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Erasmus Mundus

UNIVERSITAT POLITÈCNICA DE CATALUNYA, BARCELONA

MSC. COMPUTATIONAL MECHANICS ERASMUS MUNDUS

GID ASSIGNMENT 4

Computational Structural Mechanics & Dynamics

Author:
Nikhil Dave

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Exercise 1: Cylindrical tank

Analyse the state of stress of the tank shown in the figure, which is submitted to an internal pressure. Suppose a continuous variation of the thickness of the spherical cupola. Use revolutions shell elements with two nodes and 3D shells elements with three nodes.

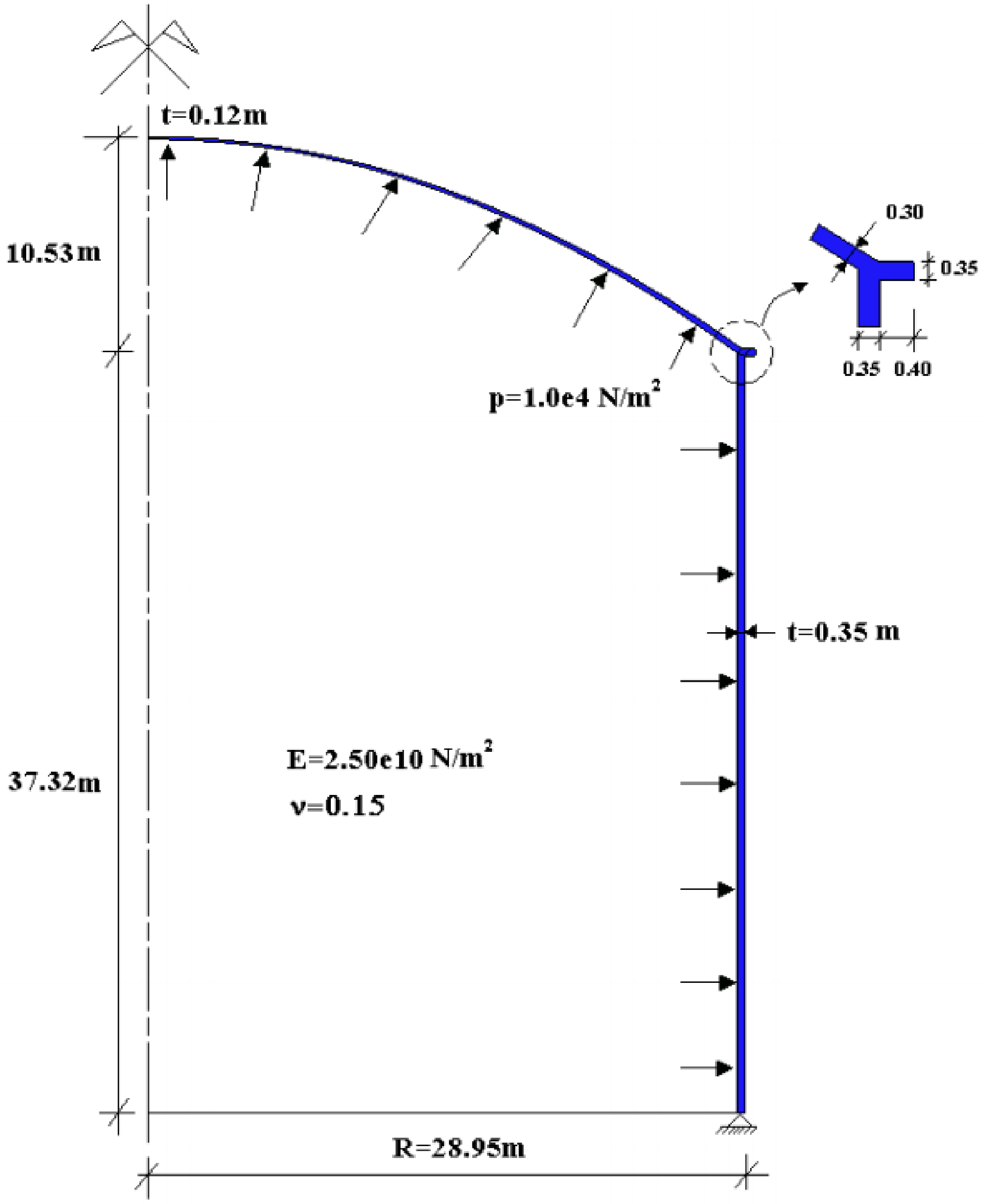


Figure 1: Cylindrical tank

Solution:

1.1. Purpose of the exercise

The objective of this exercise is to analyse the state of stress of the tank submitted to internal pressure. To understand the effect of the theory used, we will compare the results from revolution shells and 3D shells theories.

Revolution shells theory

1.2. Analysis

1.2.1 Pre-processing

(i) Geometry

The first step of pre-processing is to model the geometry as per the given dimensions in GiD as shown in Figure 2.

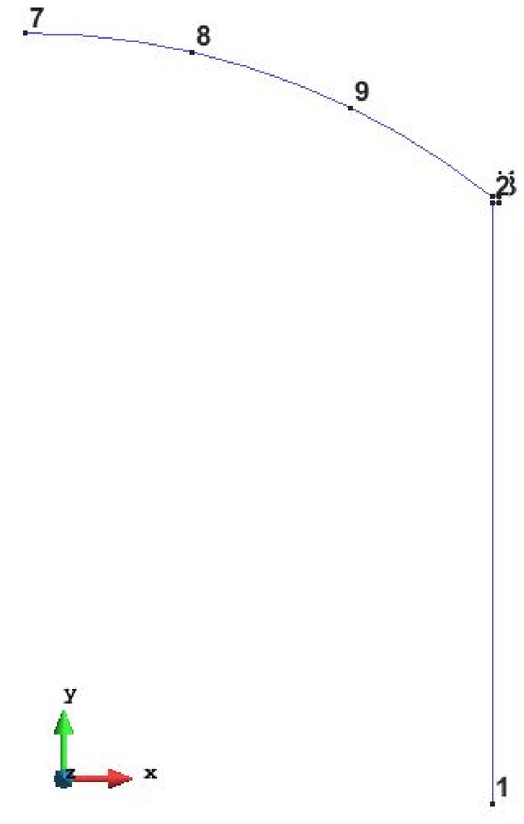


Figure 2: Defining the geometry

(ii) Data

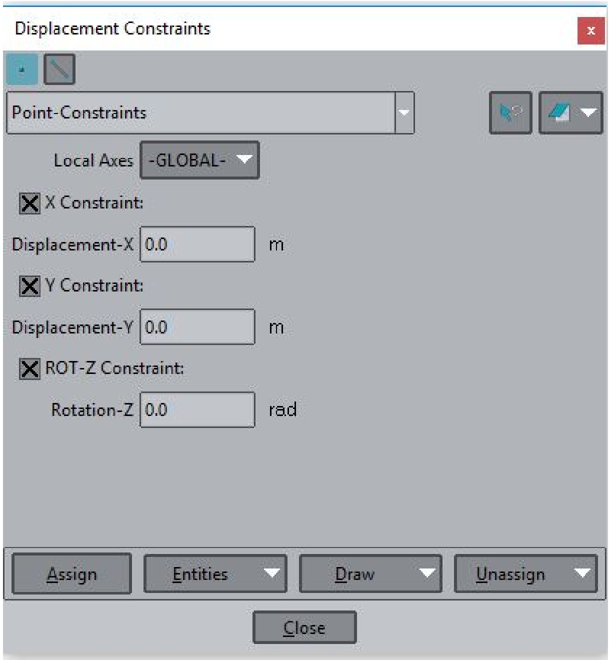
Once the geometry is defined, we apply the given data to the model.

Problem type

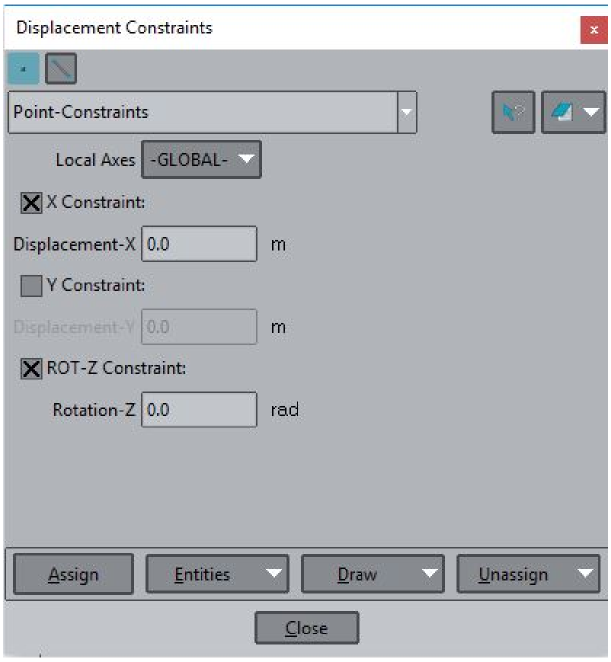
For the given problem we use the Rev_Shells problem type from the Ramseries Educational module.

Boundary Conditions

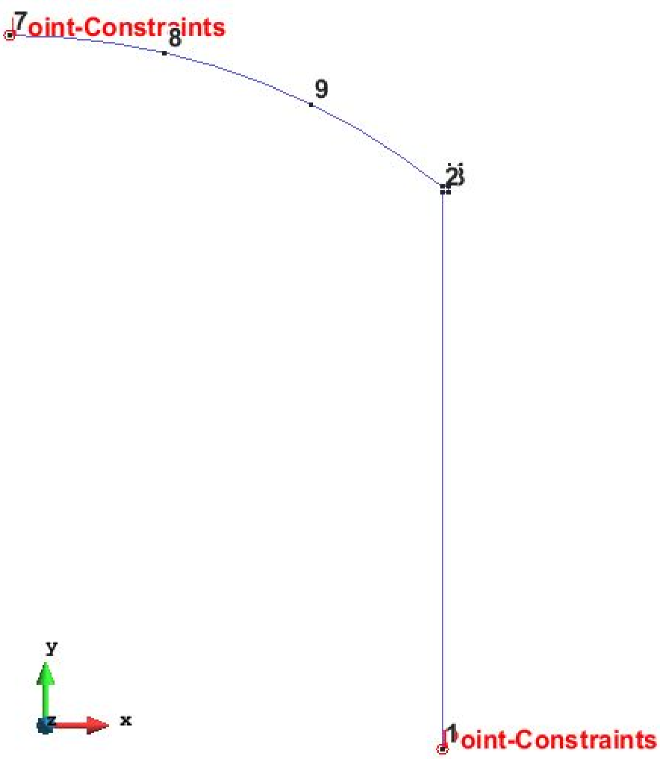
Next, we define the boundary conditions as shown in Figures 3 and 4. Firstly, displacement constraint is applied to simulate the top node restricted due to symmetry and base node of the tank with zero displacement and z-rotation. The given uniform load $p = 1.0e4N/m^2$ is then applied to the internal surface of the tank.



(a)

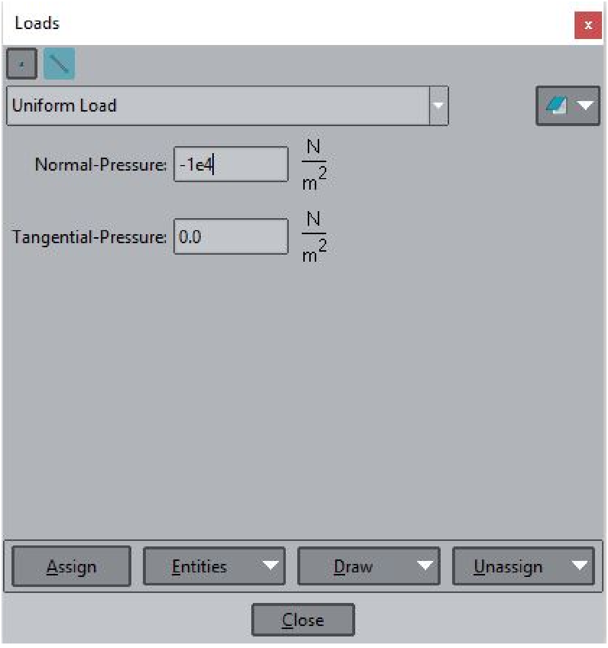


(b)

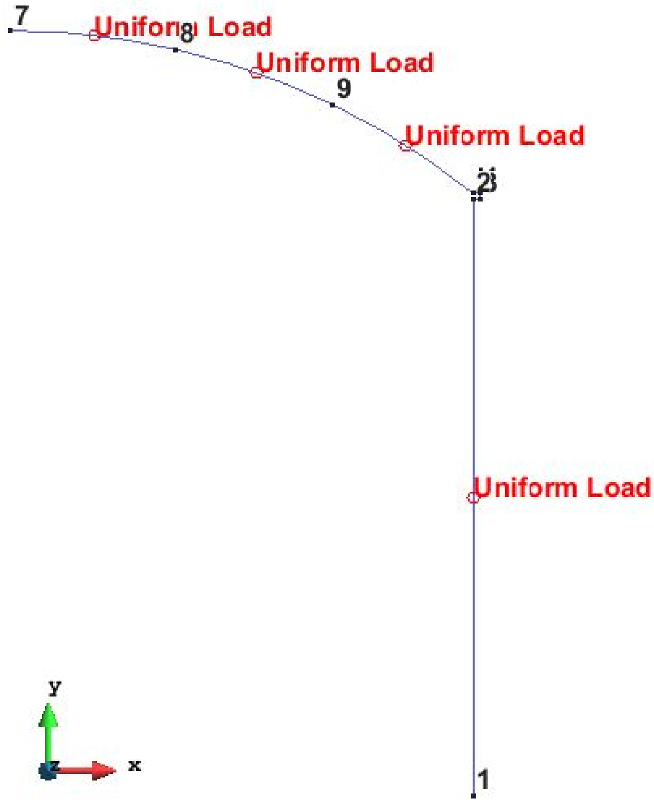


(c)

Figure 3: Boundary conditions - displacement constraint



(a)

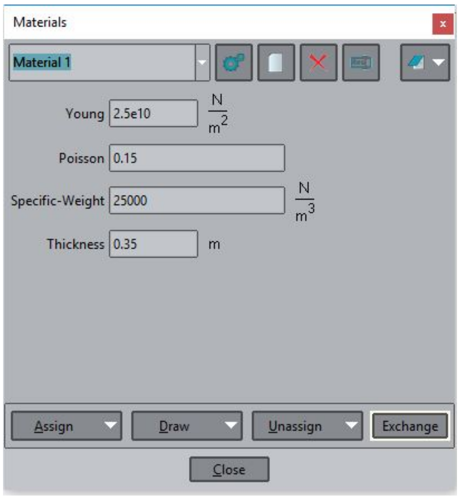


(b)

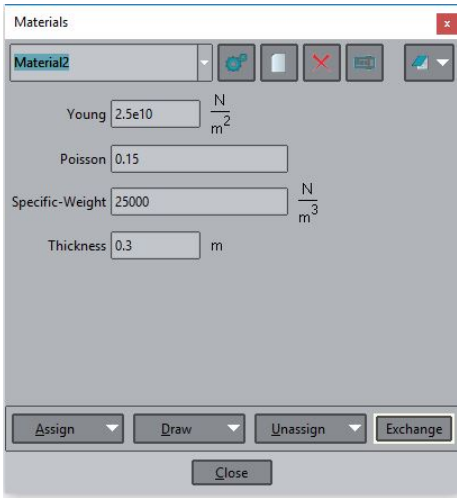
Figure 4: Boundary conditions - Uniform load

Material

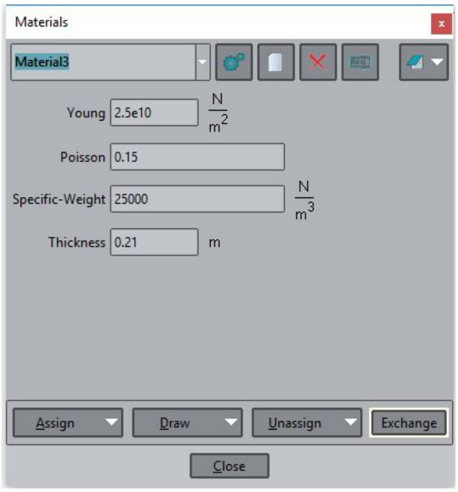
The material properties of the structure are defined with the given parameters and varying thickness as shown in Figure 5.



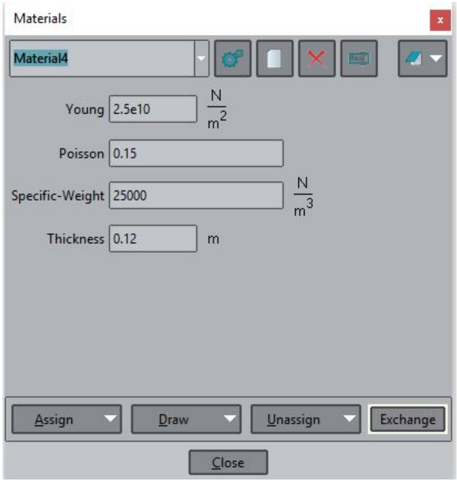
(a)



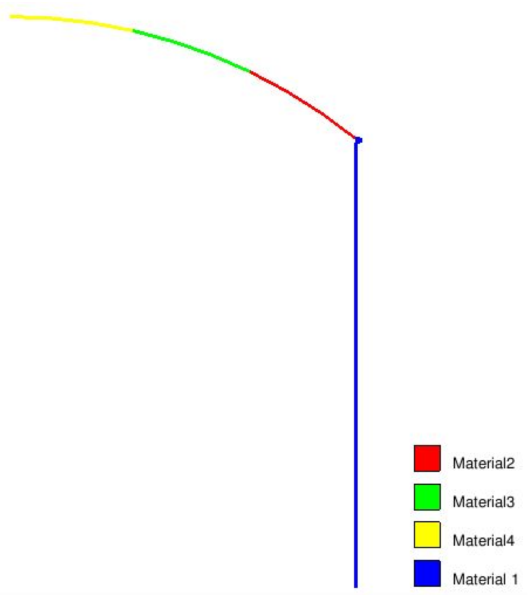
(b)



(c)



(d)



(e)

Figure 5: Material properties defined

Problem Data

The definition of problem data is an important step for the analysis where the options like title, type of problem and the result units are to be selected. It is important to note here that the self weight is considered in this problem with a scale factor of 1.0. Figure 6 shows the data used for this problem.

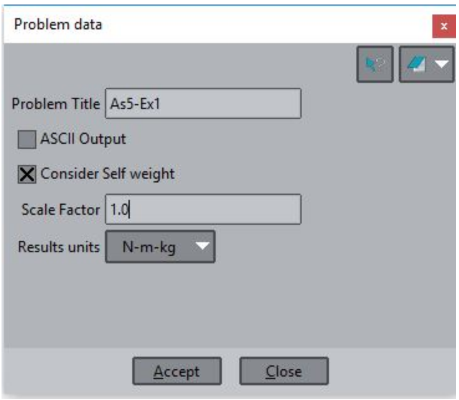


Figure 6: Problem data defined

Mesh

In this problem, a structured mesh of revolution shell elements with two nodes is used.

1.2.2 Processing

In this section, we calculate the solution of the problem for the given data, boundary conditions and generated mesh as shown in Figure 7.

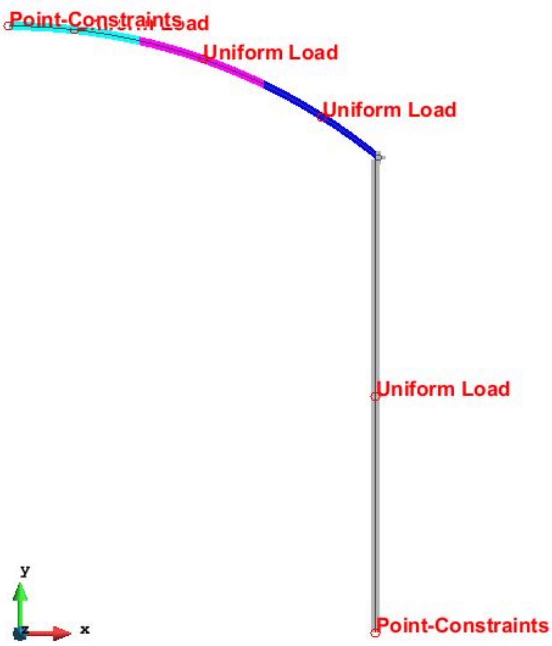


Figure 7: Problem to be solved

1.2.3 Post-processing

The following figures present the post-processed results for this analysis.

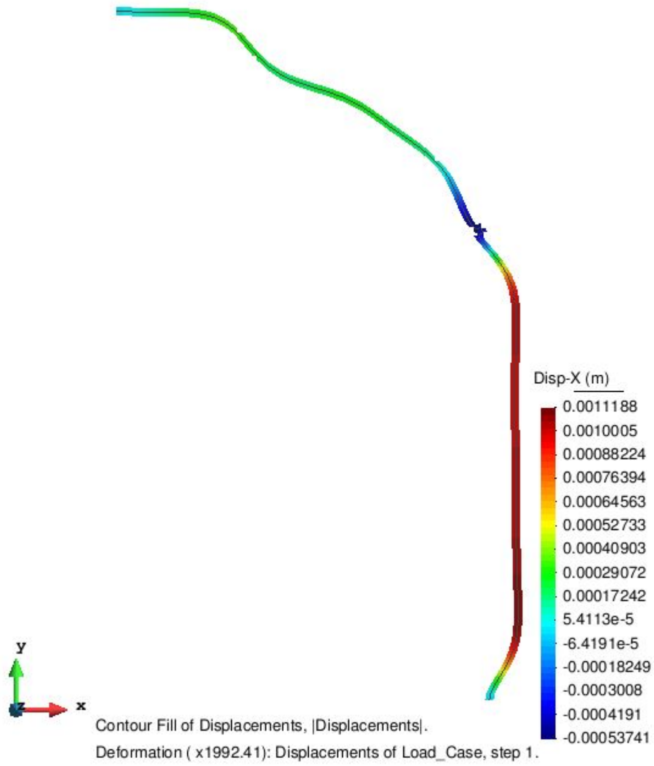


Figure 8: Displacement in the x-direction in deformed configuration

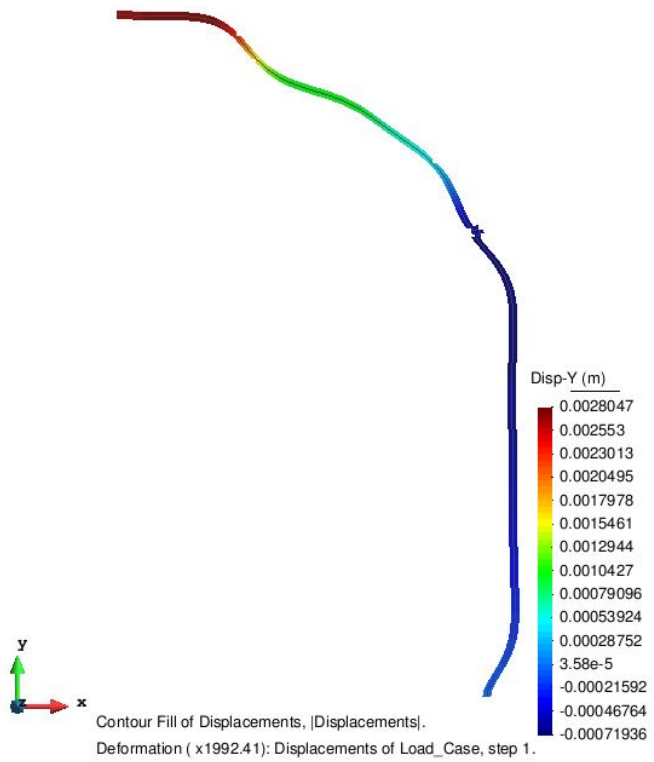


Figure 9: Displacement in the y-direction in deformed configuration

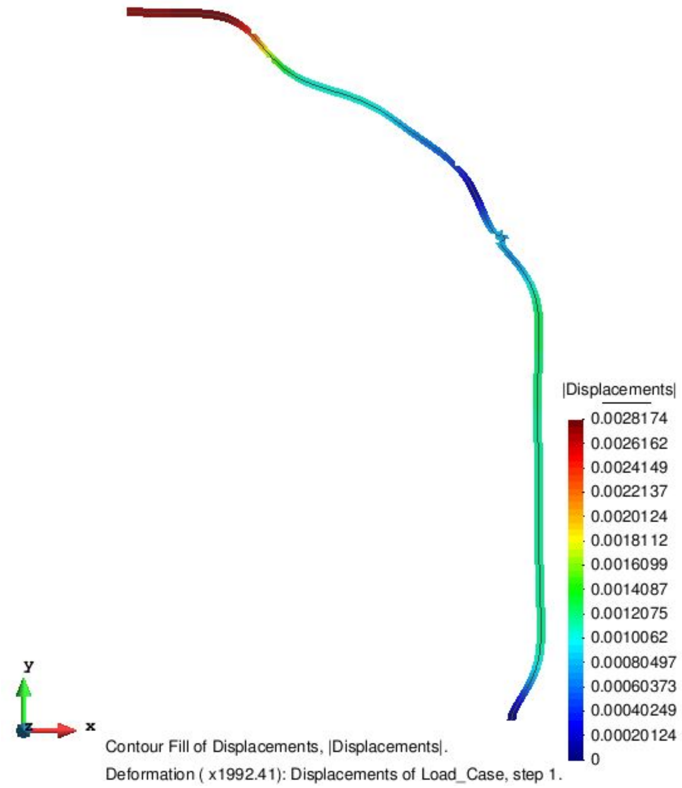


Figure 10: $|Displacements|$ in deformed configuration

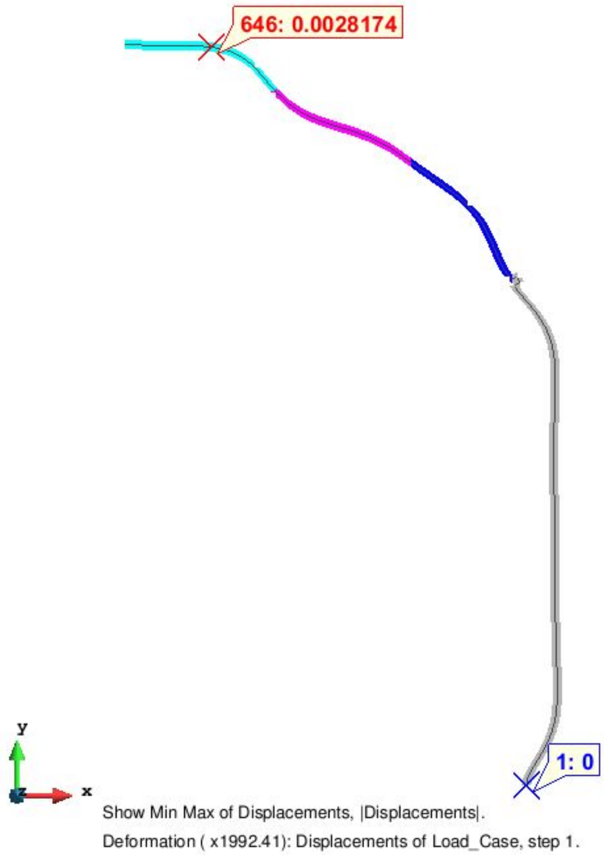


Figure 11: Maximum and minimum displacements in deformed configuration

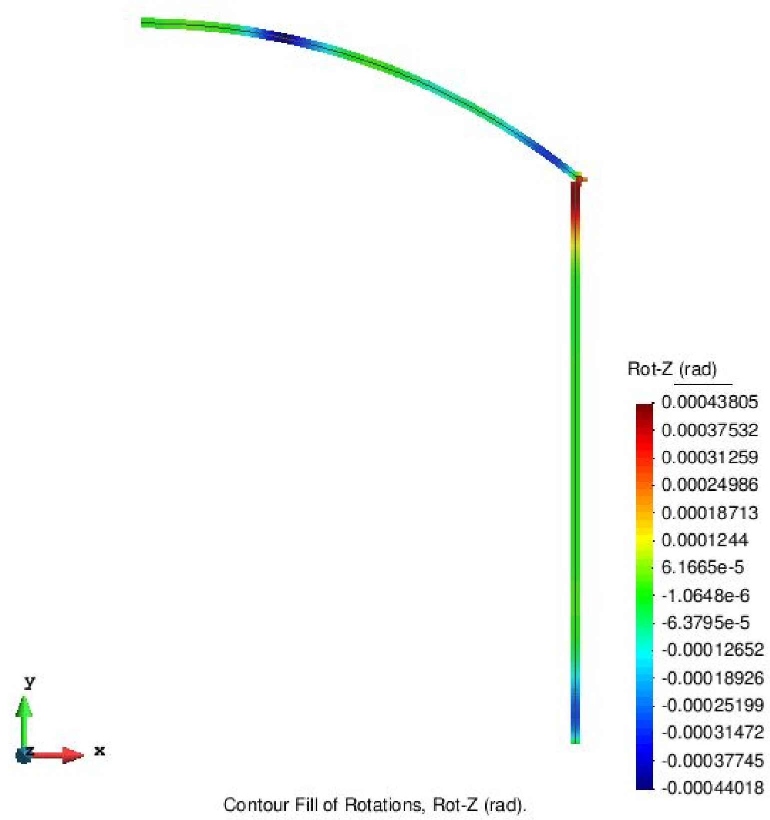


Figure 12: Rotations

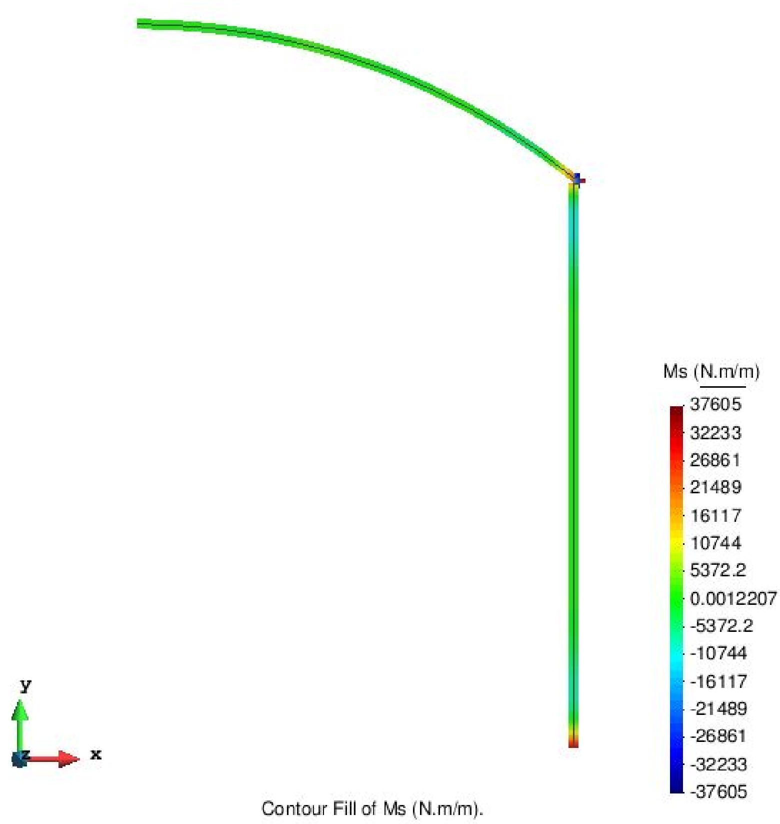


Figure 13: Momentum in the radial-direction

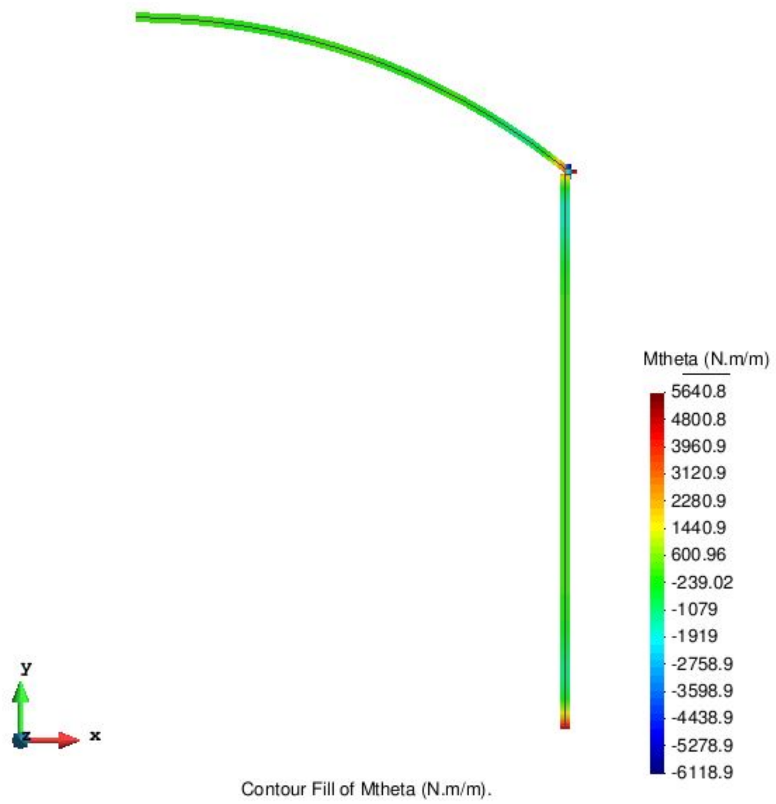


Figure 14: Momentum in the theta-direction

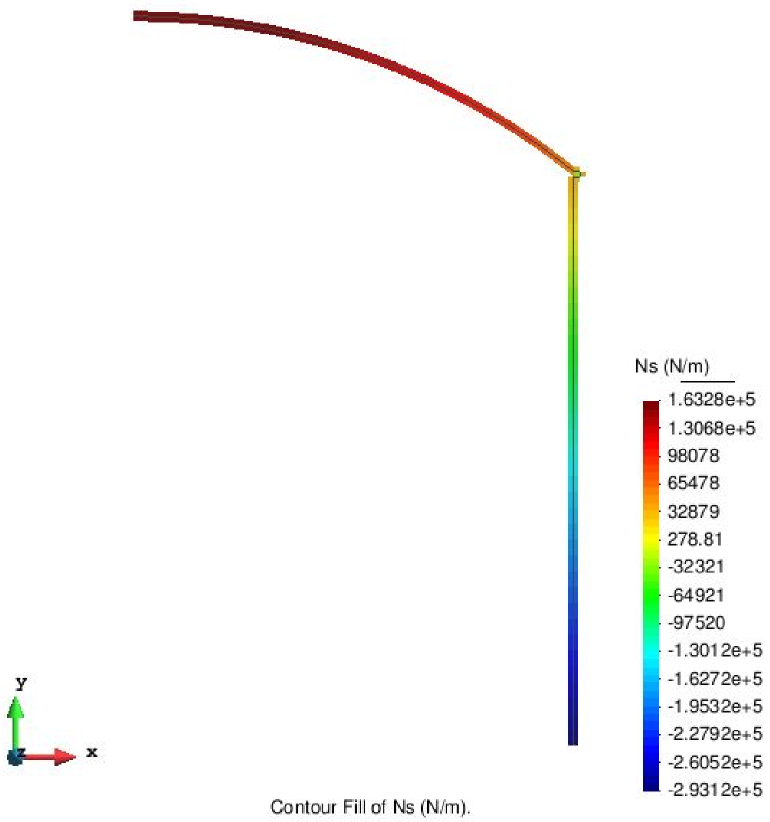


Figure 15: Axial force in the radial-direction

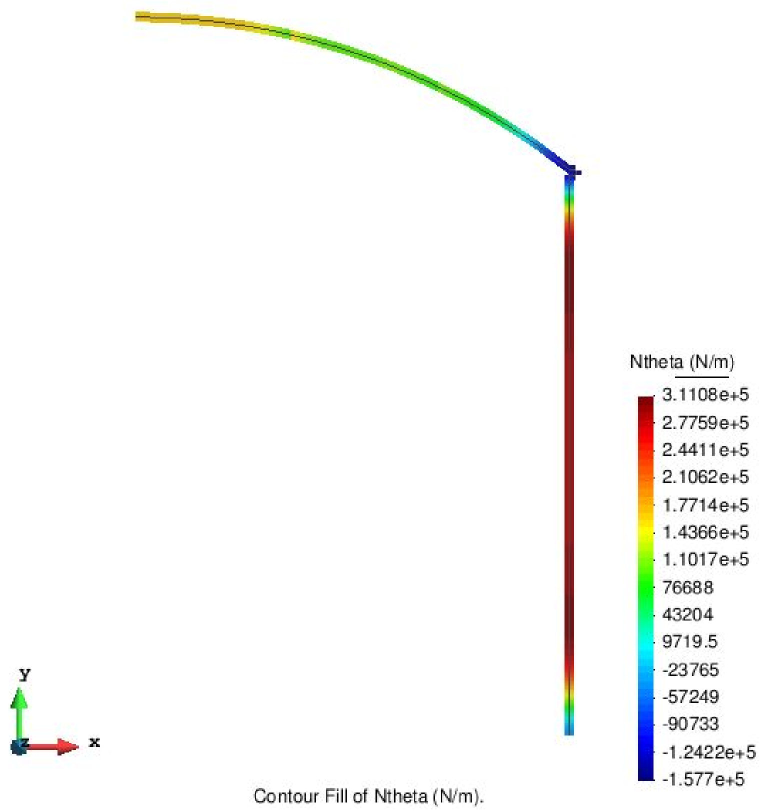


Figure 16: Axial force in the theta-direction

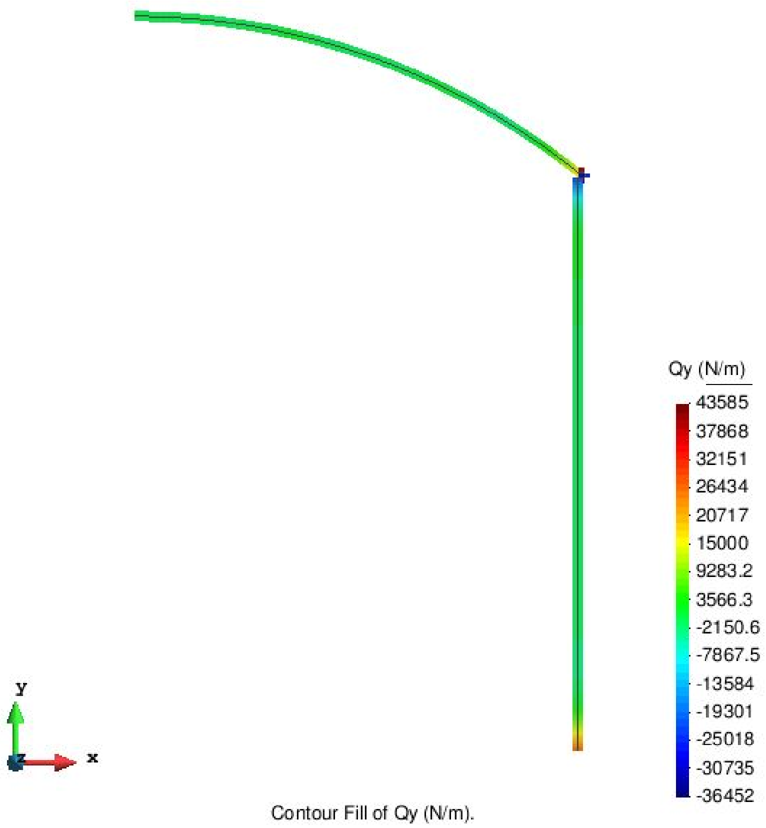


Figure 17: Tractions in the y-direction

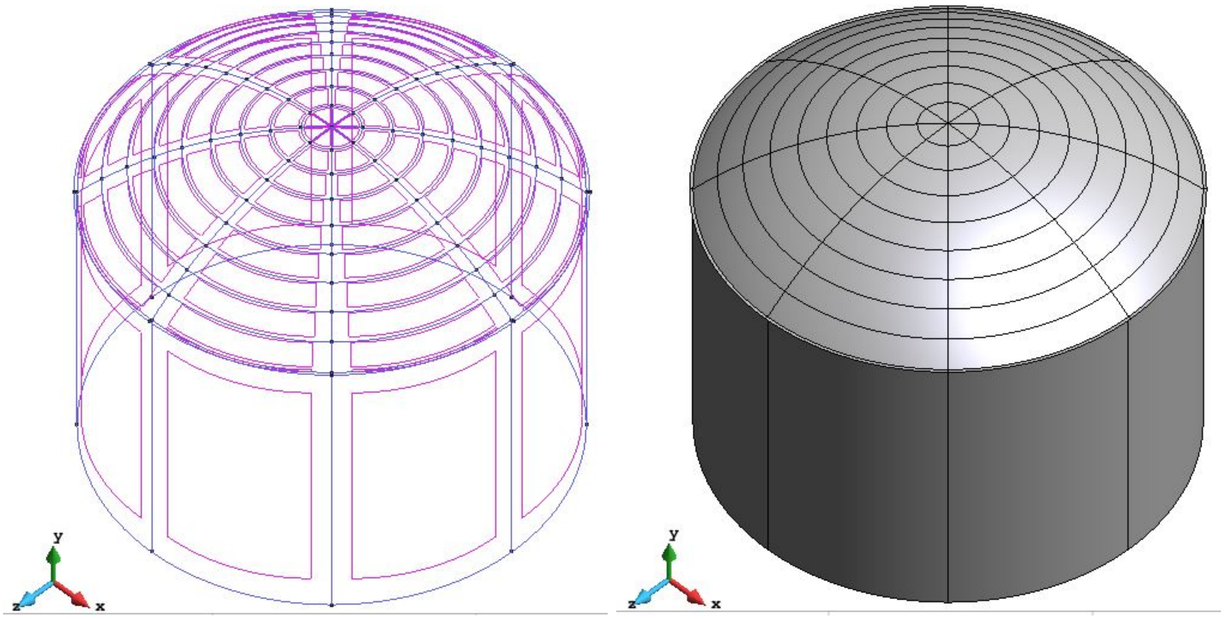
3D shells theory

1.3. Analysis

1.3.1 Pre-processing

(i) Geometry

The first step of pre-processing is to model the whole geometry as per the given dimensions in GiD as shown in Figure 18.



(a) (b)

Figure 18: Defining the whole geometry

(ii) Data

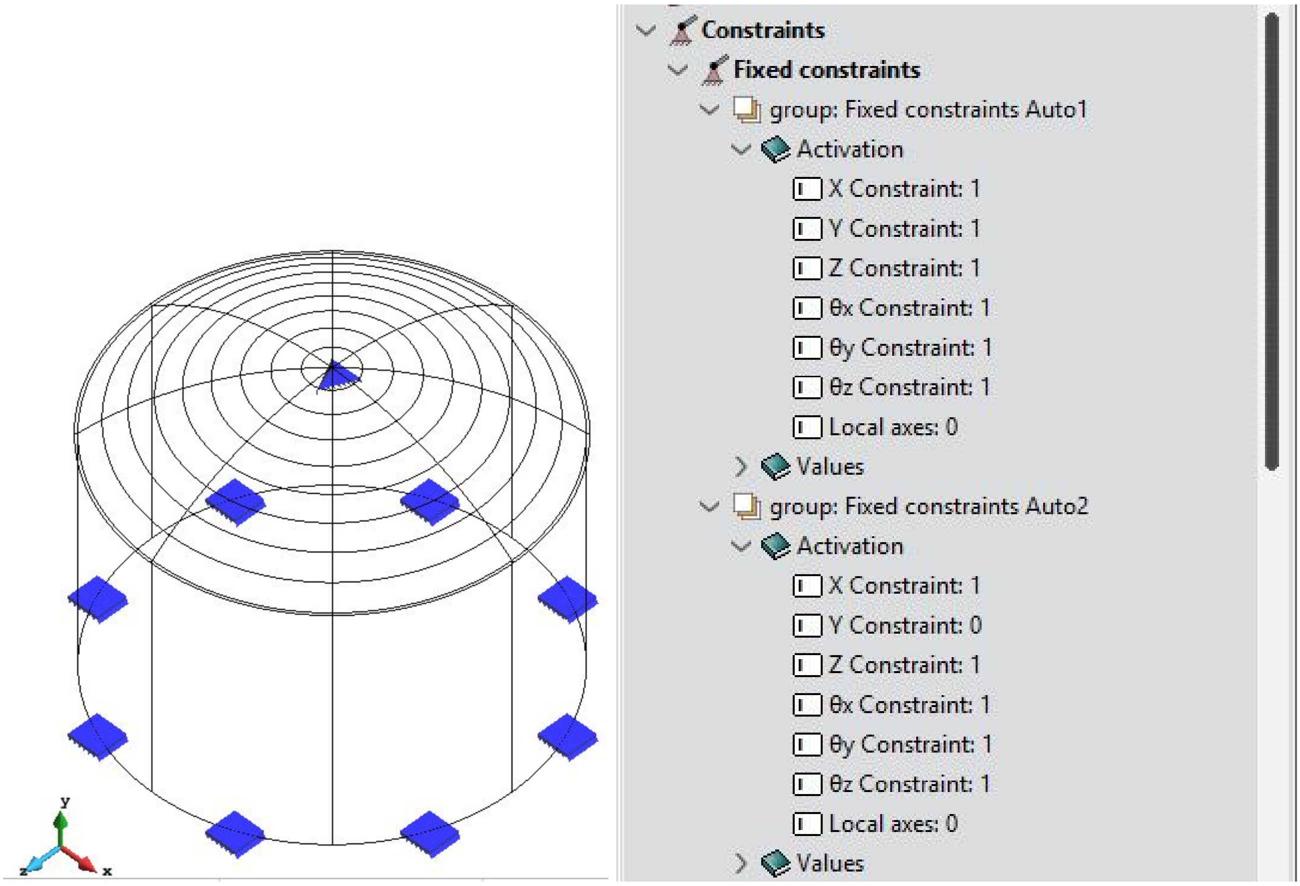
Once the geometry is defined, we apply the given data to the model.

Problem type

For the given problem we use the 3D Shells problem type from the Ramseries Educational module with Tdyn.

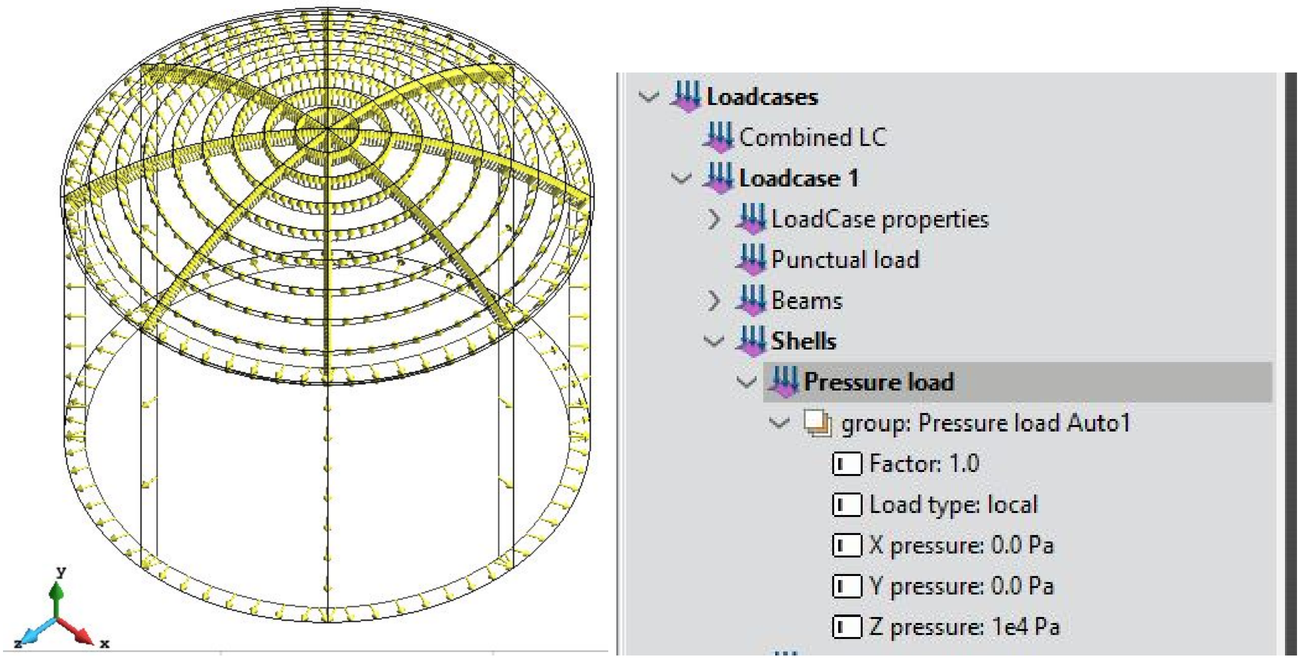
Boundary Conditions

Next, we define the boundary conditions as shown in Figure 19. Firstly, displacement constraint is applied to simulate the top node restricted in all other dofs except vertical displacement and base of the tank is fixed in all dofs. The given uniform load $p = 1.0e4\ N/m^2$ is then applied to the internal surface of the tank as shown in Figure 20.



(a) (b)

Figure 19: Boundary conditions - displacement constraint



(a) (b)

Figure 20: Boundary conditions - Uniform load

Material

The material properties of the structure are defined with the given parameters and varying thickness as shown in Figure 21. Since a continuous variation of the thickness of the spherical cupola is required to be simulated, we use the following thickness values.

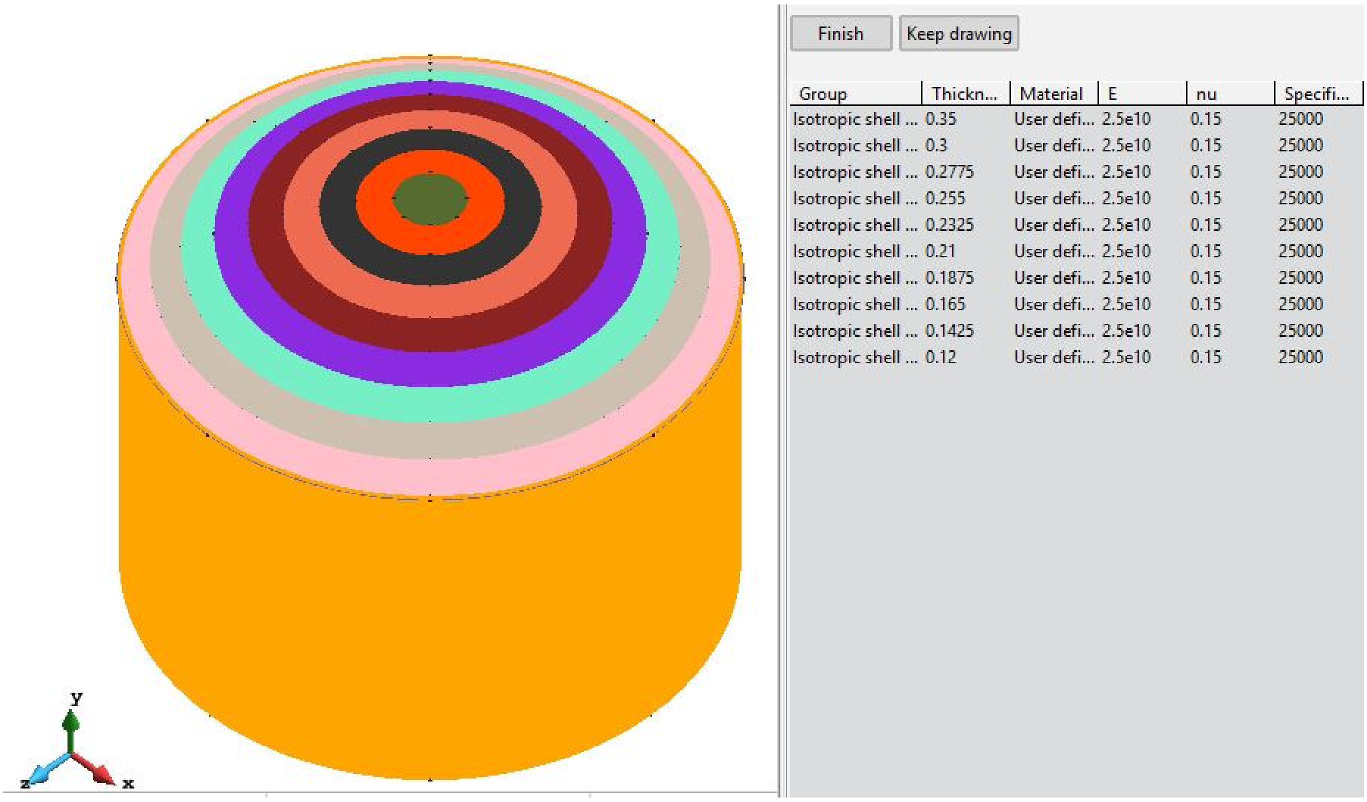


Figure 21: Material properties defined

Mesh

In this problem, a structured mesh is used. Figures 22 shows the mesh used in the analysis.

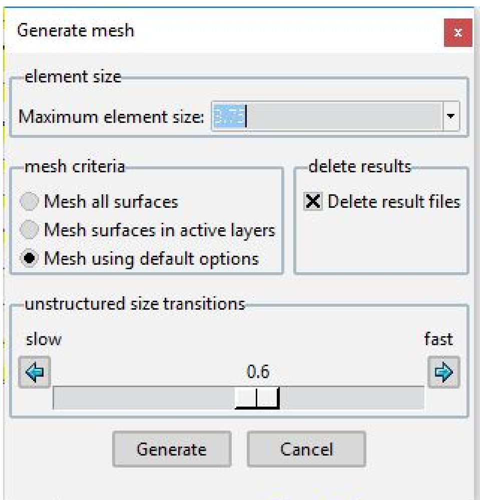


Figure 22: Generated mesh

It was noticed that the student edition of Tdyn does not support more than 1000 mesh nodes, shown in Figure 23. Therefore, instead of solving the complete model, it was decided to use the symmetry of the problem to solve the quarter model. The geometry, boundary conditions, loading, material properties and mesh of the quarter model are given in Figure 29-33.

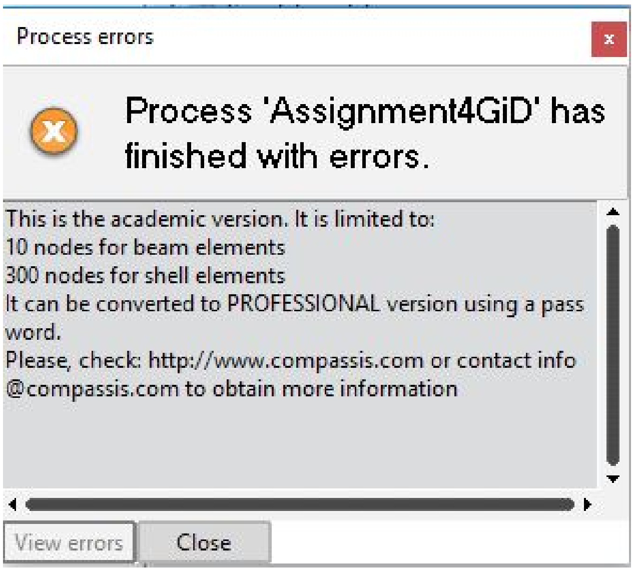
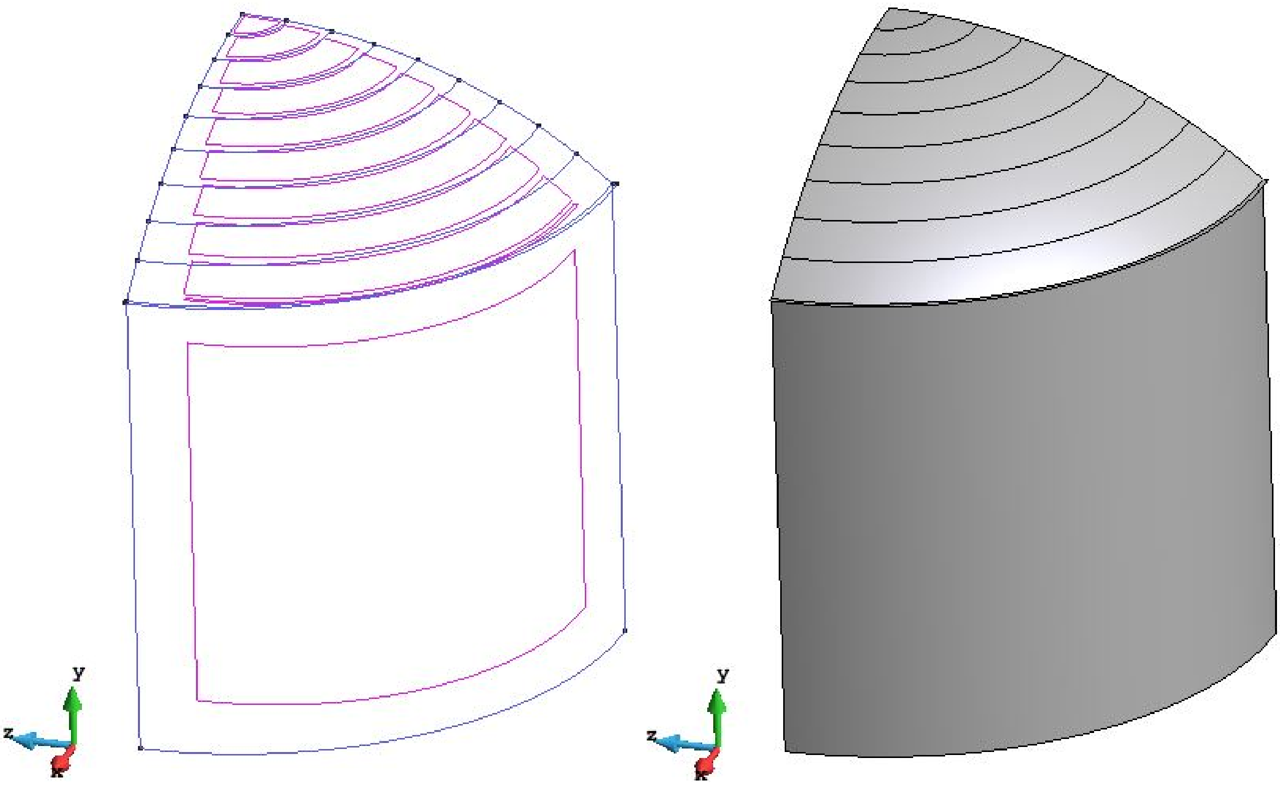


Figure 23: Mesh with errors



(a) (b)

Figure 24: Defining the quarter geometry

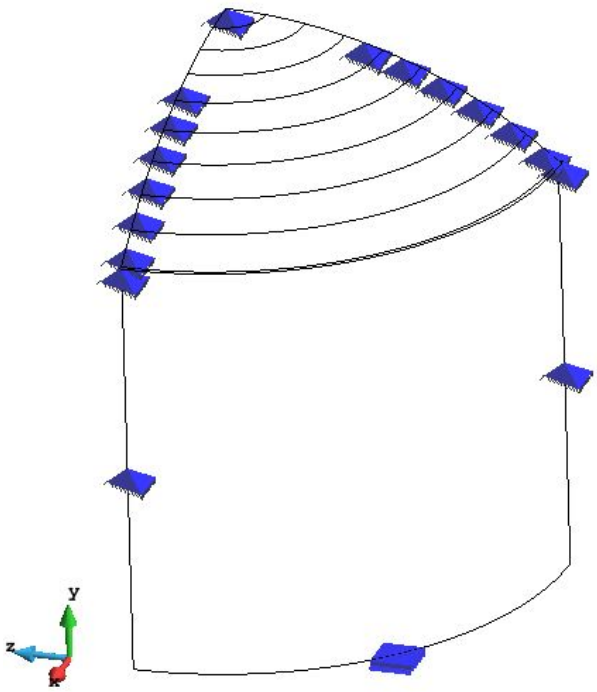
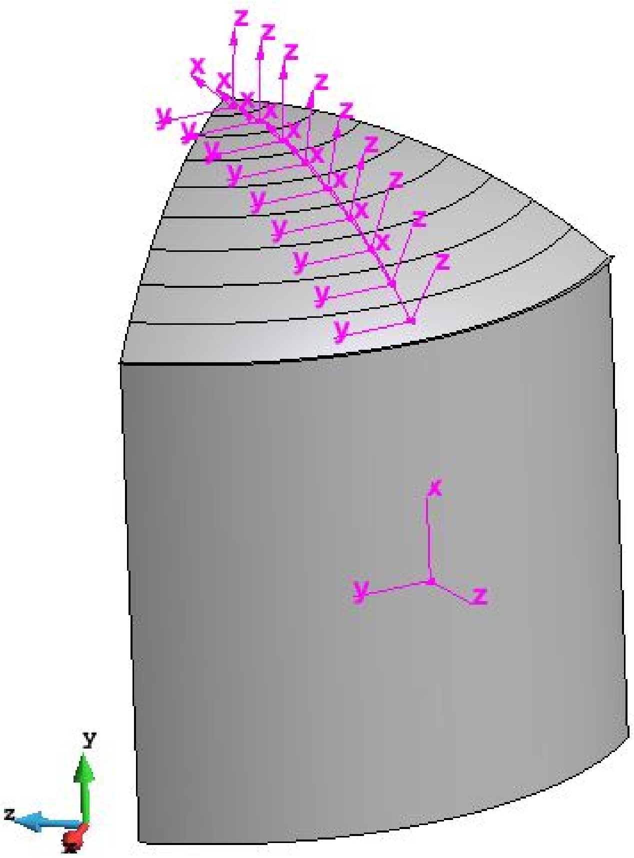
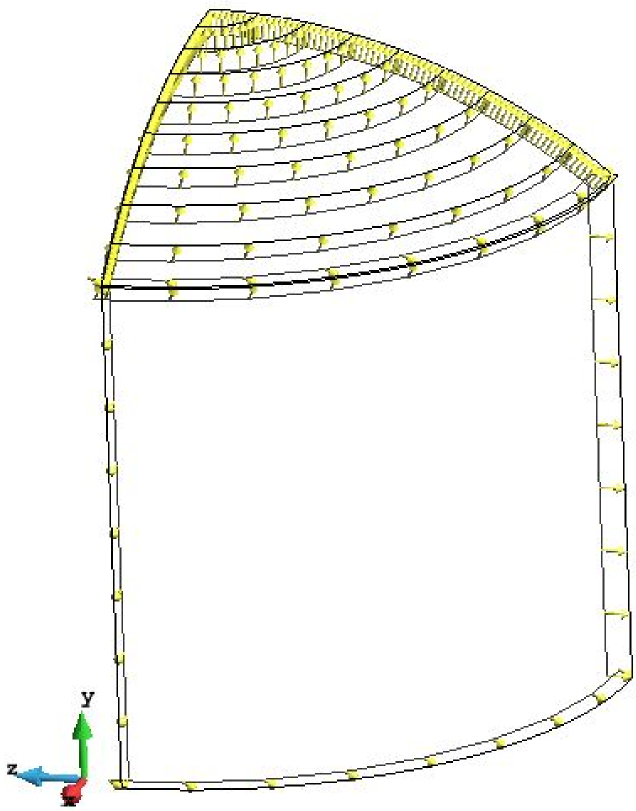


Figure 25: Boundary conditions - displacement constraint on the quarter model

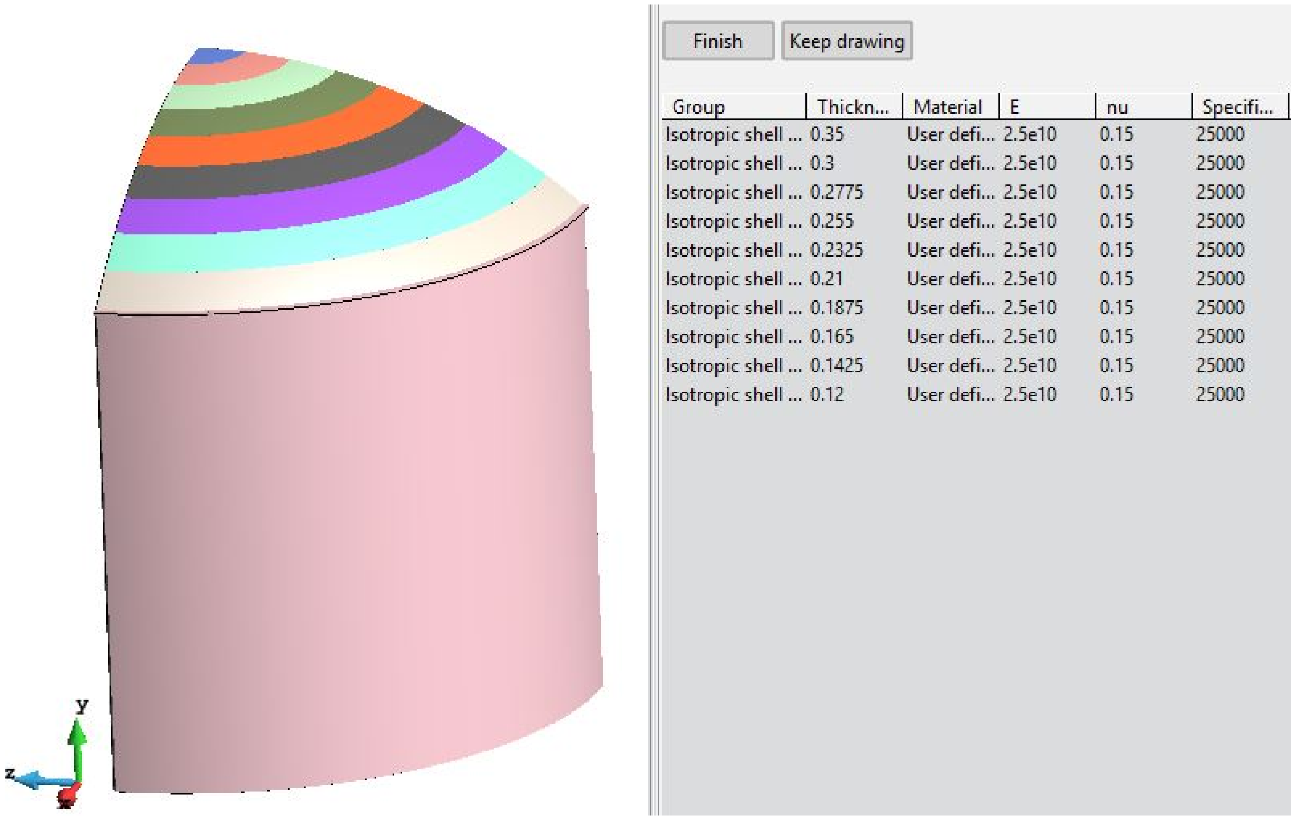


(a)



(b)

Figure 26: Local coordinates and uniform load on the quarter model



Group	Thickn...	Material	E	nu	Specifi...
Isotropic shell ...	0.35	User defi...	2.5e10	0.15	25000
Isotropic shell ...	0.3	User defi...	2.5e10	0.15	25000
Isotropic shell ...	0.2775	User defi...	2.5e10	0.15	25000
Isotropic shell ...	0.255	User defi...	2.5e10	0.15	25000
Isotropic shell ...	0.2325	User defi...	2.5e10	0.15	25000
Isotropic shell ...	0.21	User defi...	2.5e10	0.15	25000
Isotropic shell ...	0.1875	User defi...	2.5e10	0.15	25000
Isotropic shell ...	0.165	User defi...	2.5e10	0.15	25000
Isotropic shell ...	0.1425	User defi...	2.5e10	0.15	25000
Isotropic shell ...	0.12	User defi...	2.5e10	0.15	25000

Figure 27: Material properties defined for the quarter model

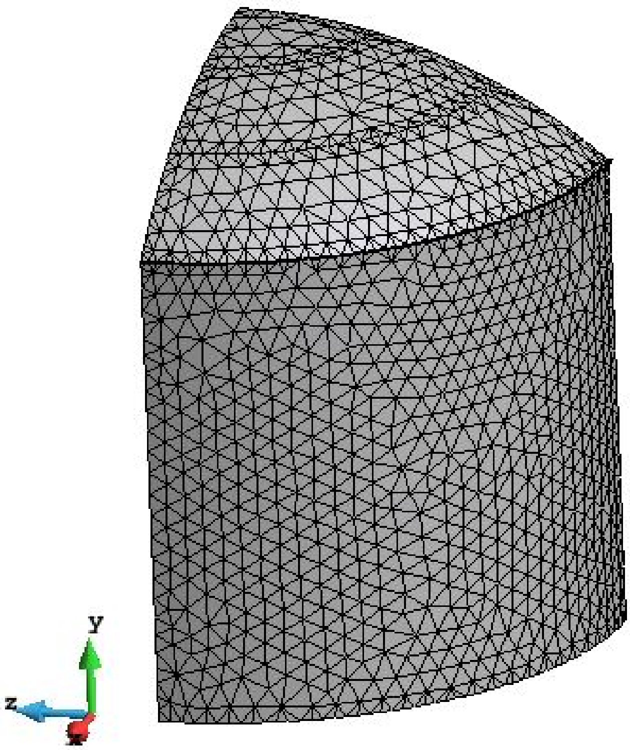


Figure 28: Mesh generated for the quarter model

1.3.2 Processing

In this section, we calculate the solution of the problem for the given data, boundary conditions and generated mesh.

1.3.3 Post-processing

The following figures present the post-processed results for this analysis.

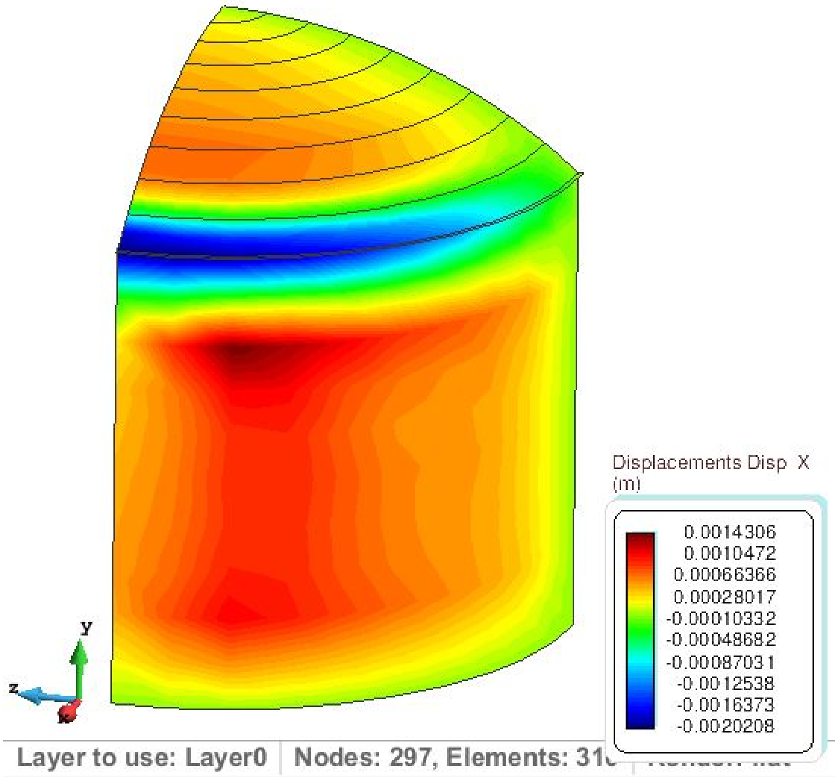


Figure 29: Displacement in the x-direction

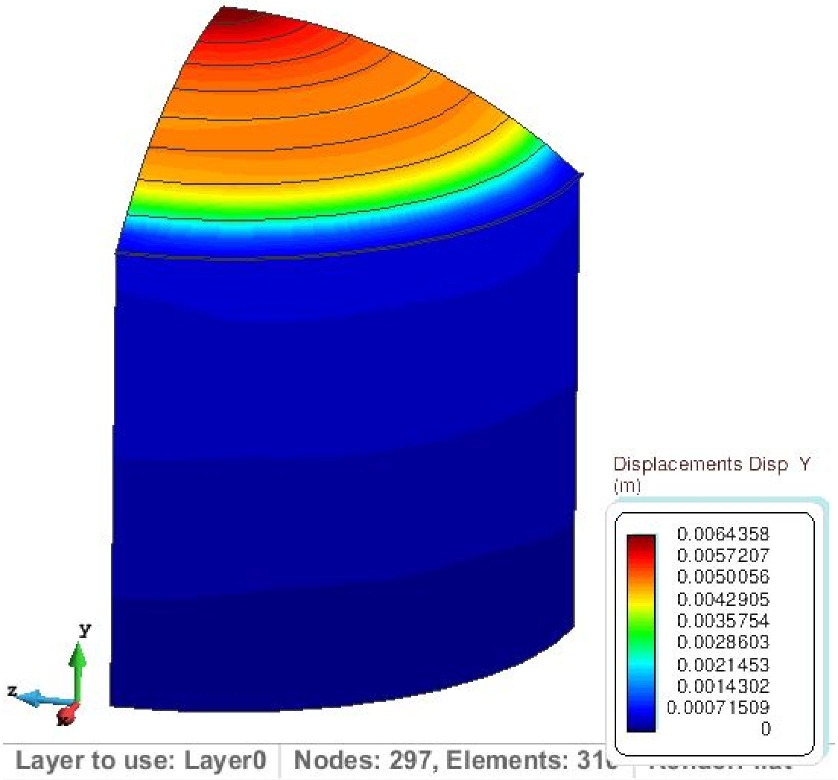


Figure 30: Displacement in the y-direction

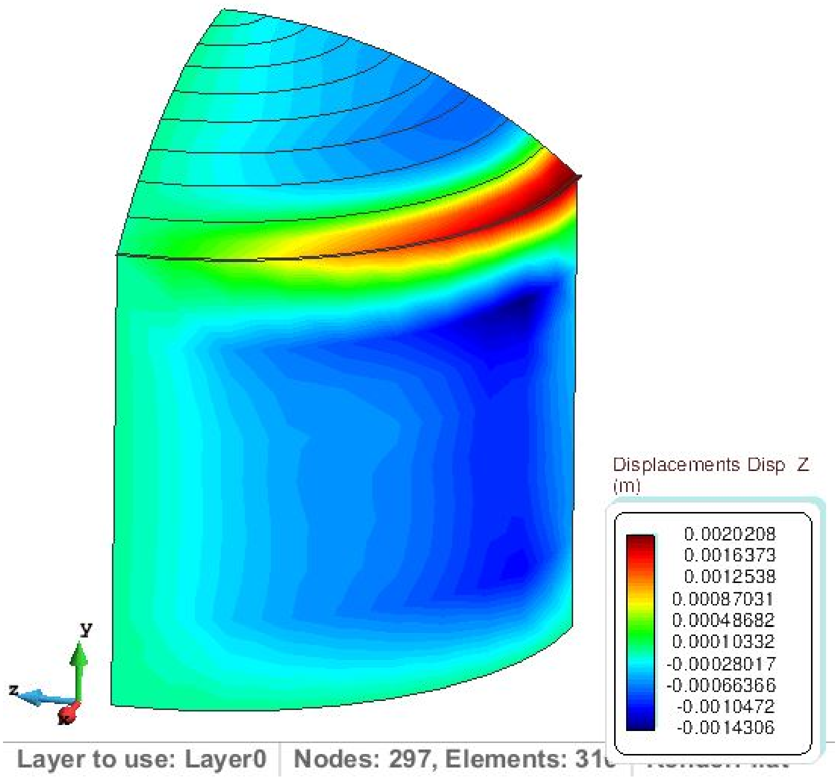


Figure 31: Displacement in the z-direction

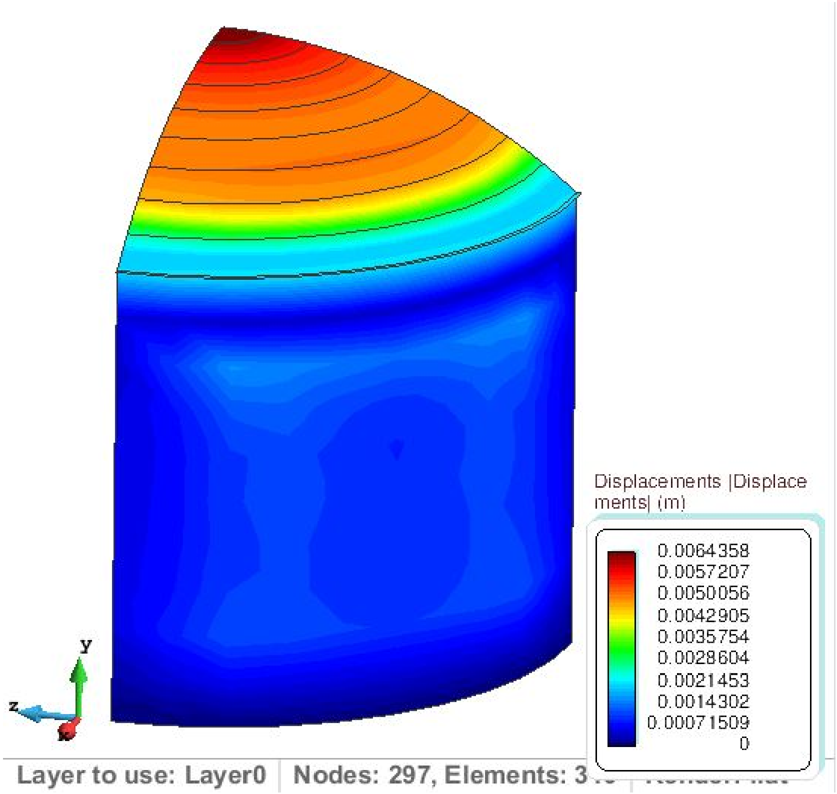


Figure 32: $|Displacements|$

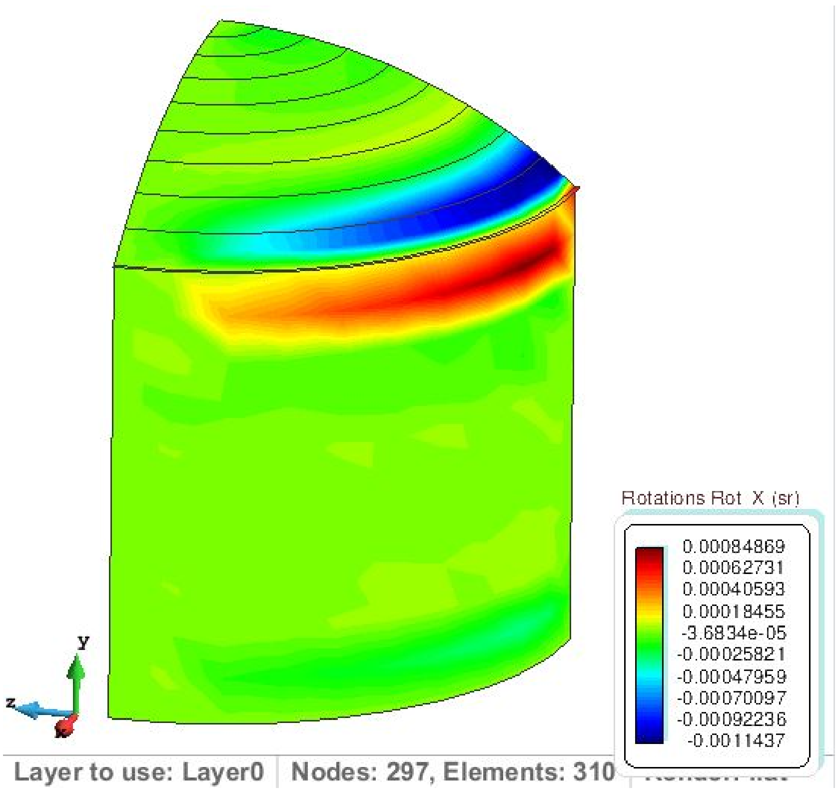


Figure 33: Rotations in the x-direction

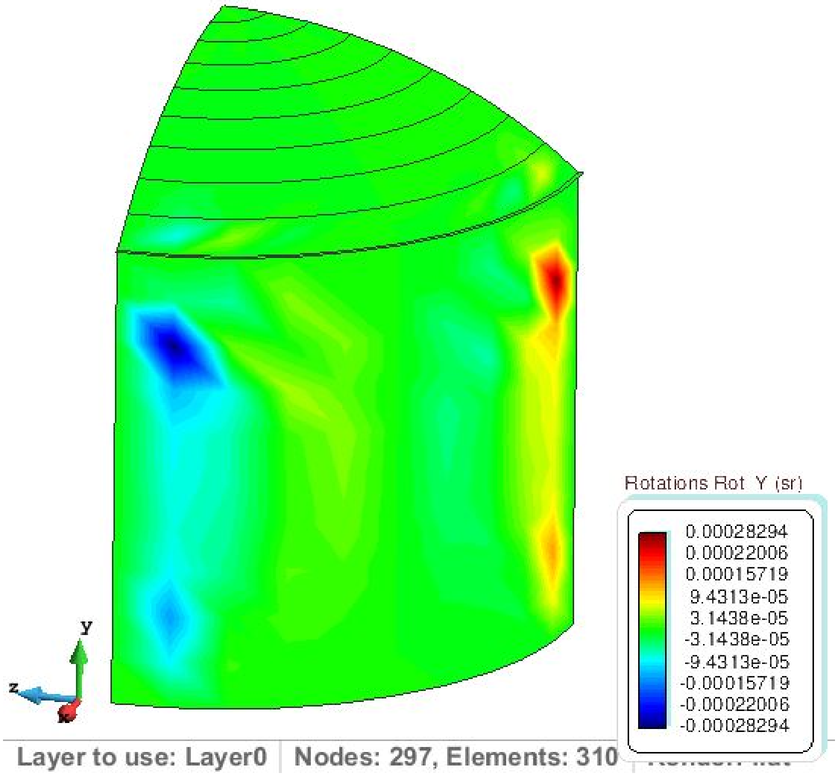


Figure 34: Rotations in the y-direction

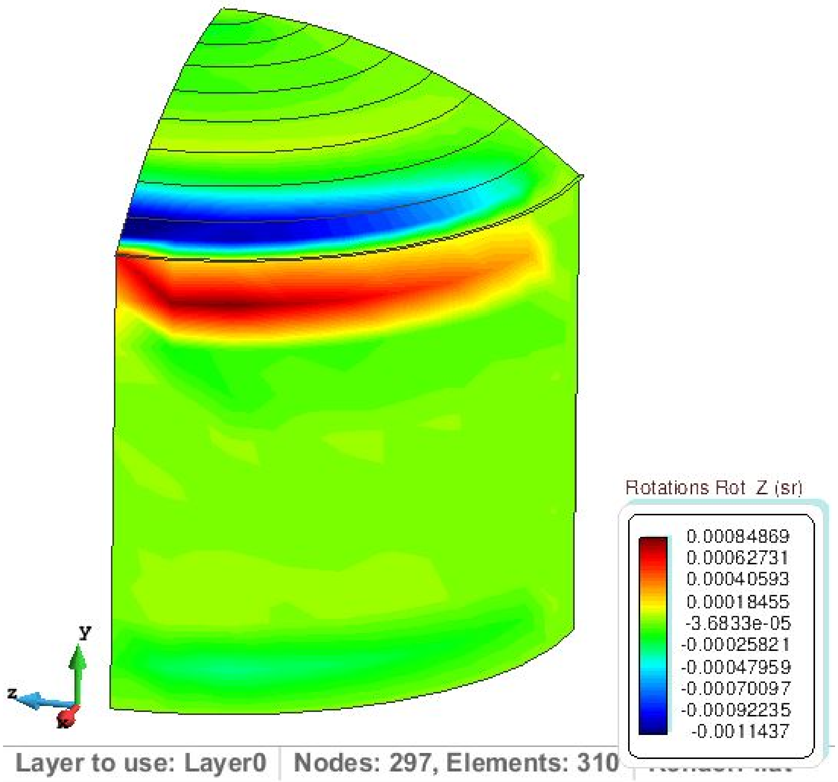


Figure 35: Rotations in the z-direction

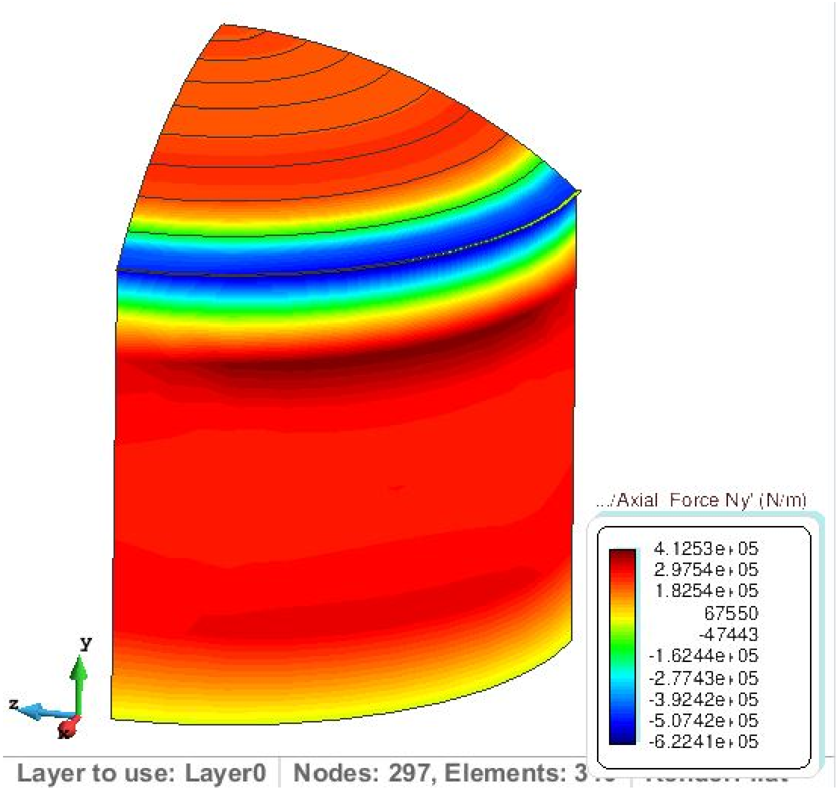


Figure 36: Axial force in y-direction

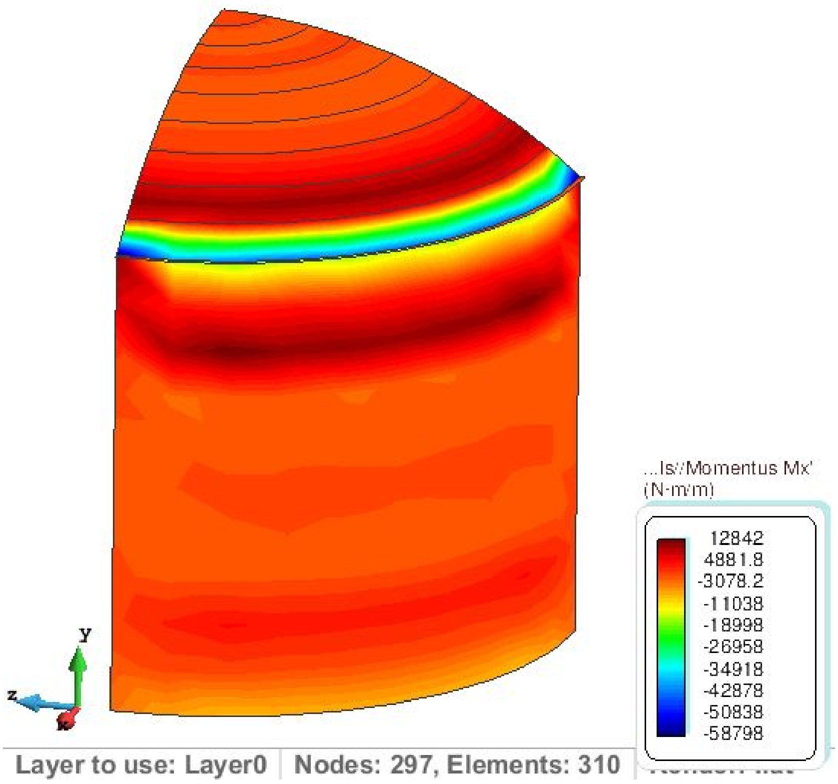


Figure 37: Momentum in the x-direction

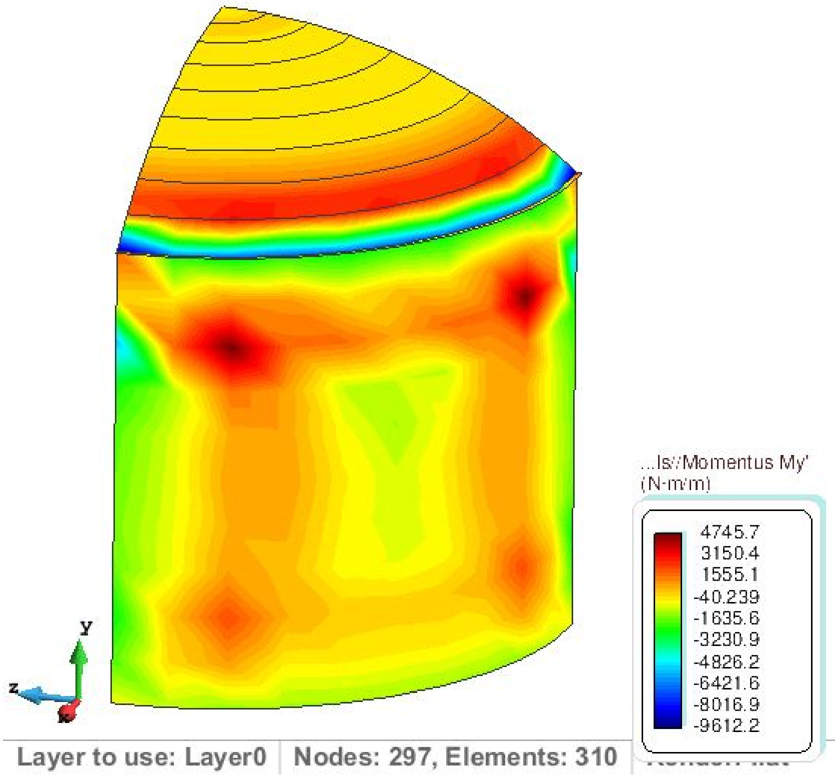


Figure 38: Momentum in the y-direction

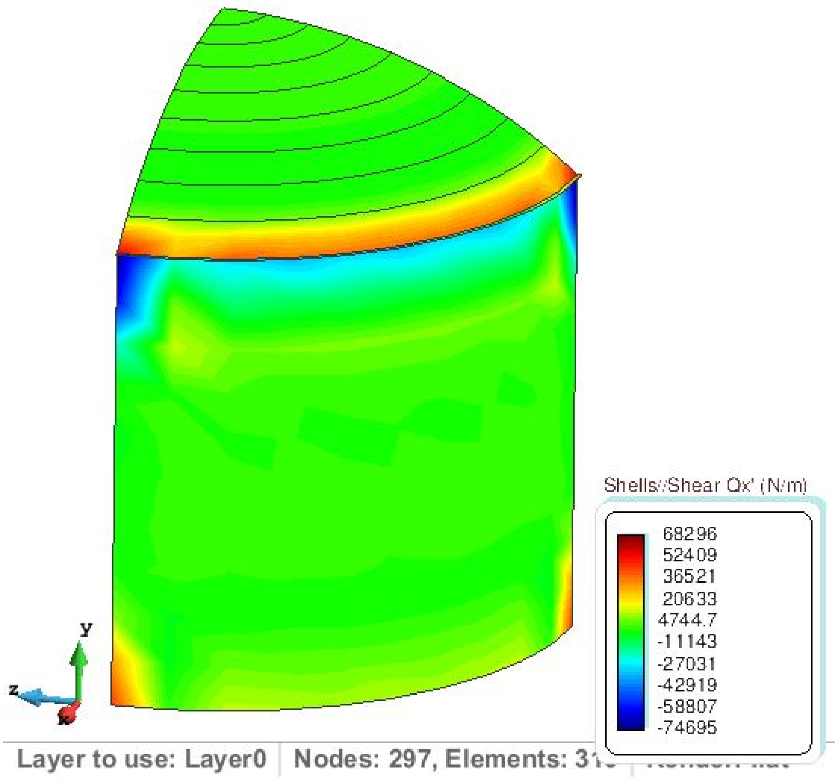


Figure 39: Shear in the x-direction

1.4. Comparison of the results

The results obtained for displacement, stresses, rotations etc. are shown for both the theories. The tank deforms vertically and the walls slightly curve to the outside with more deformation for the inner circle and high concentrated stresses on the outer annulus. It is seen that the results from the 3D quarter model with a coarse mesh are very different from the results received by theory of revolution of shells. The difference is around 40% in case of y-displacement and around 22% in case of x-displacement. This is an expected result since both theories are based on different approaches which basically makes the overall difference. One thing could be the shear locking/membrane effect which is not prominent in the revolution of shells but can be a part of the 3D shell theory due to presence of shear forces as seen in the figures above. Overall, the work done was helpful in understanding both theories to solve the same problem. However, using a complete 3D mesh could be one area which could be solved and the results could be compared with this analysis.