Computational Structural Mechanics and Dynamics - Practice 4

Martí Burcet, Adrià Galofré, Albert Taulera

May 5th, 2016

1 Cylindrical tank

1.1 Introduction

In this exercise we want to study the deformation of a cylindrical tank under internal pressure (Figure 1) and to compare the distinct response of the revolution shells with two nodes and with 3D shell elements with three nodes. The cylindrical tank have the material properties are shown in Table 1

E	ν	p
$2.5 \cdot 10^{10} \frac{N}{m^2}$	0.15	$1.0 \cdot 10^{4} \frac{N}{m^2}$

Table 1: Problem properties

2 Revolution shell elements

2.1 Preprocess

The 2D version of the cylindrical tank has been developed using the provided problem statement, with simple lines representing the walls and the cover of it.

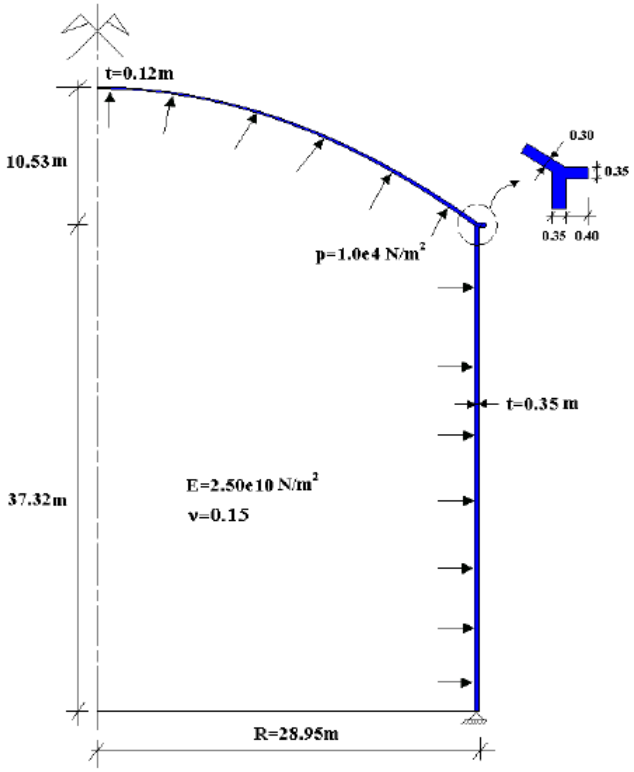


Figure 1: Problem statment.

To impose the variable thickness of the tank cover we have divided it in 3 parts (the same procedure than in 3D), of different thicknesses $t = 0.12$, $t = 0.21$ and $t = 0.3$, while the tank wall was $t = 0.35$, constant.

When it comes to boundary conditions, only two nodes require them. The upper node defines the symmetry condition with a restriction of

X-displacement and Z-rotation, and the bottom node is fully restricted (clamped).

These boundary conditions, along with the normal pressure all over the internal surface of the tank, define the full problem, only left to be meshed and calculated.

2.2 Results

Results of the 2D case are going to be commented together with the results for the 3D case in the comparison subsection of the document.

3 3D shell elements

3.1 Introduction

The 3D study of the cylindrical tank has been done with the program Tdyn, with its application of simulation type for Structural Analysis, for the specific case:

Simulation Type
Shells
Linear-static model
Static analysis
Linear geometry
3D

3.2 Preprocess

As we only have access to a temporal version of the program with a limited maximum of nodes, taking advantage of the revolution symmetry of the problem only a quarter of the cylindrical tank has been studied (Figure 2a). The top spherical cupola has a continuous variation of the thickness what it is not possible to achieve in a shells model because the thickness of the shell has to be continuous. In order to simulate this change in the thickness three shells have been defined with decreasing thickness from top to bottom: $t = 0.12m$, $t = 0.21m$ and $t = 0.3m$. The lateral wall has constant thickness $t = 0.35m$.

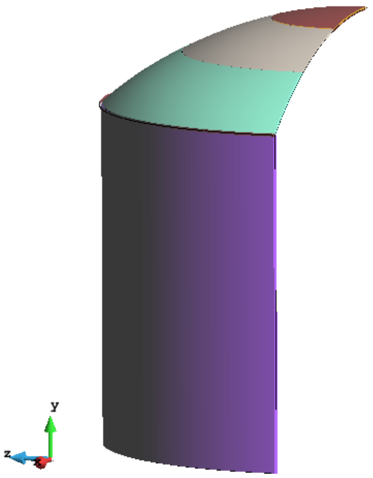
In the bottom of the geometry the tank is clamped, so all the degrees of freedom have been set to zero. On the other hand in order to be able to use the reduced model some symmetry boundary have to be imposed in the cut edges. These symmetry constrains are impeded displacement in the transverse direction to the lateral cut edges (x and z directions respectively). Also the rotations in the vertical rotation y-axis and also in the normal axis to the division edge (x and z axes respectively).

In order to impose the pressure load in the internal surfaces of the tank first it is needed to define local axes to the shells. In our case we have defined the local axes with z-axis in the direction of the external normal (pointing outwards the tank). Doing this the pressure load p are imposed in the z-direction and with positive sign.

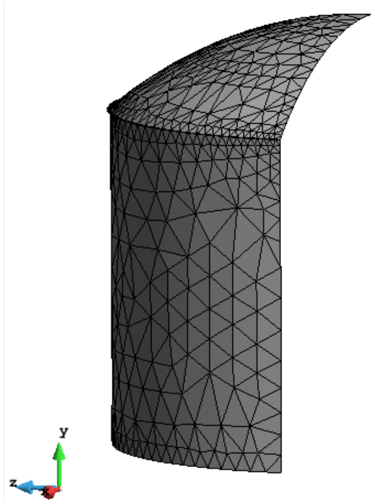
After all this previous considerations a mesh of 884 triangular shell elements and 490 nodes has been generated.

3.3 Results

The principle stresses have been plotted in Figure 3. As seen all the shells are compressed due to the normal pressure applied excepts the union between the lateral surface and the top cupola.



(a) Simplified 3D model studied.



(b) Mesh used for the 3D study. 490 nodes and 884 elements.

Figure 2: Shells model and mesh.

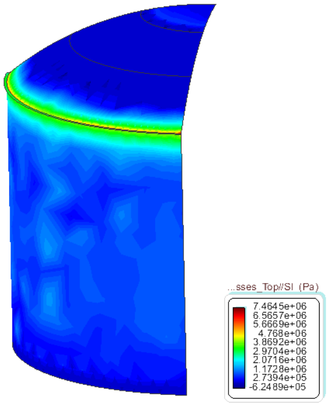
In this edge there is traction because pressure acts in opposite directions in the lateral faces and in the cupola, and therefore they tend to separate and causes tensions.

4 Comparison of results

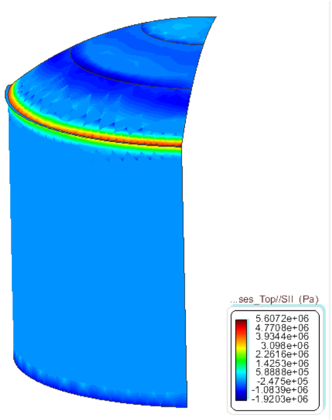
Comparing the 2D and 3D shell models we can see that they give very similar results for both the displacements and rotations (Figures 4 and 5). Therefore the two models can be used to study deformations without main differences. So it is proven that a 2D reduced model with revolution shell elements which is computational cheaper than a full 3D model gives reliable results regarding deformation.

On the other hand the axial forces in the 2D model presents a singularity in the top node that destroys the smooth visualization of the results in this model (Figures 6a and 7a). The longitudinal axial force in the shell are compared in Figure 6. In this field only the 3D model gives good and continuous results in all the shells, that presents a transient change in all the geometry (Figure 6b). The transverse axial force in the rotation direction are compared in Figure 7. Here again the 2D model also have the singularity in the top node and results cannot be visualized correctly. The 3D model performs well also for this component of the axial stress which are maximum at the union between the cupola and the lateral face.

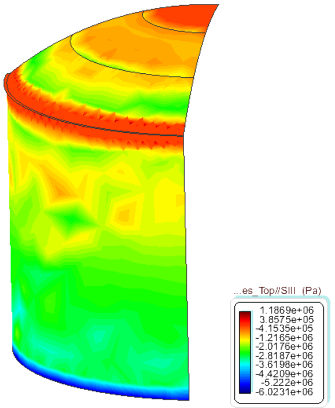
As a summary, we have seen that both models can be used indistinguishably when computing deformations but the 3D model is the only that can be used to simulate stresses states because the restrictions and symmetry conditions doesn't allow to display continuous smooth results.



(a) Principle stress S_i.

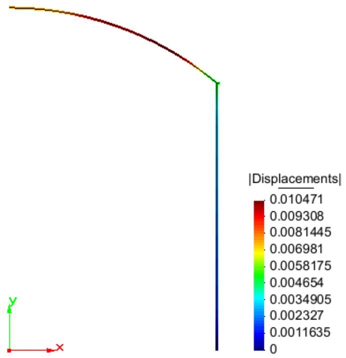


(b) Principle stress S_{ii}.

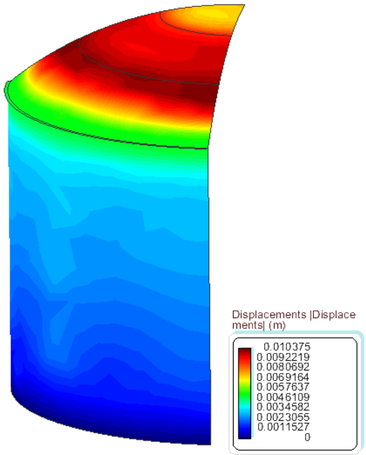


(c) Principle stress S_{iii}.

Figure 3: Principle stresses in the 3D shell model.

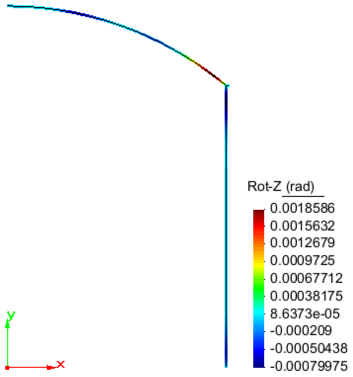


(a) Displacements in the 2D revolution shell model.

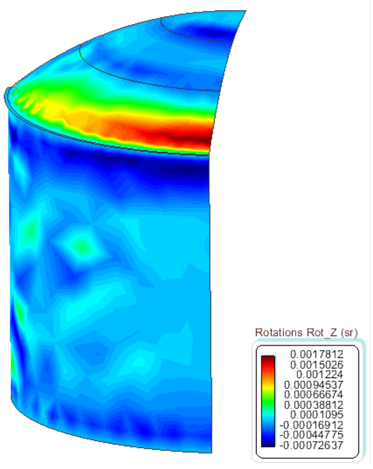


(b) Displacements in the 3D shell model.

Figure 4: Comparison between the displacements in the 2D and 3D models.

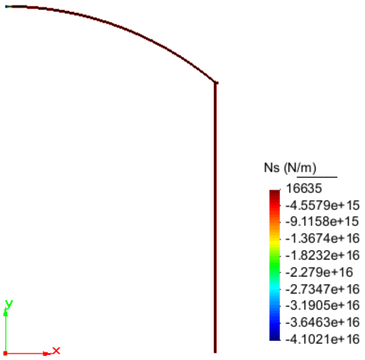


(a) Rotation in the z-axis in the 2D revolution shell model.

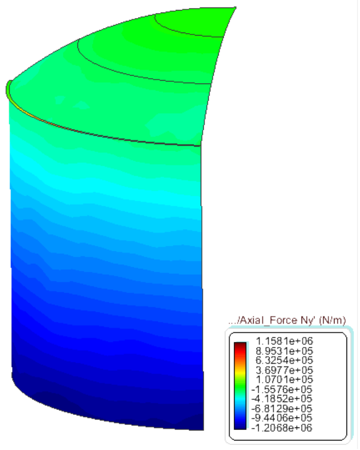


(b) Rotation in the z-axis in the 3D shell model.

Figure 5: Comparison between the rotations in the z-axis in the 2D and 3D models.

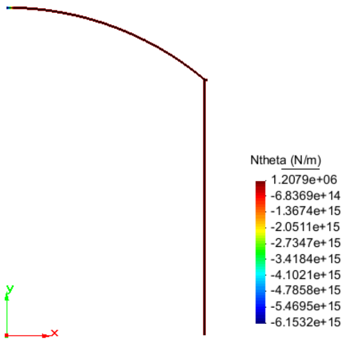


(a) Internal shell axial force in the 2D revolution shell model.

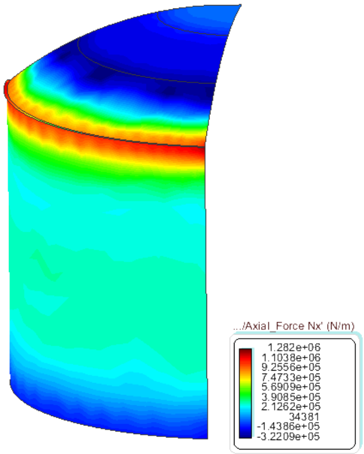


(b) Axial stress in the local y'-axis in the 3D shell model.

Figure 6: Comparison between the in shell axial forces in the 2D and 3D models.



(a) Radial shell axial force in the 2D revolution shell model.



(b) Axial stress in the local x'-axis in the 3D shell model.

Figure 7: Comparison between the radial axial forces in the 2D and 3D models.