2013

FEA of Tank with a Hole

DHARMIT THAKORE

MOONISH ENT PTY LTD |

Executive Summary

The objective of the project was to study the effect of self-weight on a 30m Diameter 10m high Carbon Steel empty Tank from which a 3m wide x 2.5m high sheet is removed.

Only self-weight of the tank was considered in this study. All other external loads viz. Wind Loading, Seismic loading were ignored for this study.

Open Source Software Salome was used for 3D modelling and Post Processing of results. Open Source Software Code_Aster was used for performing FEA analysis.

Cutting a 3m x 2.5m sheet from the empty tank will generate negligible stress and strain in the tank.

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Introduction

Client wanted to cut out a strake of metal sheet from an existing Tank and replace it with new one as the original was heavily corroded. The task required for this assignment was to calculate the deflection and Stresses in the tank after the metal sheet was removed.

Finite element analysis was carried out for this exercise to evaluate if the stresses in the tank after the strake was cut out would be within elastic limit or will it go above the elastic limit and will the tank yield. Deflection of the portion of the tank from where the metal strake was to be removed was also of importance as if the deflection was excessive, it would be hard for the repair crew to install replacement metal strake.

To accomplish above task, Linear Static Finite Element Analysis was carried out to calculate the deflection and stresses in Tank.

Model Geometry

For this analysis, a 3D model was used which was created in Salome Geometry module. To study the impact of the use of Symmetry in the model another model with only half of the tank was also generated for comparision.

Only 3D model was used as applying gravity loads on shell elements would not give satisfactory results.

Dimensions of the tank are as follows

OD of Tank:	30000mm (30m)
Thickness of Tank:	10mm (0.01m)
Height of Tank:	10000mm (10m)
Length of Hole1 in tank:	3000mm (3m) [this equates to 12°]

Some other holes were also cut in the tank to perform comparative study

Hole2 in Tank:	45°
Hole3 in Tank:	90°
Hole4 in Tank:	180°
Hole5 in Tank:	225°
Hole6 in Tank:	270°
Hole7 in Tank:	315°

Mesh

For meshing the geometry Automatic Tetrahedralisation Algorithm was used with 1D average length of 500. No additional mesh controls or mesh refinements were applied to this mesh.

This mesh was adequate for the first pass study of this analysis.

Loads and Restraints

For Whole tank (without hole cut and with hole cut) had only 1 boundary condition at the bottom of the tank. The bottom face of the tank was given DX, DY, DZ = 0.0 constraint.

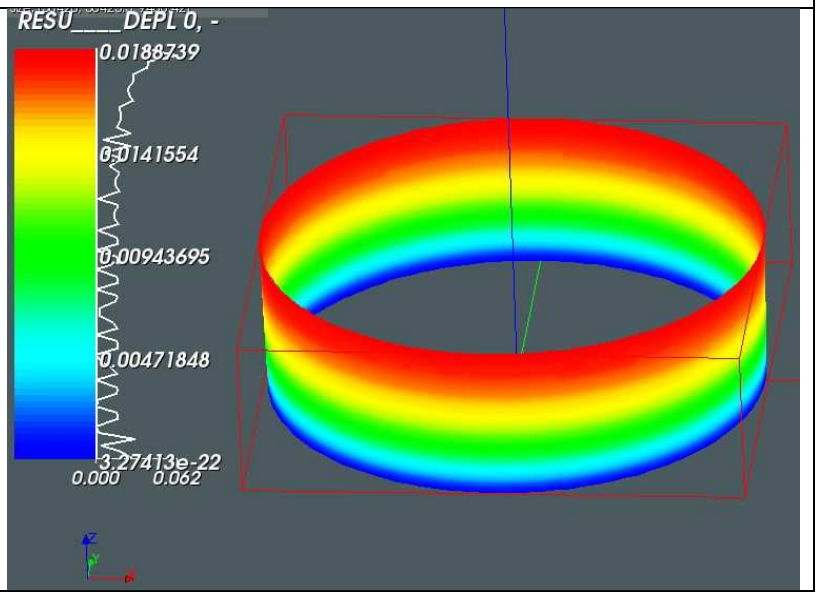
For Half tank (without hole cut and with hole cut) had 2 boundary conditions, one at the bottom of the tank and other on two vertical faces at the half geometry. The bottom face of the tank was given DX, DY, DZ = 0.0 and the two vertical faces were given DX = 0.0.

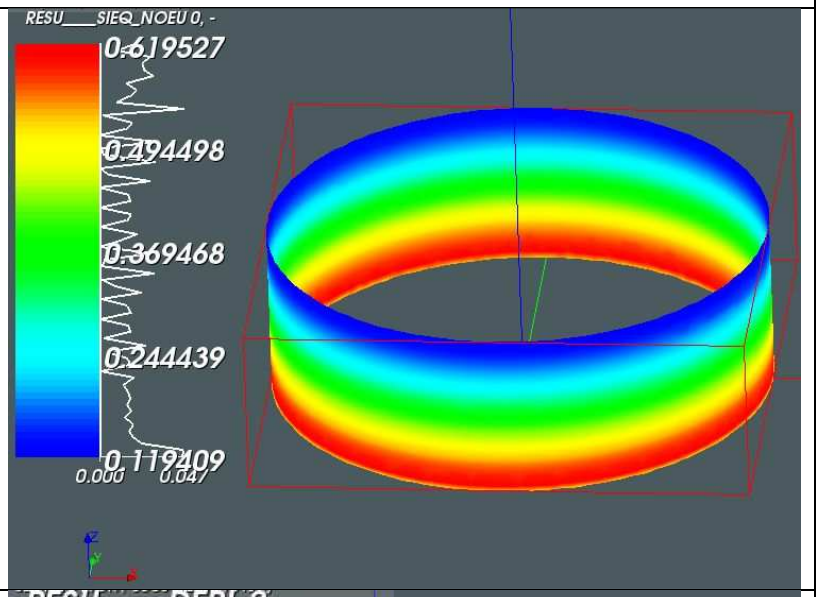
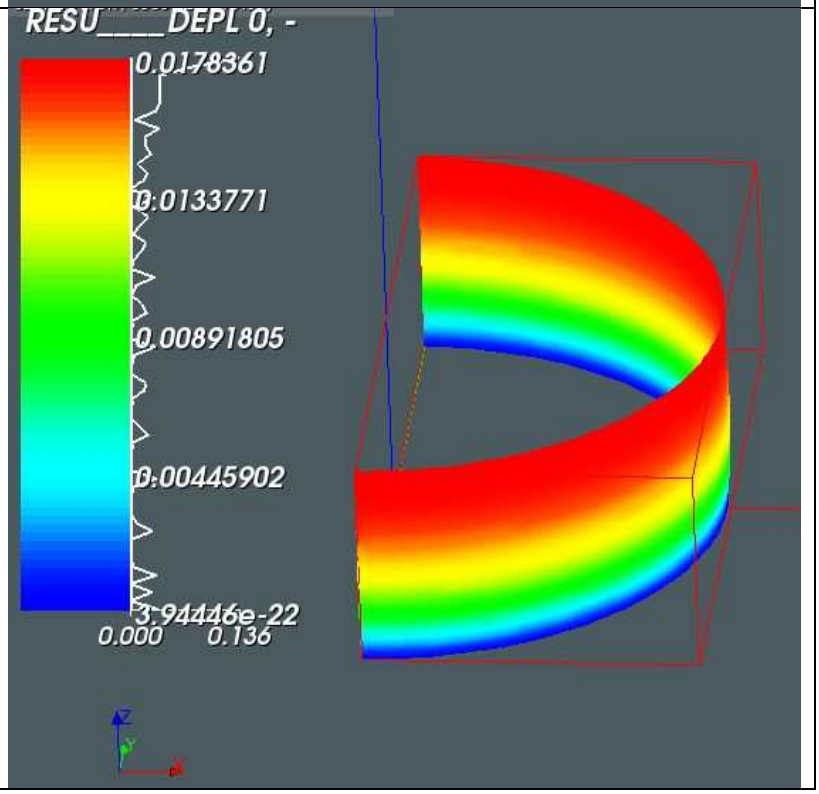
The entire study was conducted to find out the stresses due to self-weight of the cut hole in the tank. Only Gravity load of 9800 mm/s^2 was applied on the entire geometry (3D volume)

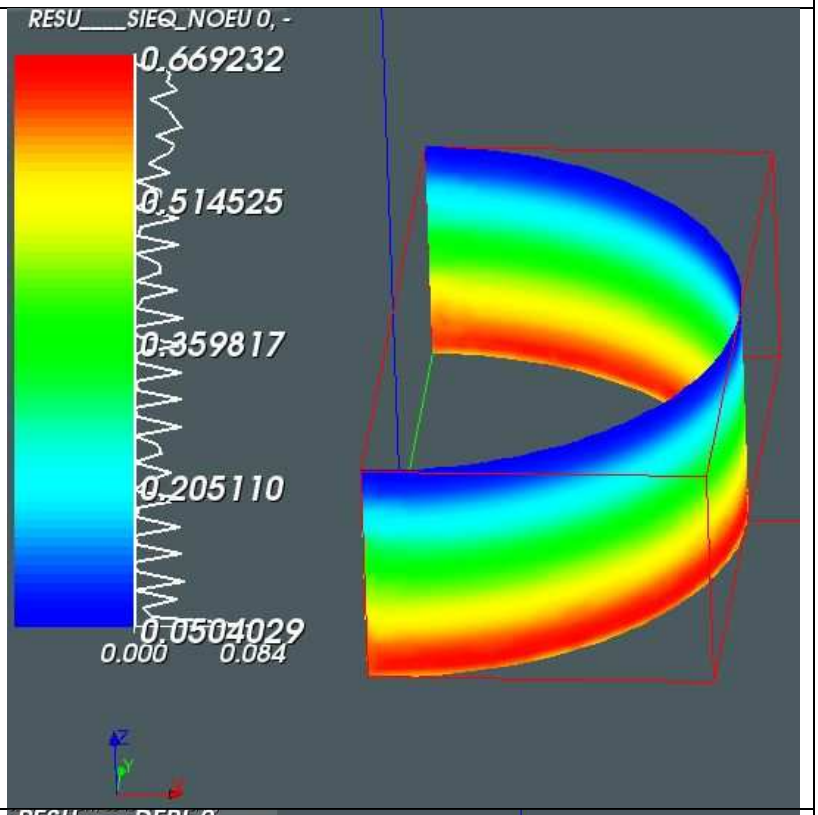
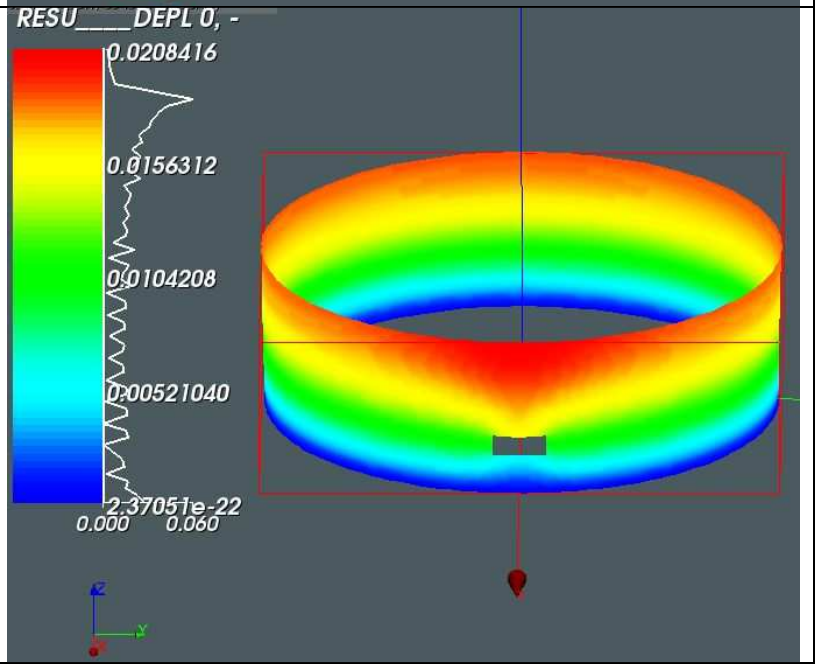
Analysis of results

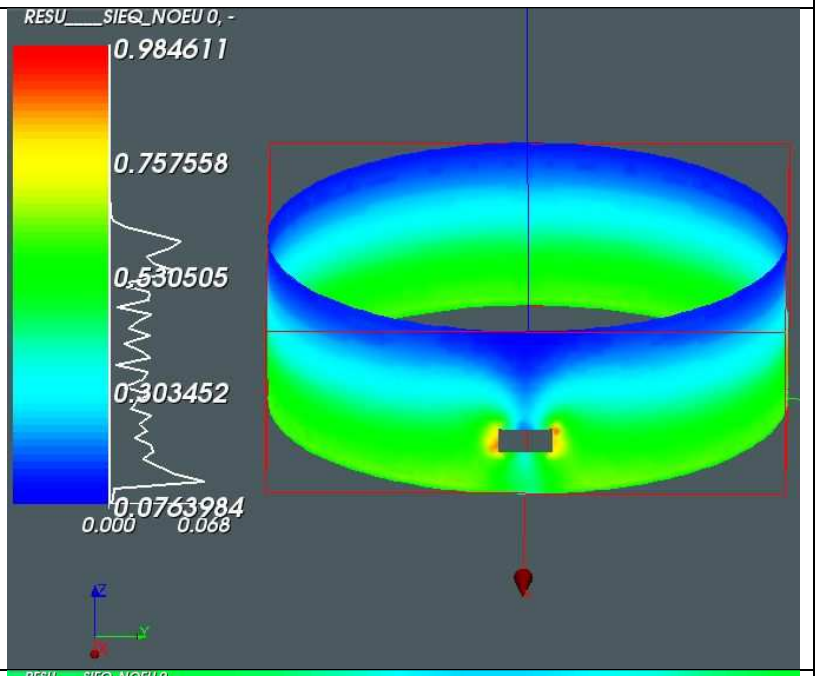
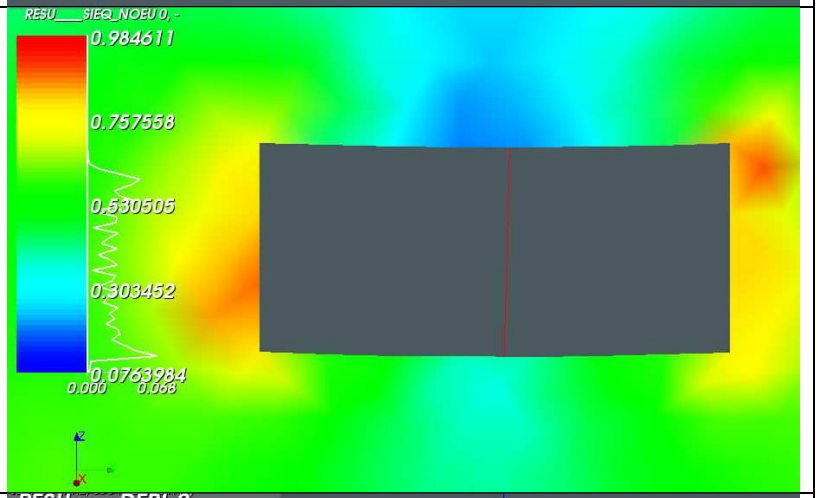
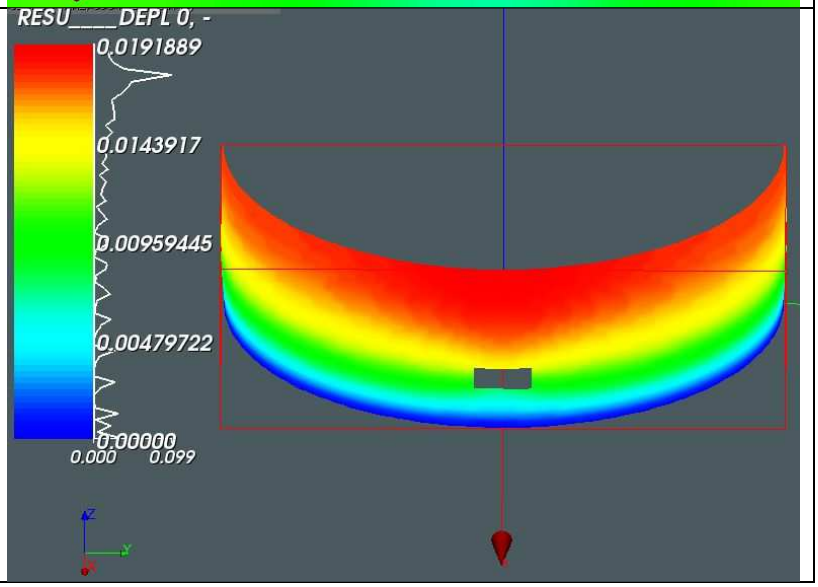
- Present the displacement and Stress results (Including plots and animation)

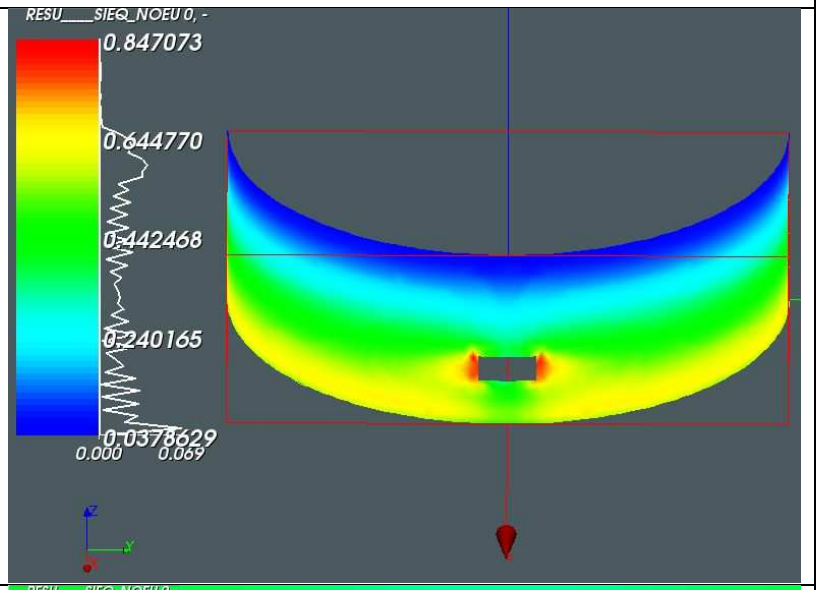
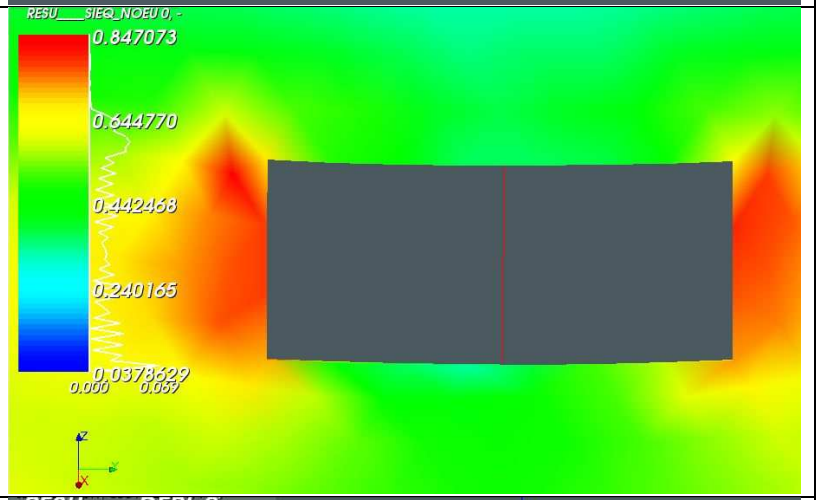
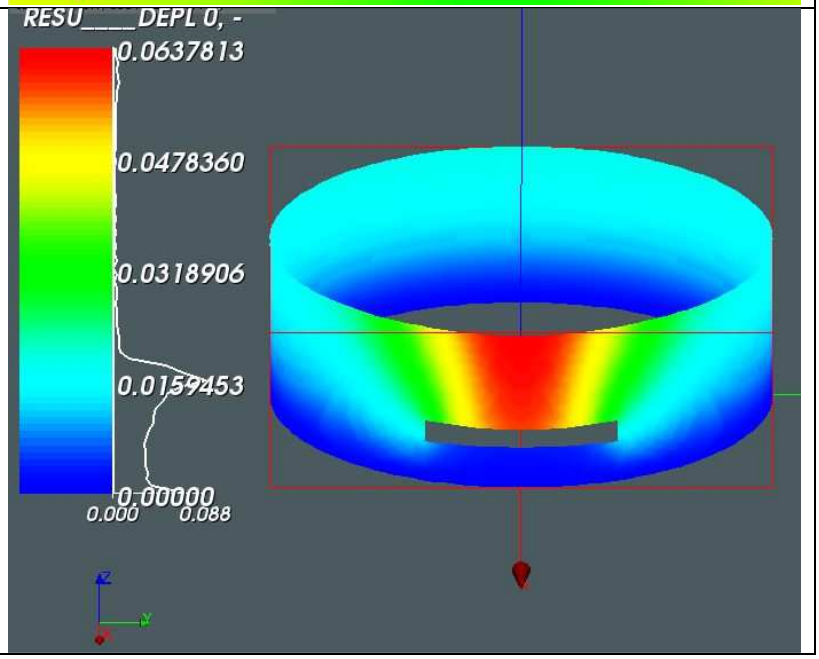
Displacement and Stress results are shown below

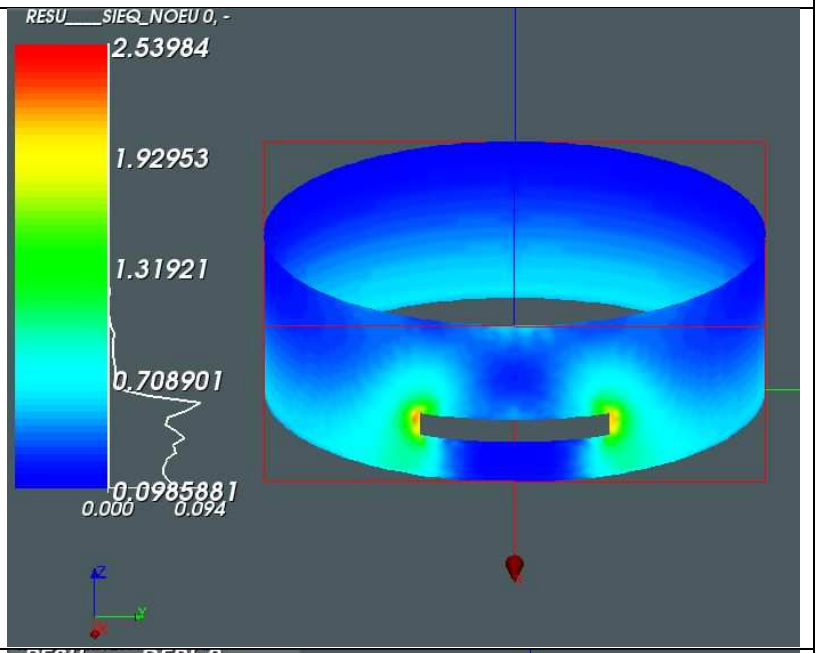
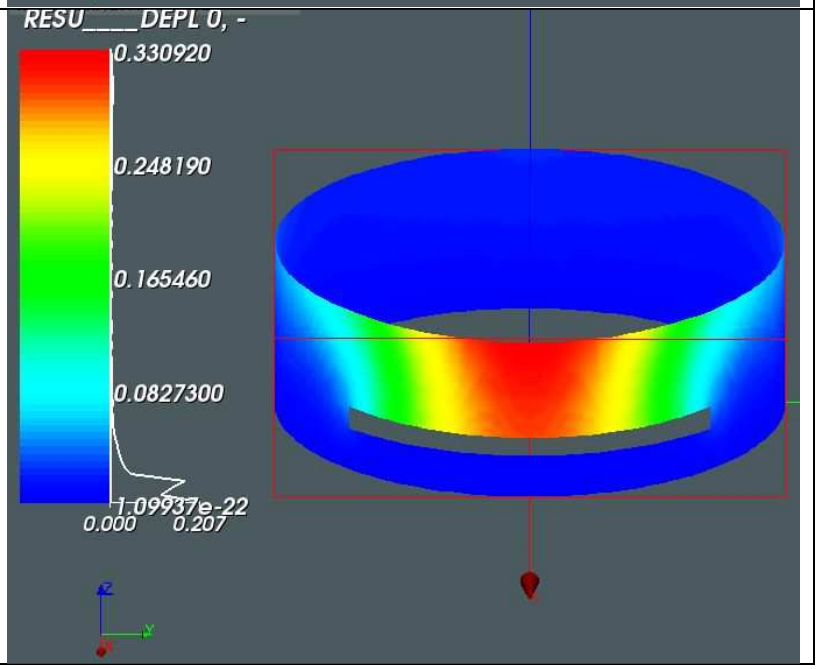
Sr No	Details	Snapshot
1	Whole Tank Gravity load Max Deflection 0.0188mm	

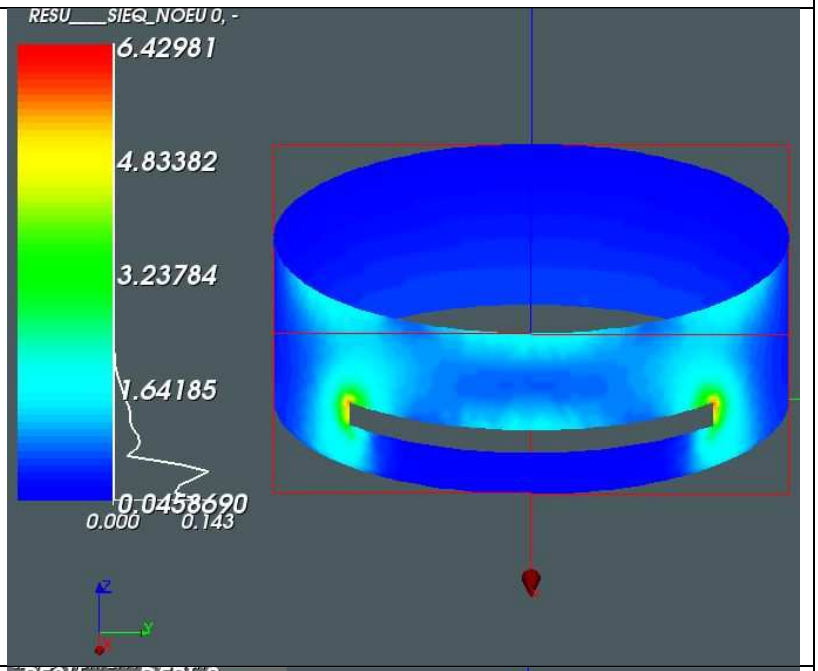
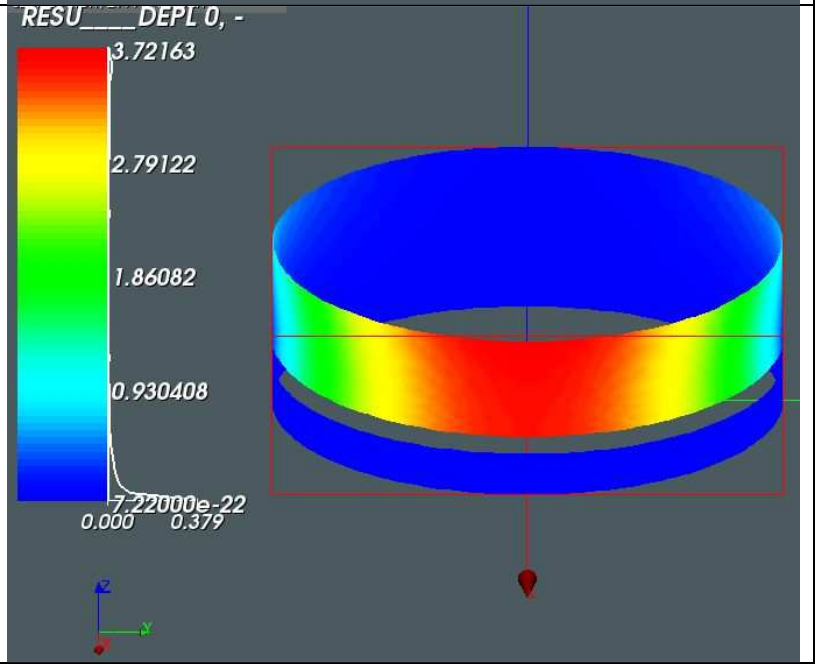
Sr No	Details	Snapshot
2	Whole Tank Gravity load Max VonMises Stress 0.6195 MPa	
3	Half Tank Gravity Load Max Deflection 0.0178 mm	

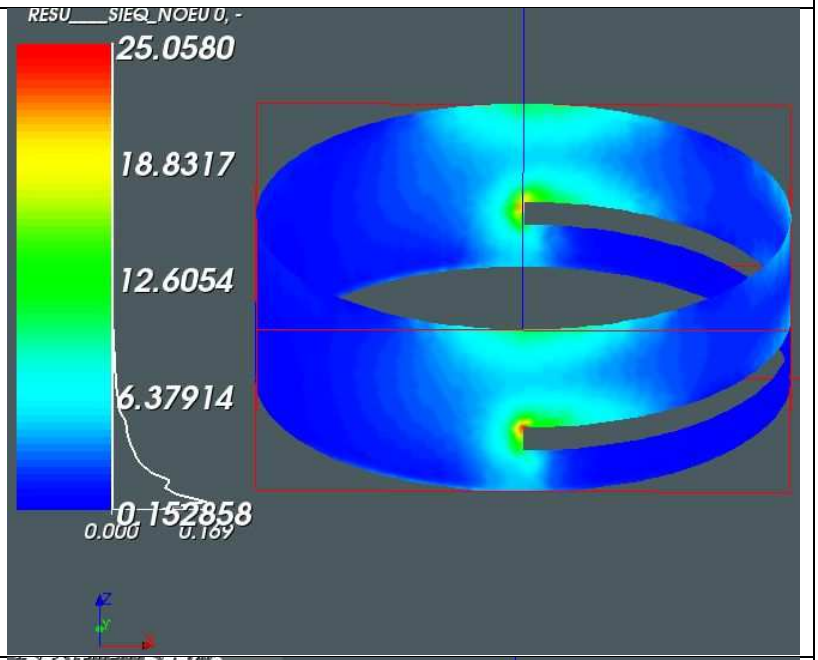
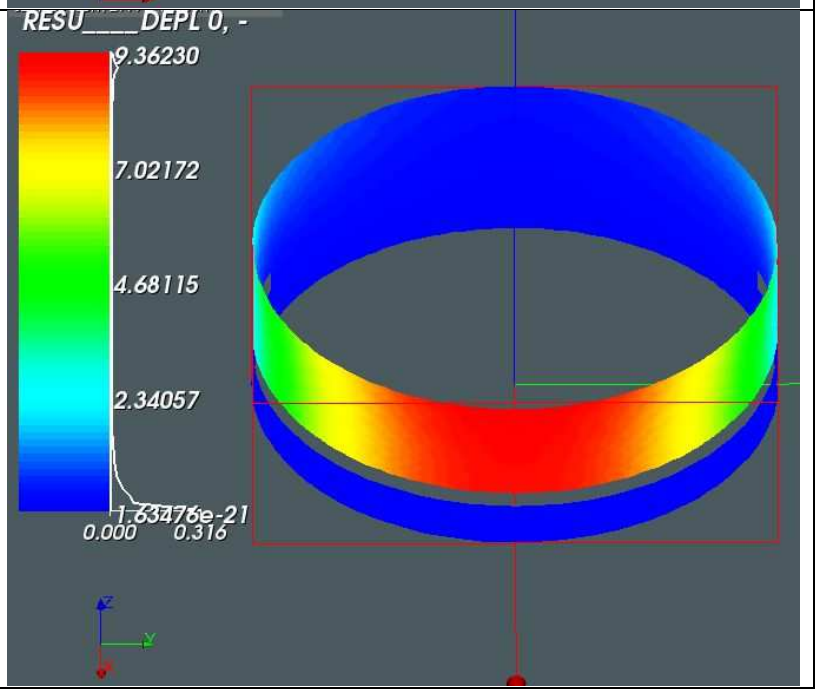
Sr No	Details	Snapshot
4	Half Tank Gravity Load Max VonMises Stress 0.6692 MPa	
5	Full Tank 3m Cut Max Deflection 0.0208 mm	

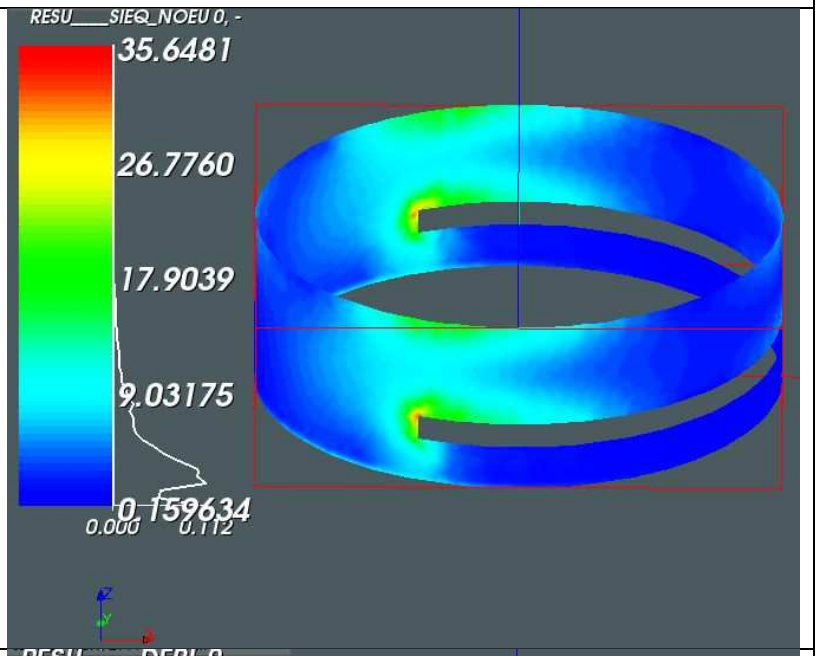
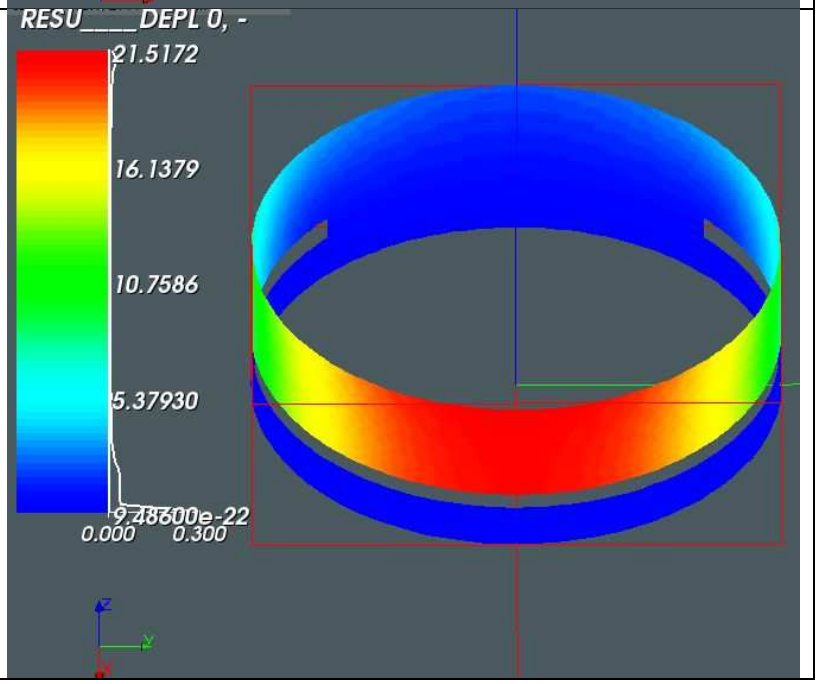
Sr No	Details	Snapshot
6	Full Tank 3m Cut Max VonMises Stress 0.9846 MPa	
7	Full Tank 3m Cut Stresses UpClose	
8	Half Tank 3m Cut Max Deflection 0.01919 mm	

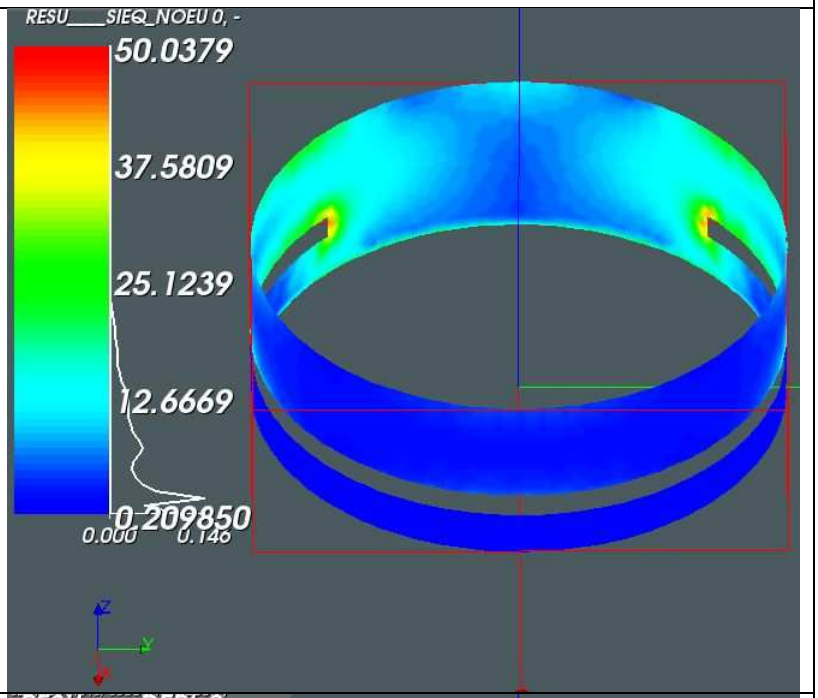
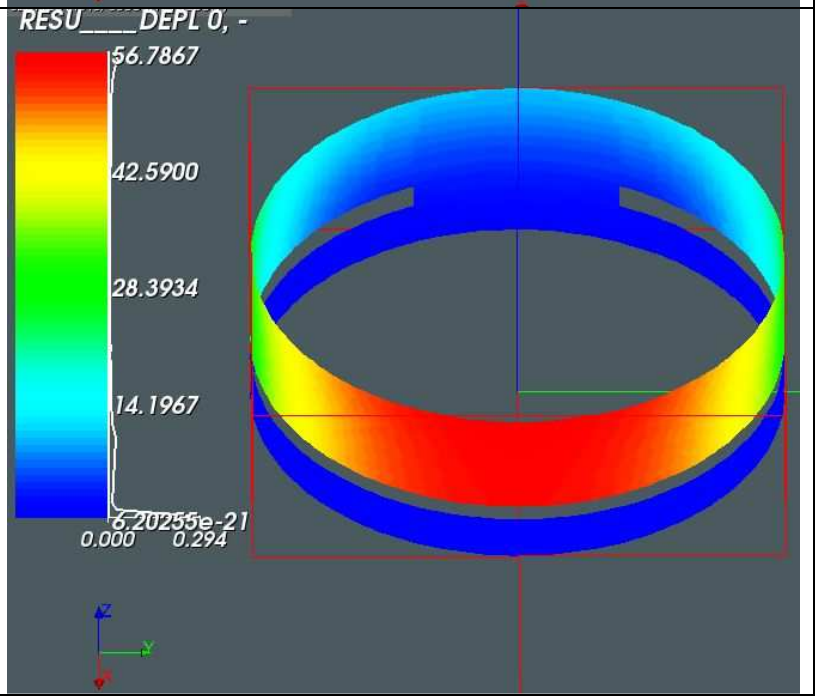
Sr No	Details	Snapshot
9	Half Tank 3m Cut Max VonMises Stress 0.847 MPa	
10	Half Tank 3m Cut UpClose	
11	Full Tank 45° Cut Max Deflection 0.0638mm	

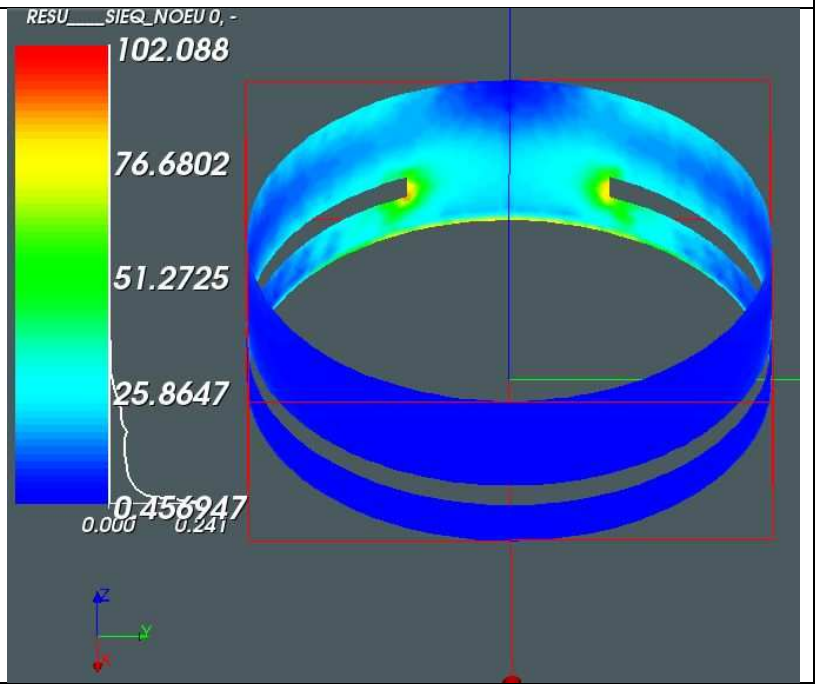
Sr No	Details	Snapshot
12	Full Tank 45° Cut Max VonMises Stress 2.539 MPa	
13	Full Tank 90° Cut Max Deflection 0.33mm	

Sr No	Details	Snapshot
14	Full Tank 90° Cut Max VonMises Stress 6.43 MPa	
15	Full Tank 180° Cut Max Deflection 3.72 mm	

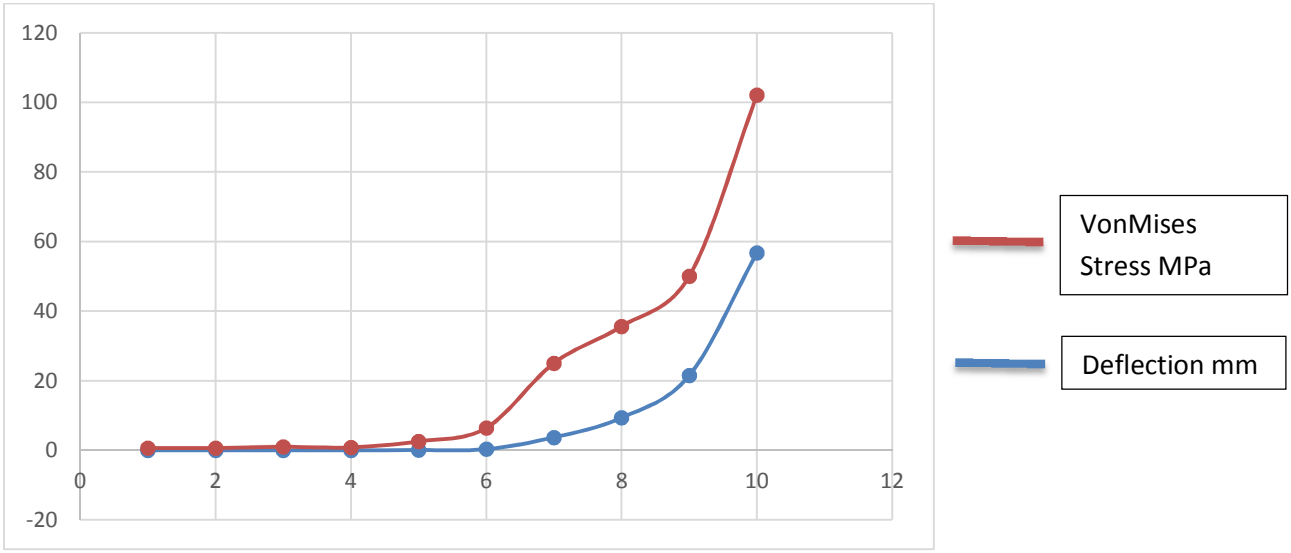
Sr No	Details	Snapshot
16	Full Tank 180° Cut Max VonMises Stress 25.05 MPa	
17	Full Tank 225° Cut Max Deflection 9.36 mm	

Sr No	Details	Snapshot
18	Full Tank 225° Cut Max VonMises Stress 35.65 MPa	
19	Full Tank 270° Cut Max Deflection 21.517 mm	

Sr No	Details	Snapshot
20	Full Tank 270° Cut Max VonMises Stress 50.038 MPa	
21	Full Tank 315° Cut Max Deflection 56.79 mm	

Sr No	Details	Snapshot
22	Full Tank 315° Cut Max VonMises Stress 102.1 MPa	

Details	Max Deflection	Max VonMises Stress
Whole Tank Gravity load	0.0188 mm	0.6195 MPa
Half Tank Gravity Load	0.0178 mm	0.6692 MPa
Full Tank 3m Cut	0.0208 mm	0.9846 MPa
Half Tank 3m Cut	0.0192 mm	0.8470 MPa
Full Tank 45° Cut	0.0638 mm	2.5390 MPa
Full Tank 90° Cut	0.3300 mm	6.4300 MPa
Full Tank 180° Cut	3.7200 mm	25.050 MPa
Full Tank 225° Cut	9.3600 mm	35.650 MPa
Full Tank 270° Cut	21.517 mm	50.038 MPa
Full Tank 315° Cut	56.790 mm	102.10 MPa



Full analysis was carried out till 315° cut to compare the deflections and stresses generated due to gravity only. Maximum stress generated for 3m cut in the vessel is negligible compared to original stress of gravity without cut (0.9846 MPa vs 0.6195 MPa respectively) and the deflections encountered is also negligible.

Conclusions

From the analysis conducted it can be concluded that 3m cut in a 30m tank would generate negligible deflection and stress in self-weight load case.

Initially comparison was made between Whole Tank and Half Tank model. The results generated by both approaches were similar and so for this analysis Whole Tank model was chosen and taken forward.

Higher amount of cuts (45°, 90°, 180°, 225°, 270° and 315°) were made in the tank to evaluate the amount of deflection and stresses generated in the tank due to self-weight. However this additional evaluation was not required as part of the original scope of work, it was conducted to see the effects on stresses.

As the study shows, cut of 90° generates deflections below 1mm and stresses below 10 MPa. This amount of deflection is suitable to remove the cut sheet, install new sheet without too much worried about deflections, portion of tank to support during installation of new sheet and residual stresses.

Further studies can be undertaken, if required by the client, to evaluate stresses in the tank during Cyclonic wind and Earthquake load cases.

To understand yielding of the tank, Non-linear material can be considered in further studies and the analysis repeated to find out if the results match.