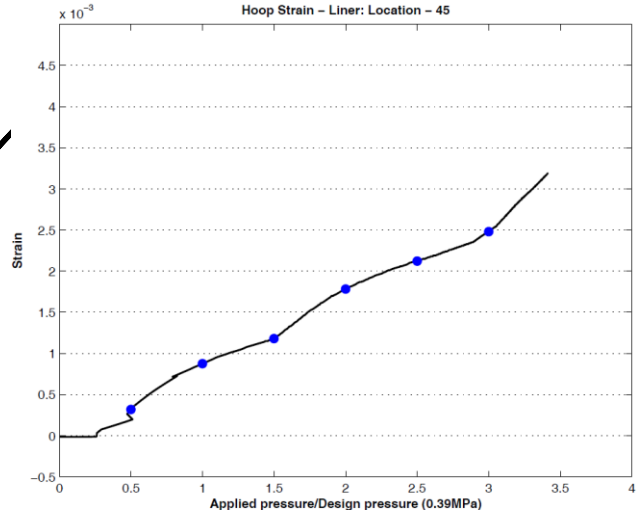




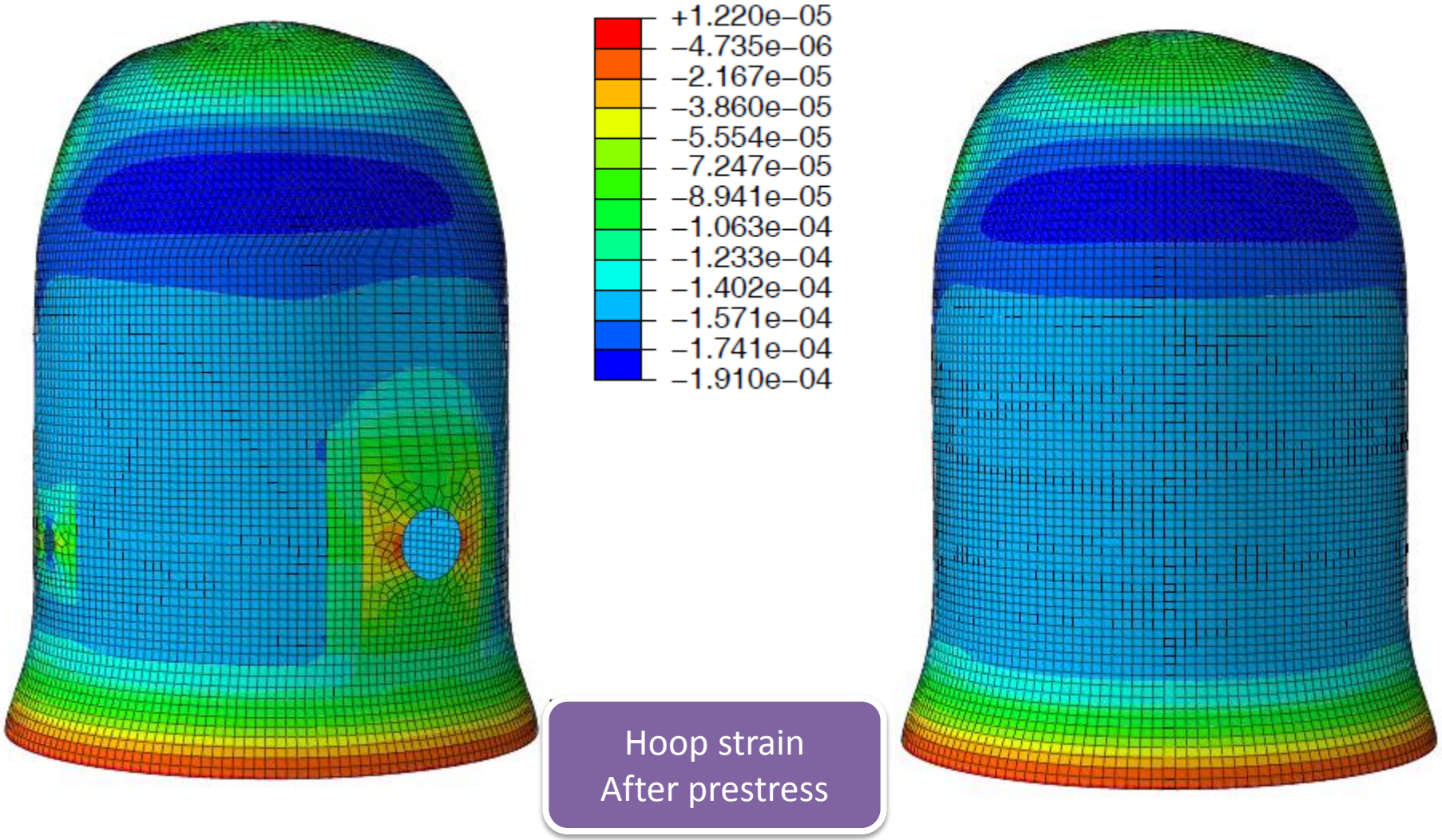






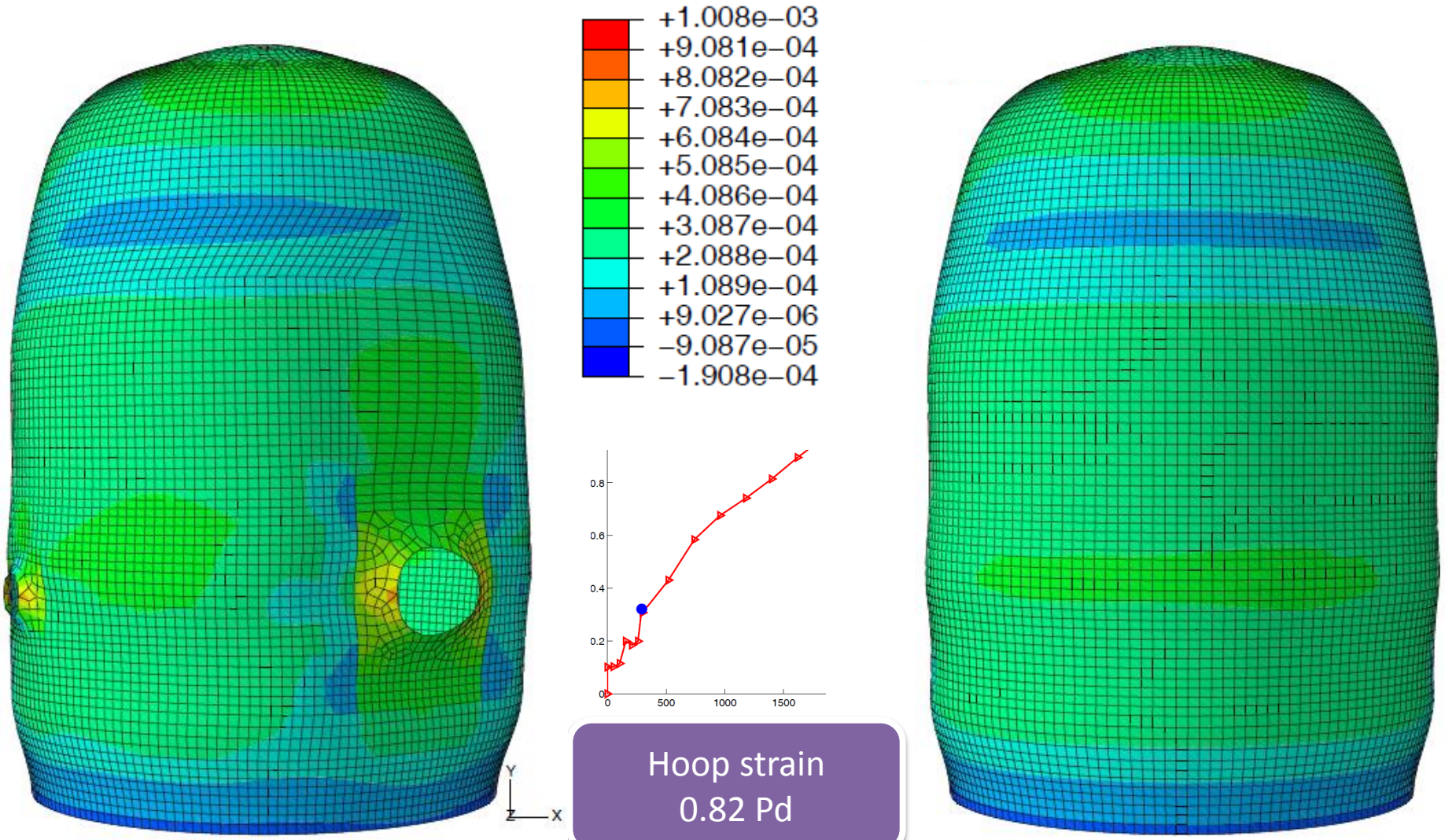


Liner strain contours



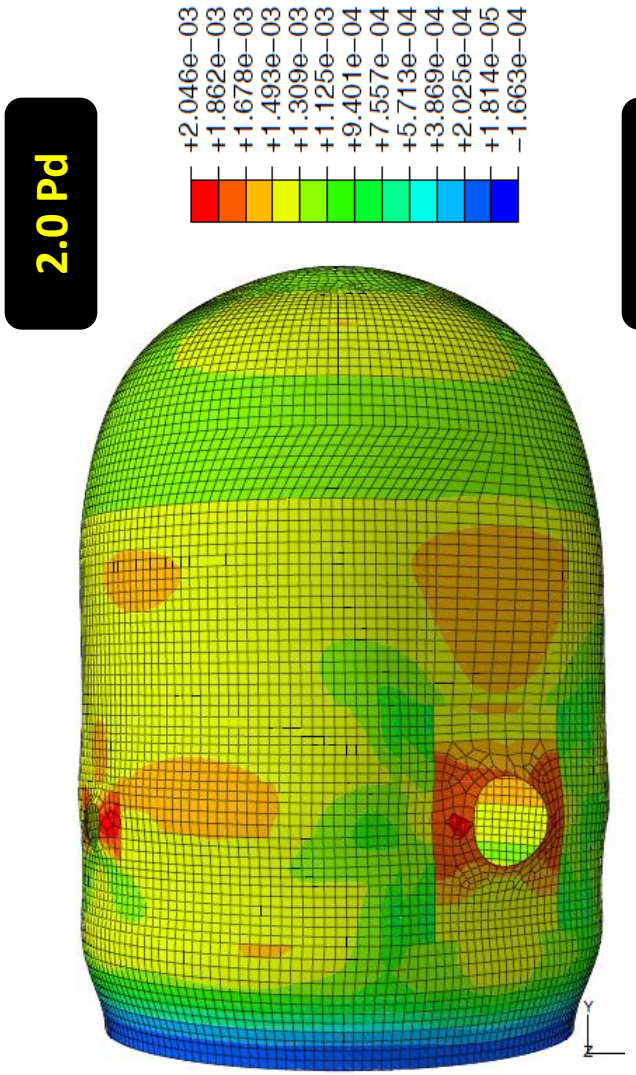
Hoop strain
After prestress

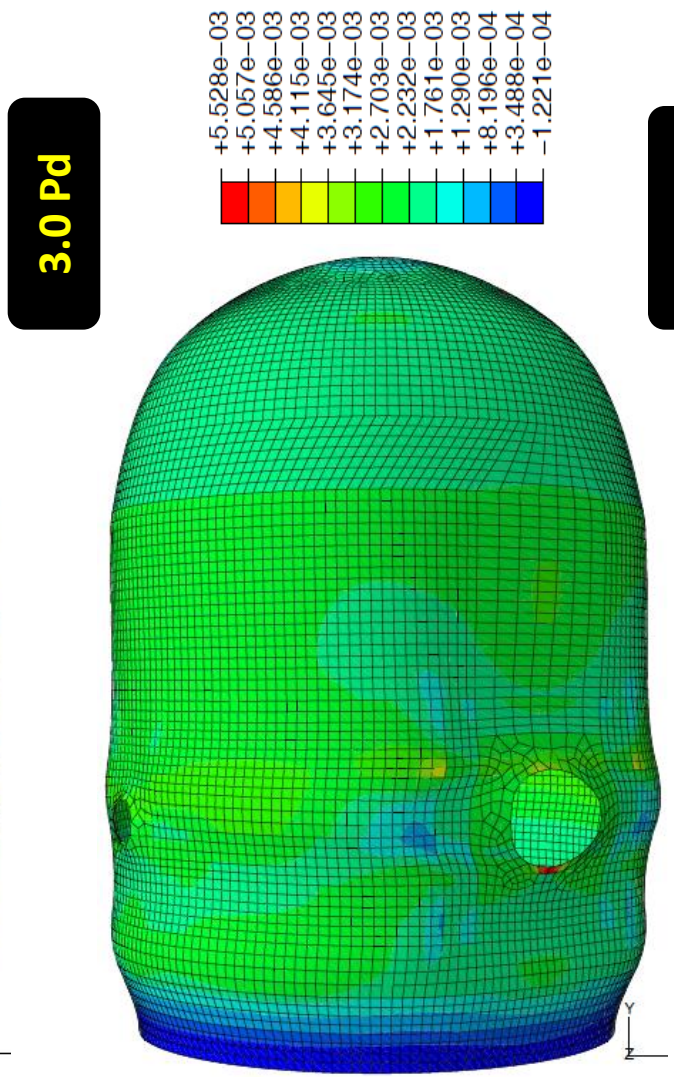
Liner strain contours

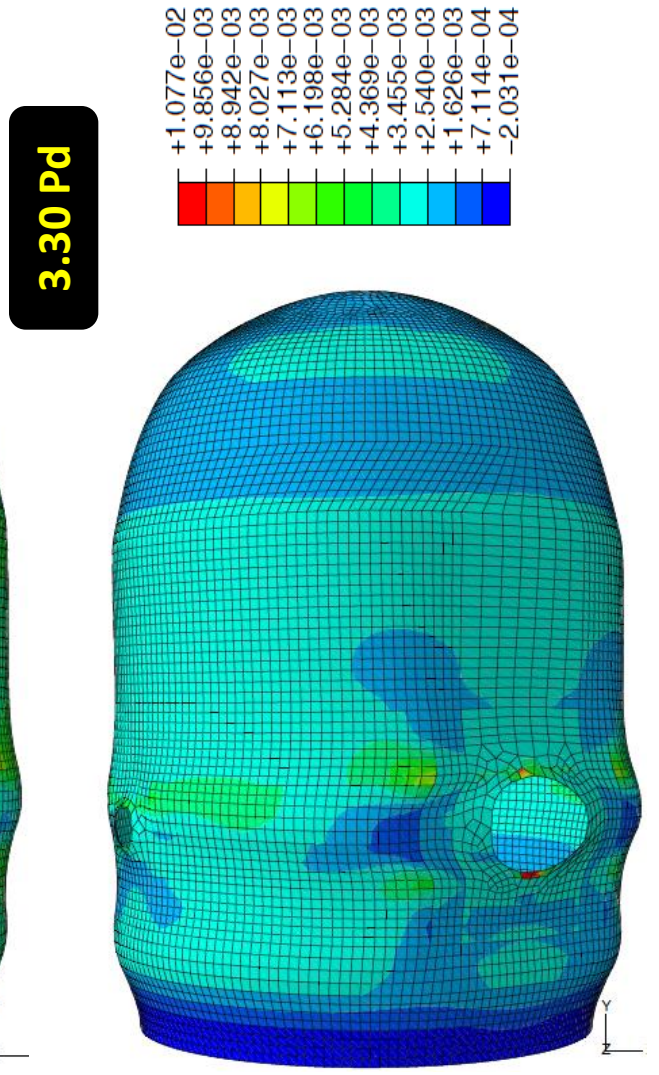


Hoop strain
0.82 Pd

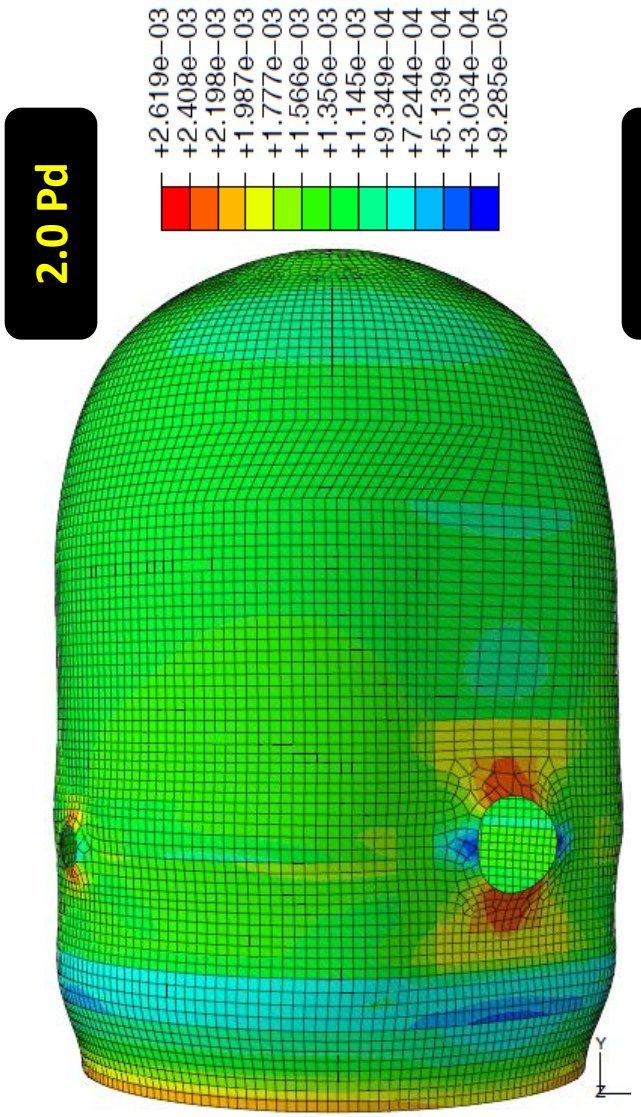
Liner strain contours - Hoop

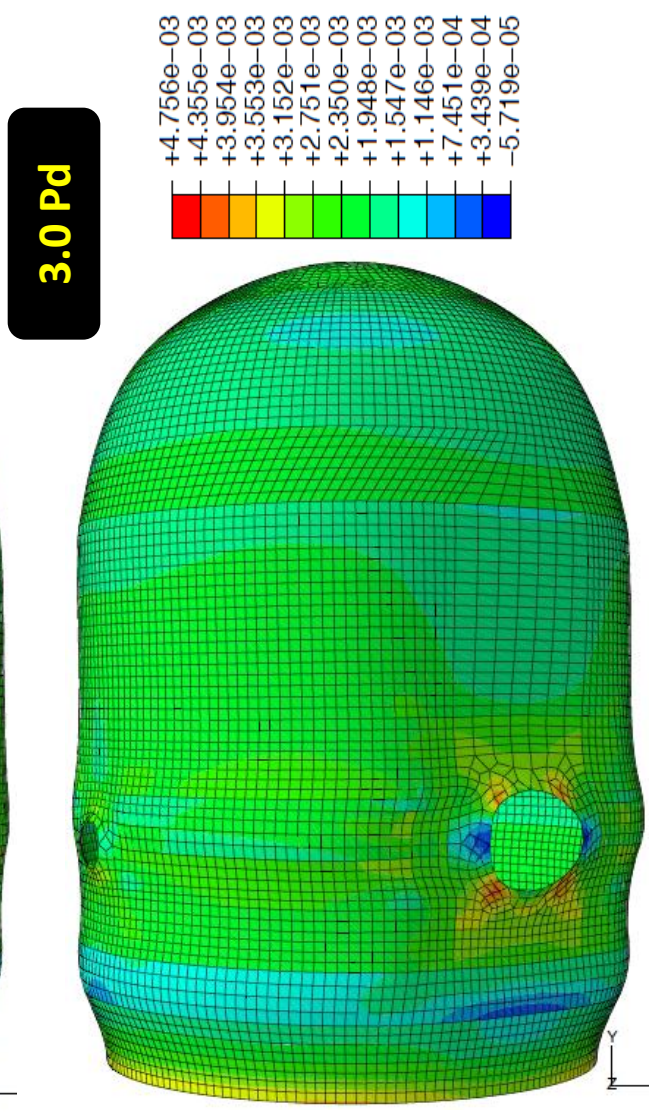


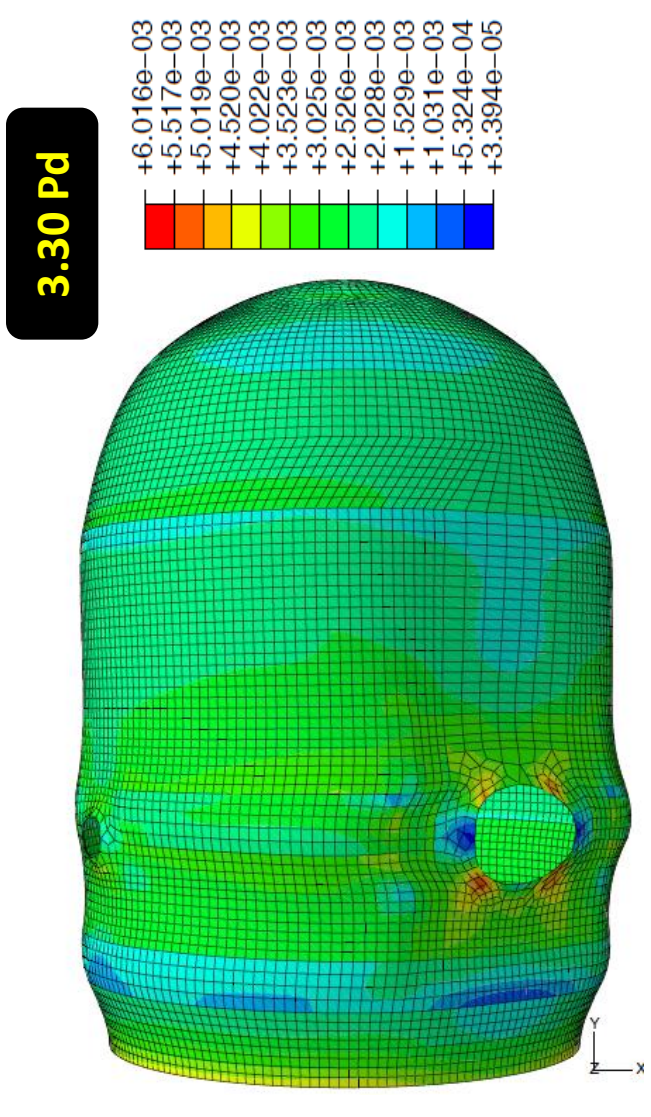




Liner strain contours - meridional

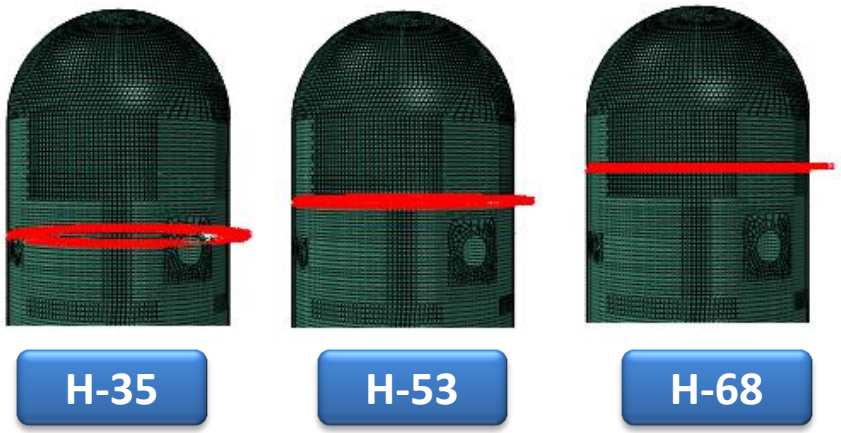


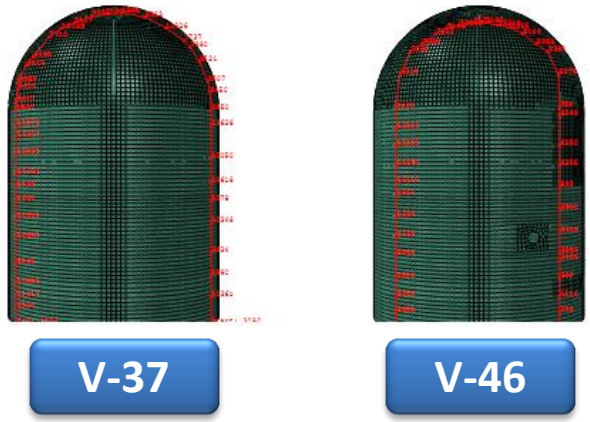




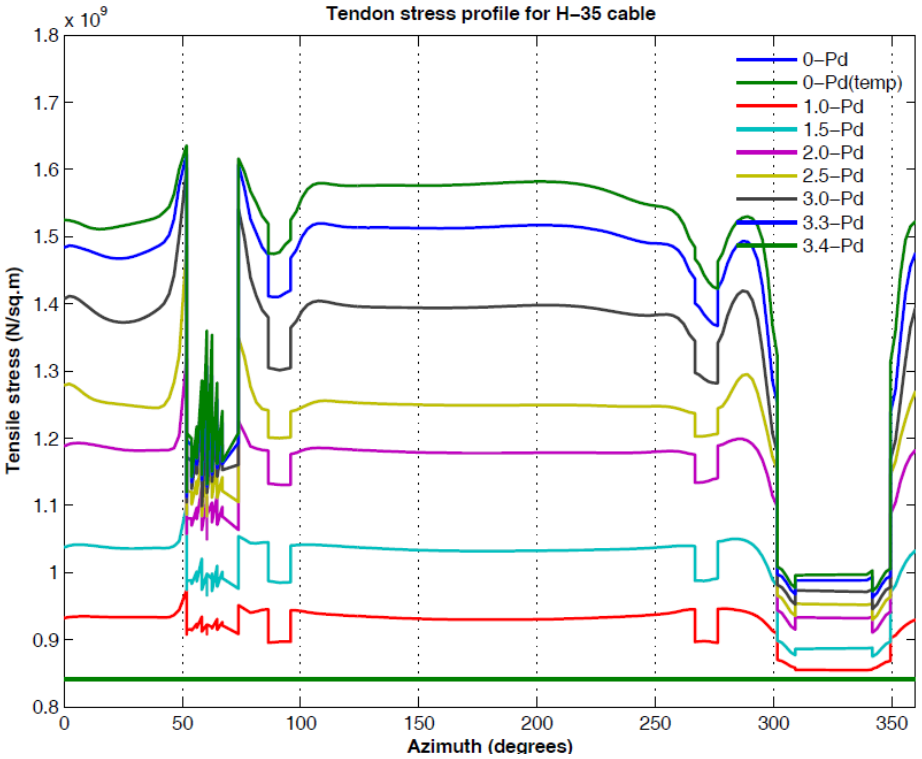
Tendon stress profile

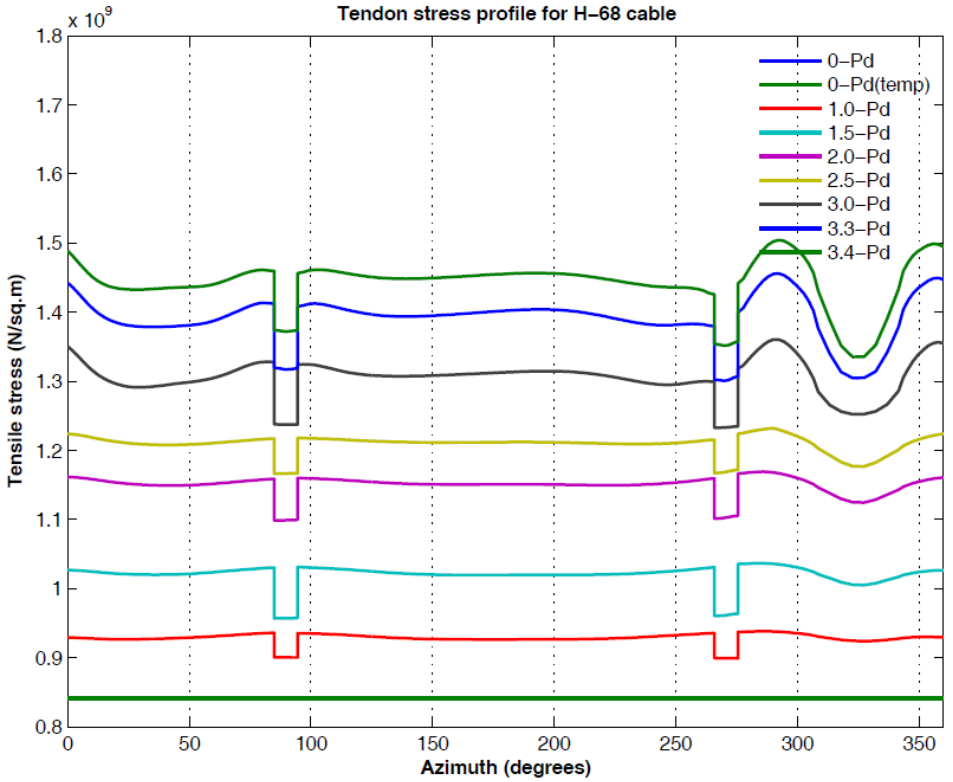
- Tendons not modeled individually
- Stress at tendon layer at the level of specified tendon
- Path for each tendon



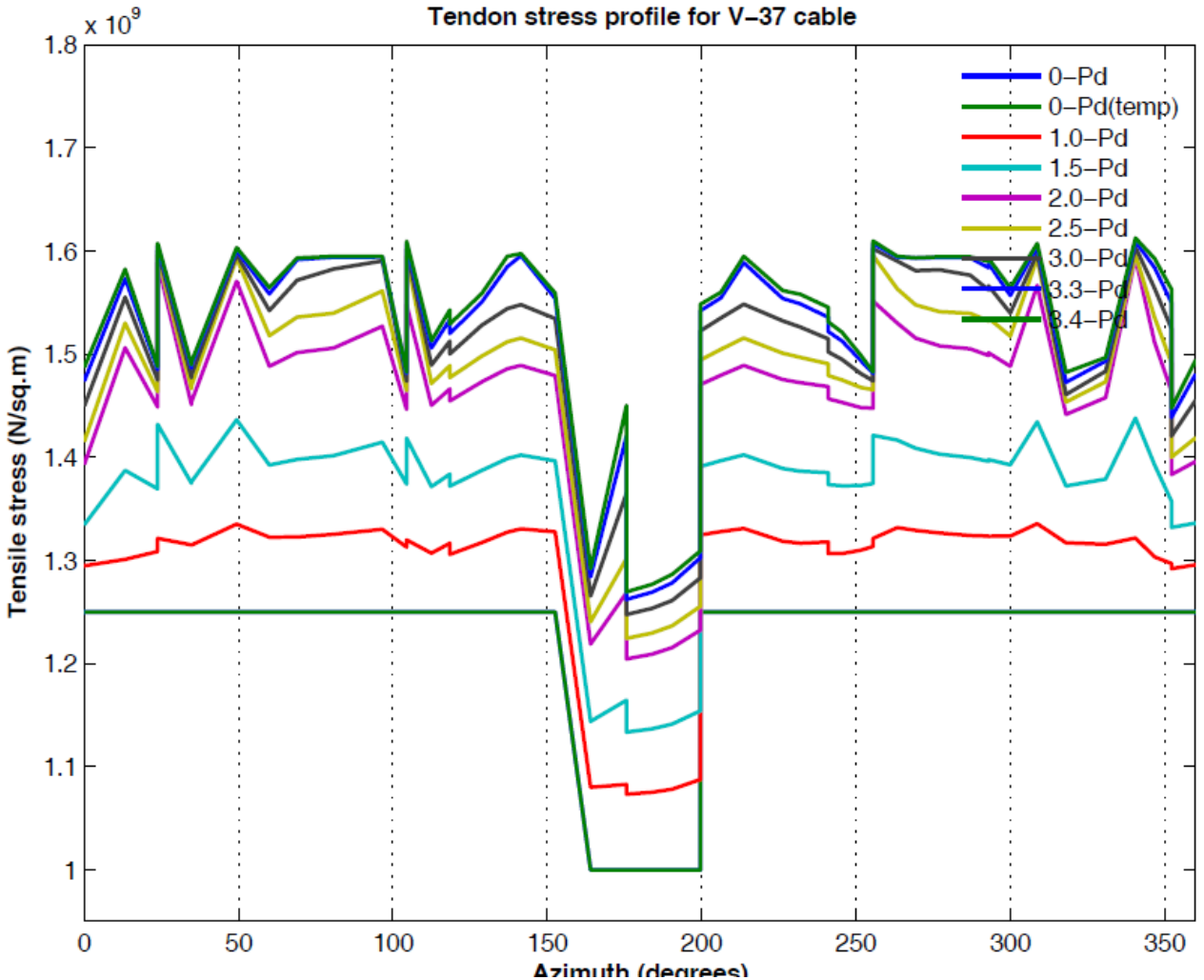


Tendon stress profile



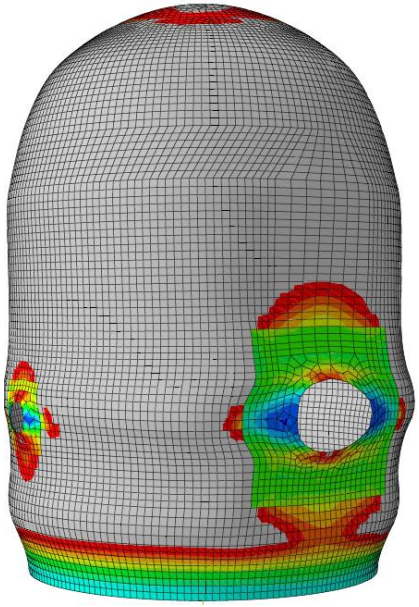


Tendon stress profile

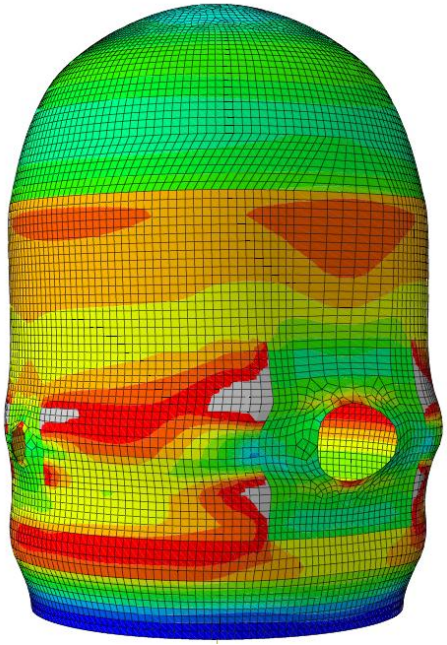


Ultimate capacity

Stress in reinforcement layers

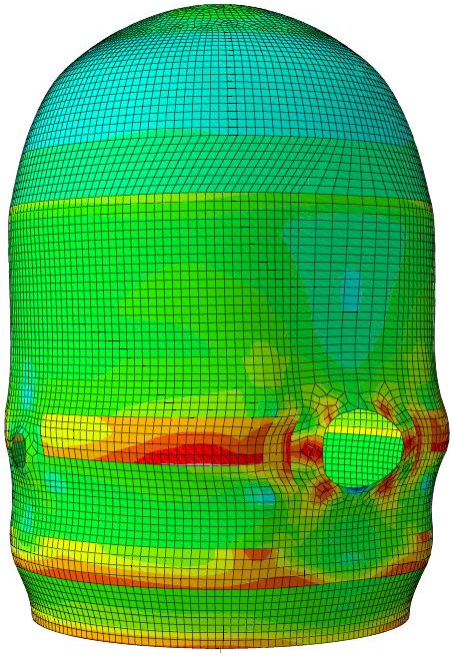


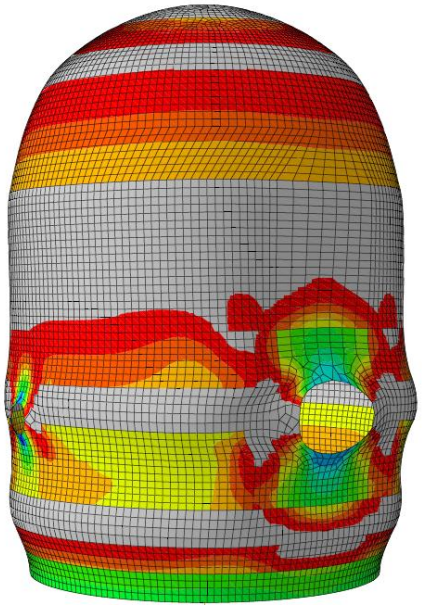
Hoop - In



Hoop - Out

Mer - In

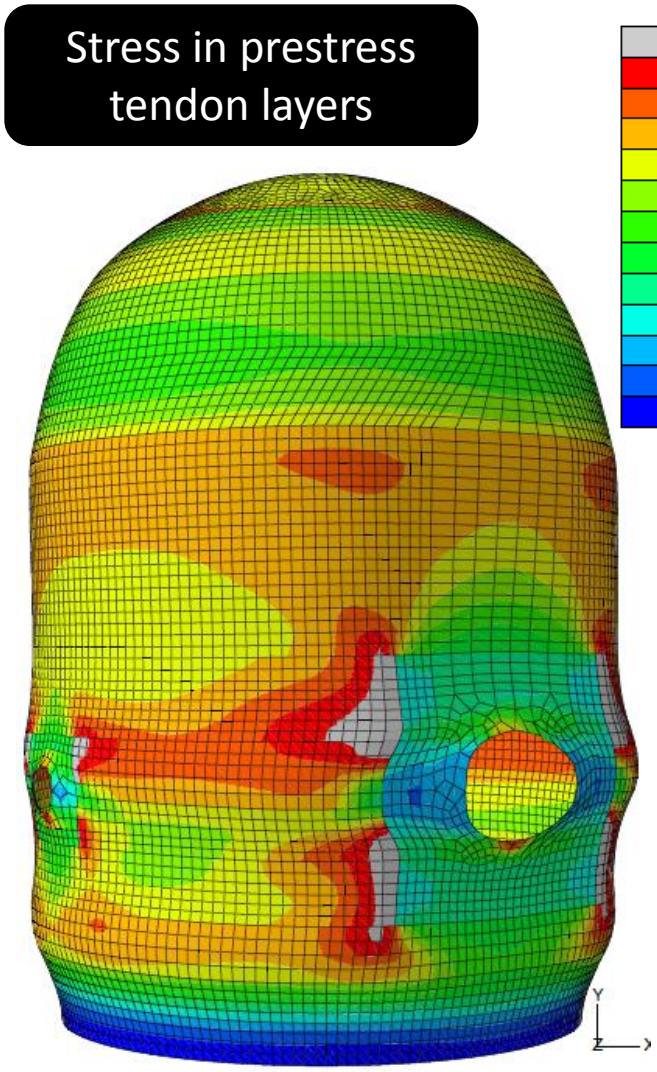




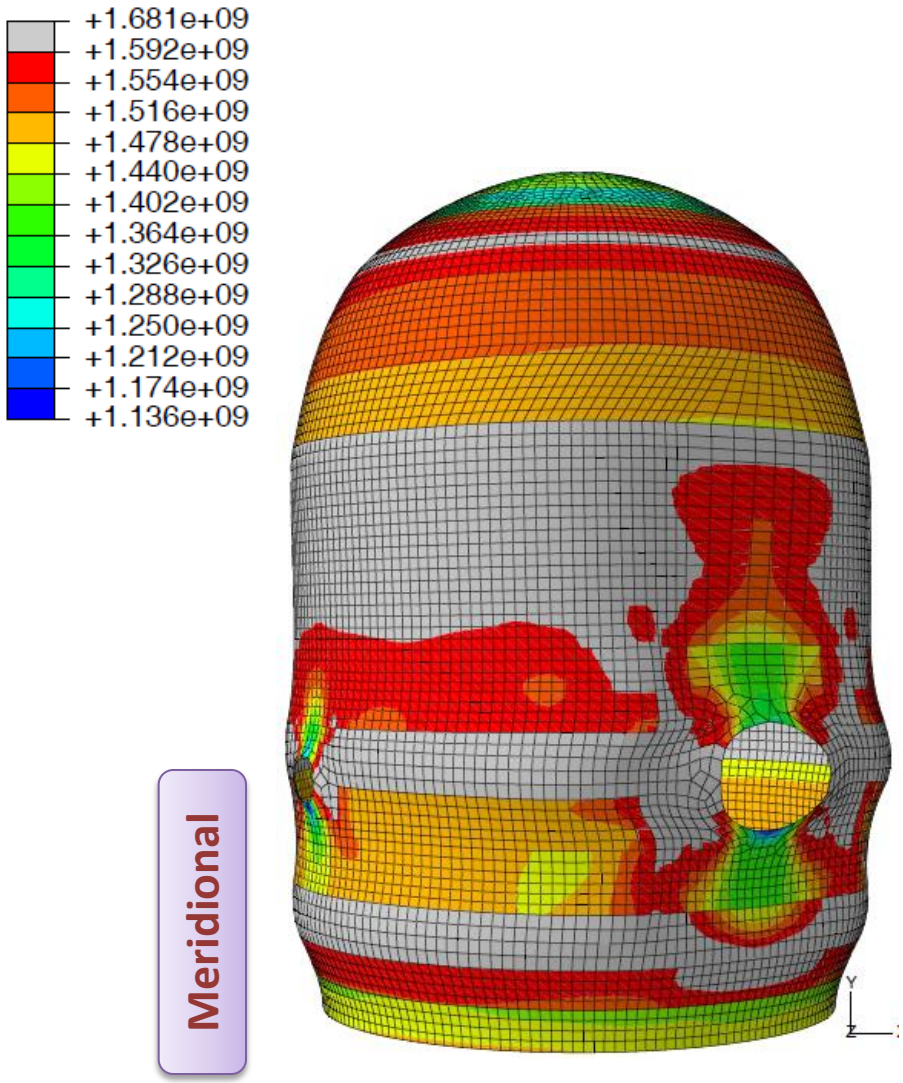
Mer - Out

Ultimate capacity

Stress in prestress tendon layers



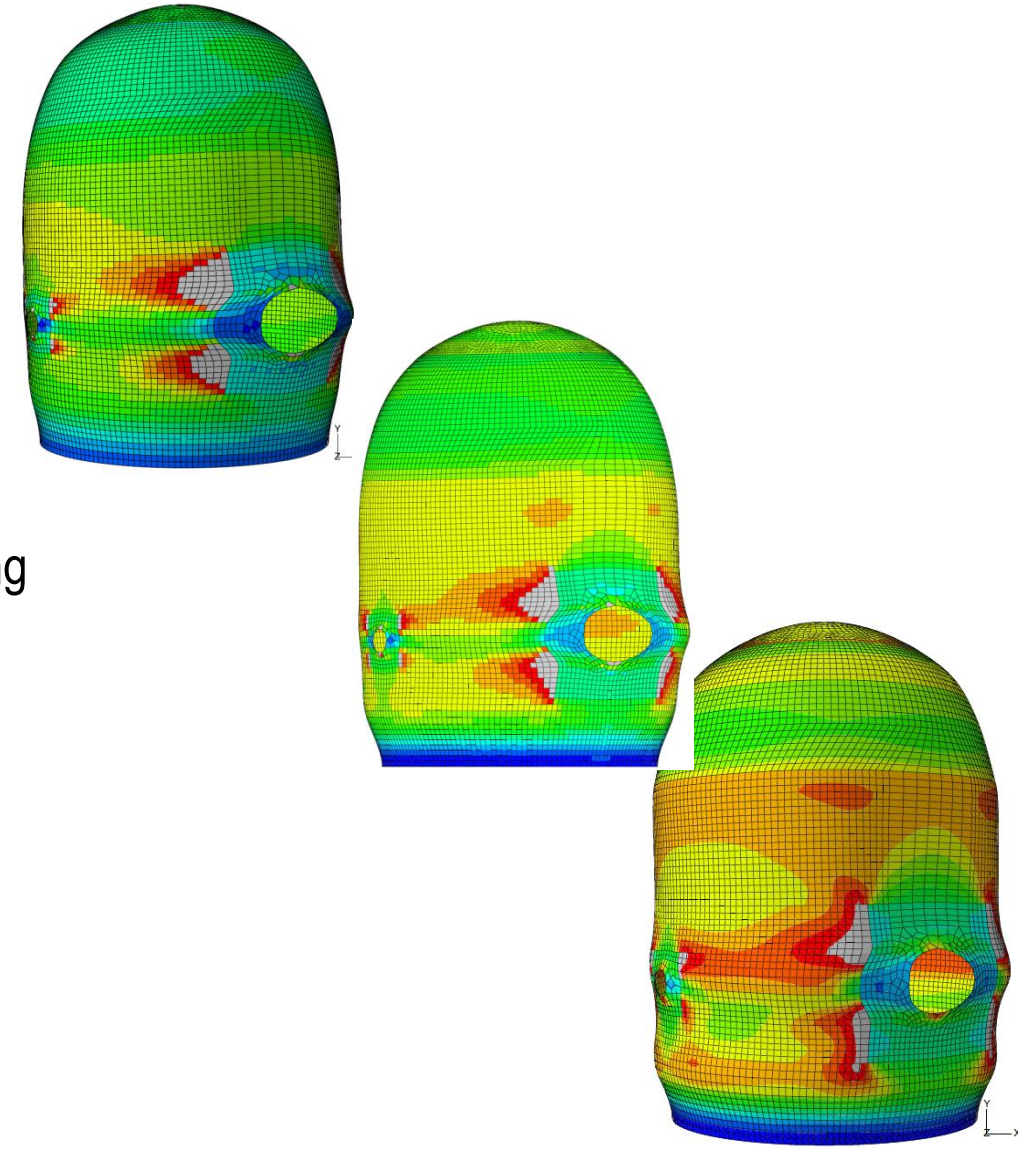
Hoop



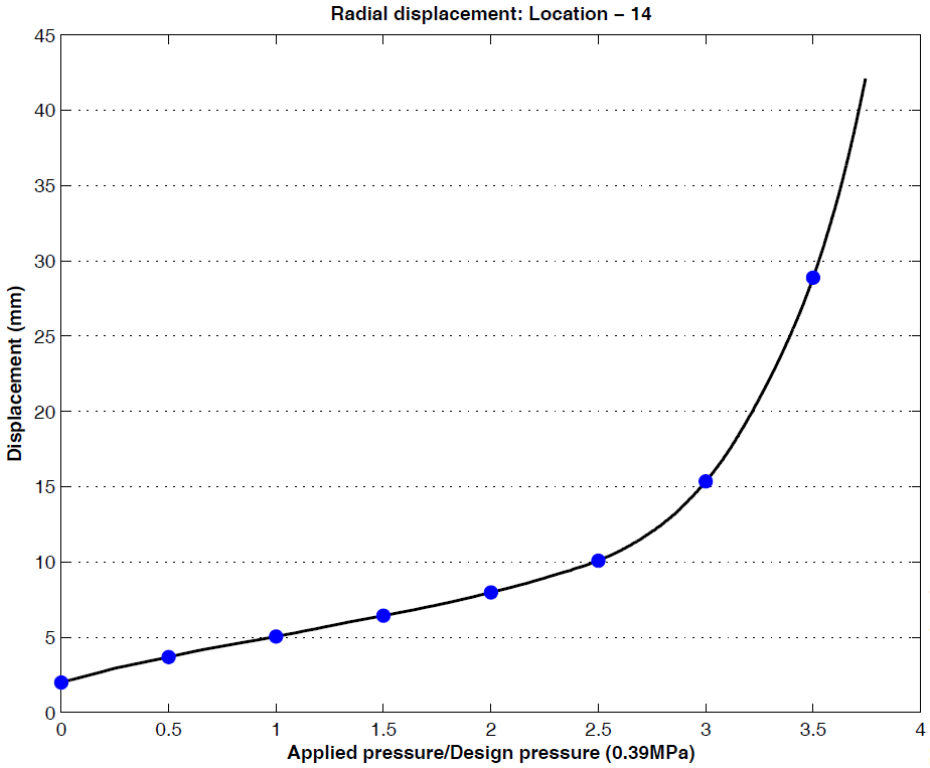
Meridional

Summary

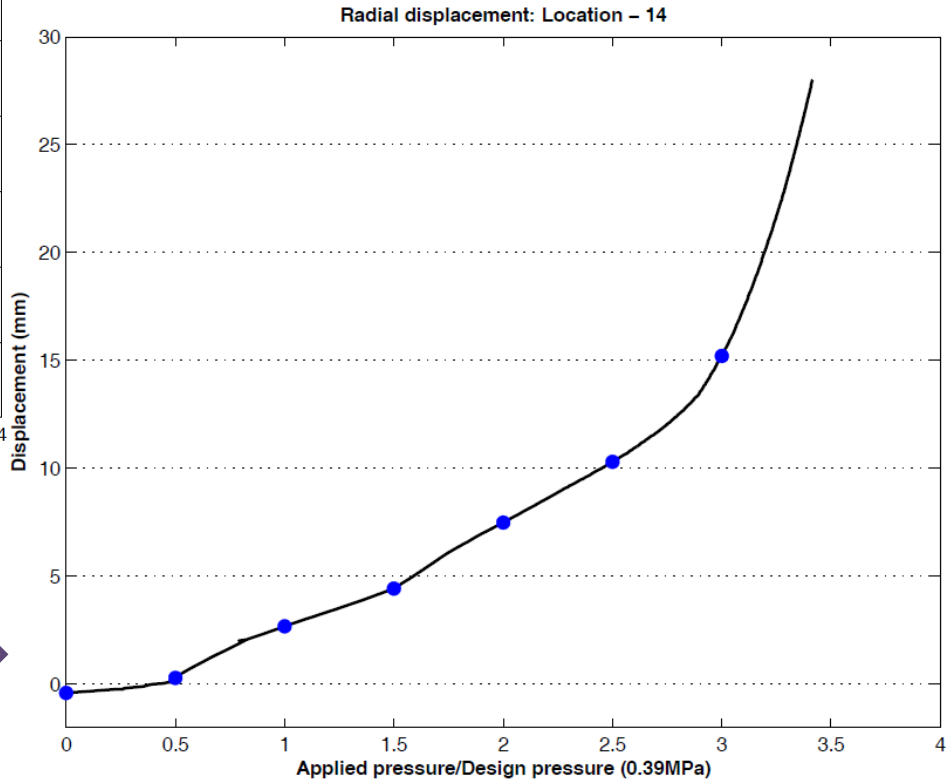
- Comparison of results with case1
  - Ultimate capacity
    - Phase – 1: 3.65 x P_d
    - Case - 1: 3.46 x P_d
    - Case – 2: 3.30 x P_d
  - Displacement at E/H and A/L opening
  - Liner strain contour
  - Tendon stress profile



Displacement comparison: E/H opening

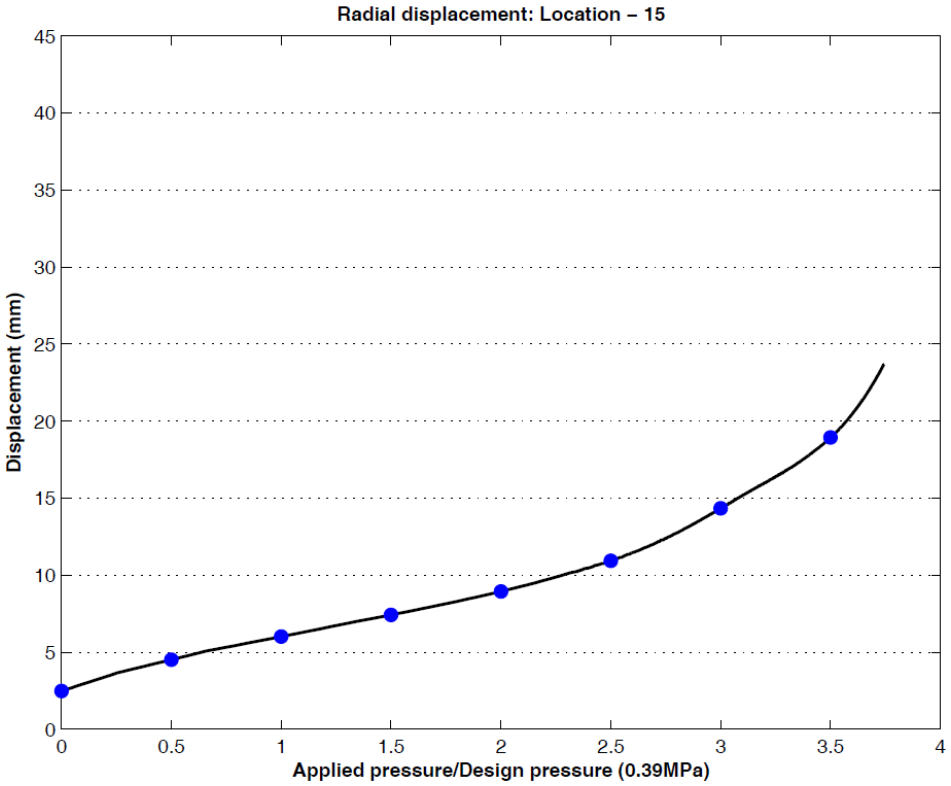


Case-1



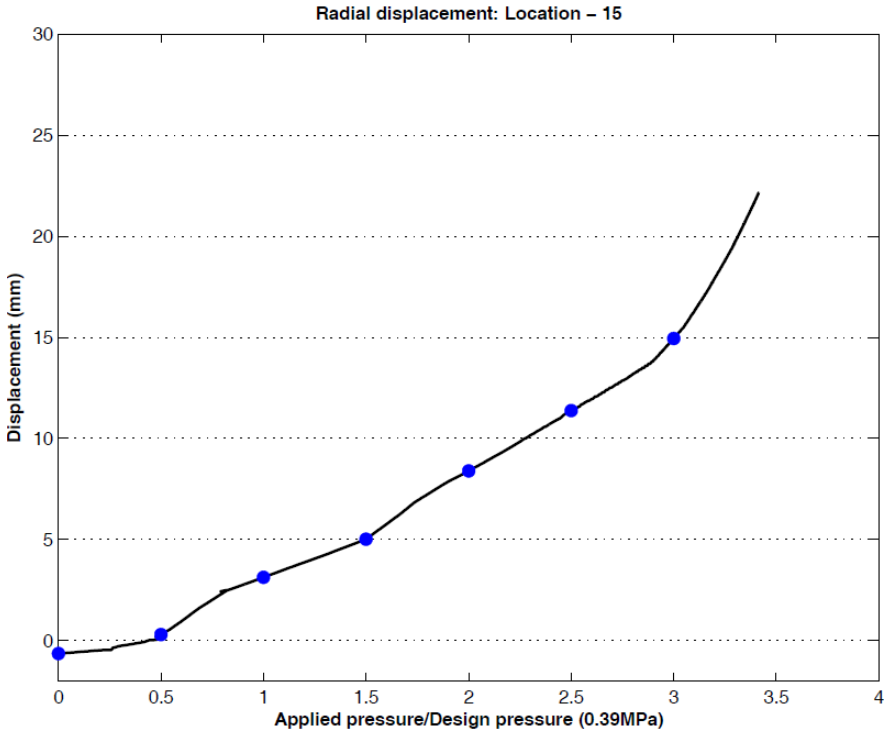
Case-2

Displacement comparison: A/L opening

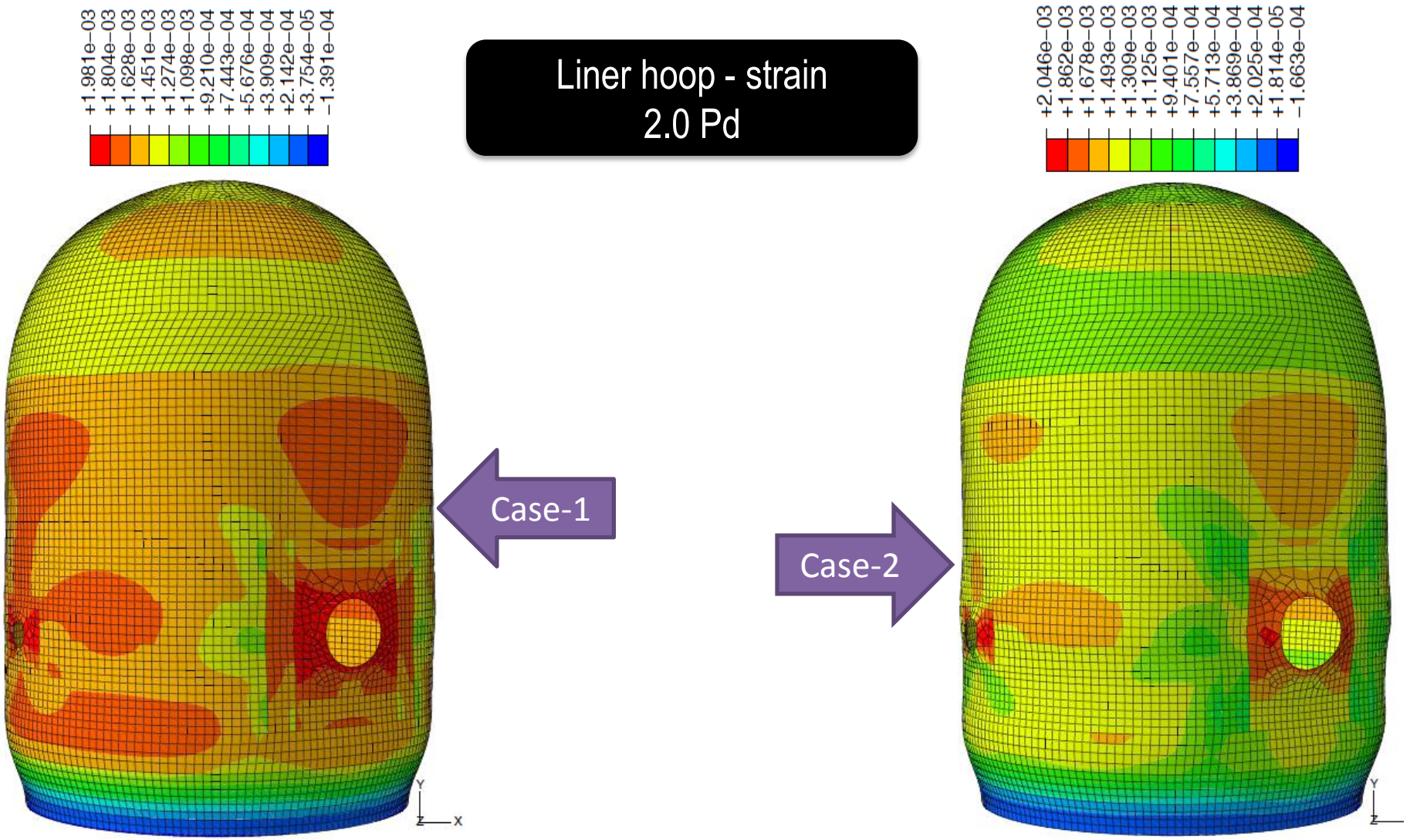


Case-1

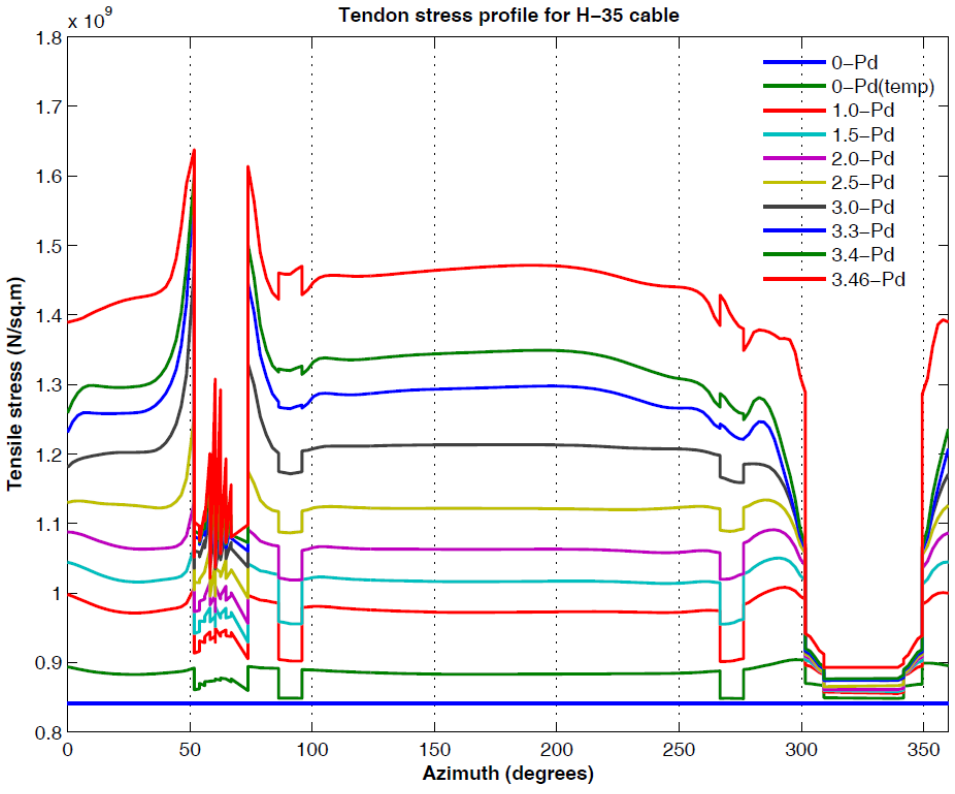
Case-2



Comparison of liner hoop strain

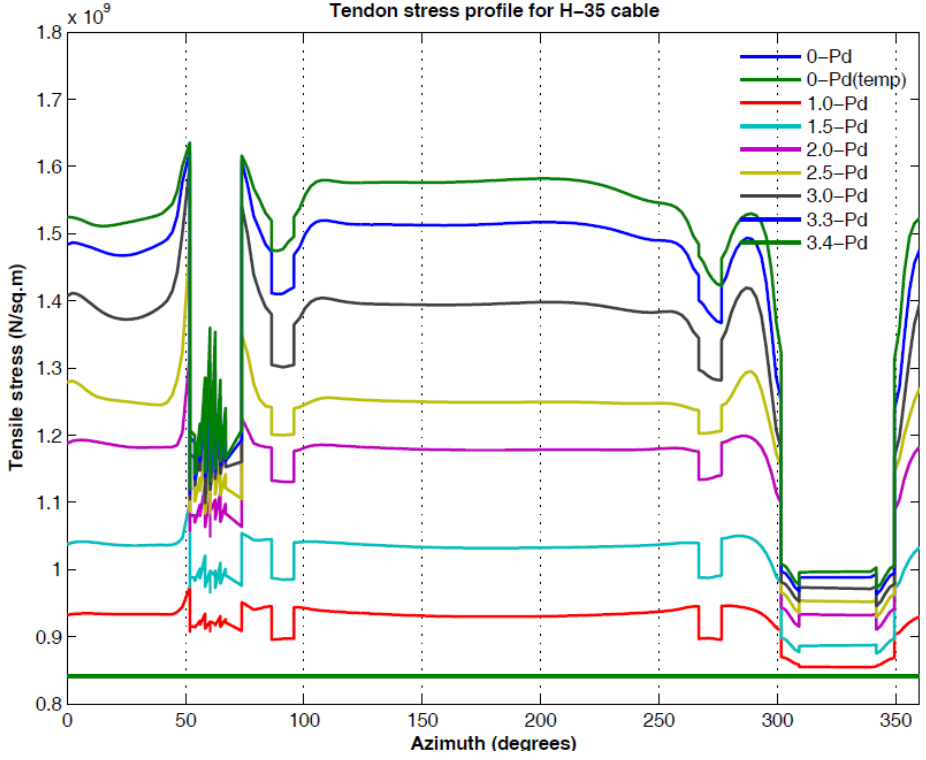


Comparison of tendon stress profile



Case-1

Case-2



Certain refinements planned for future

- The variation of tendon force along its length could not be included in the present model
- The mapping of strain in the developed view of the model could not be carried out
- Studies planned to be reattempted
  - Model -1 study of phase-1
  - Fracture mechanics studies with model - 2


Thank You