# Politecnico di Bari

**Dipartimento di Scienze dell' Ingegneria Civile e dell'Architettura**


# An Innovative solution for Water Bottling Using PET


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# The idea


To pressurize PET bottles in order to balance an external axial load and to reduce the amount of utilized PET.

Two conditions:

1) The bottle must not exceed the elastic limit of PET.
2) The geometry must not reach the geometric instability (buckling).

# Main Physical Phenomenon

The deformed geometry depends on the applied forces, that is on the external load and the inner pressure of fluids (water and air).

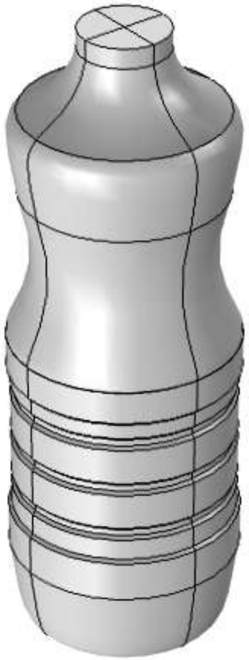
Since the bottle is a closed system, the contained matter is constant. The pressure of fluids depends on the free volume and consequently on the deformed shape of the bottle.

V=f(pi)

pi=f(V)

Implicit System

# Geometry and meshes

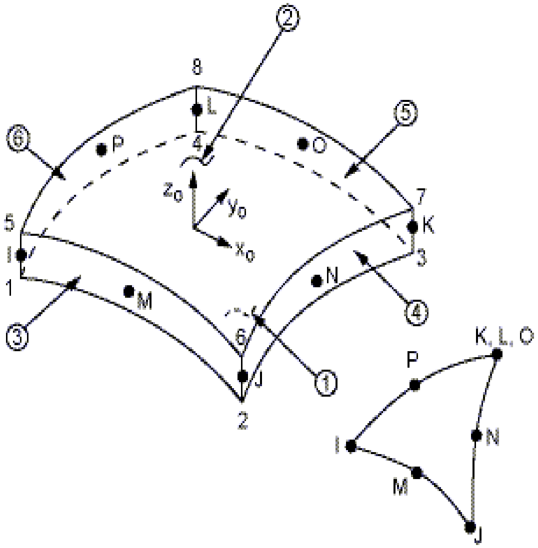


Generic geometry
Height 190 mm
Diameter 67 mm

Mesh of surface
23 thousand triangles

Mesh of volume:
76 thousand tetrahedra

# Mathematical models




- Solid phase:

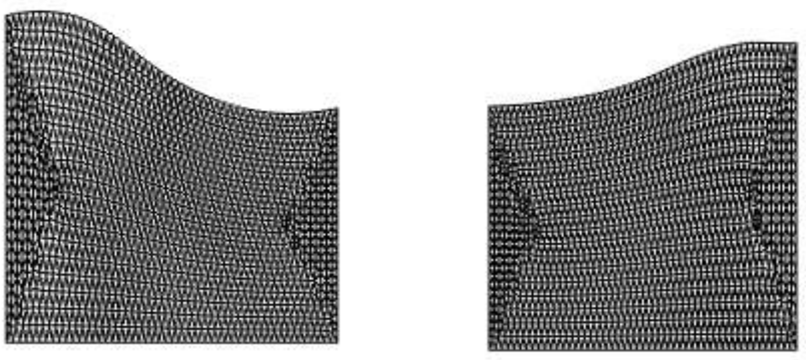
SHELL MODULE

With geometric nonlinearities

d=0,167 mm

D=67 mm

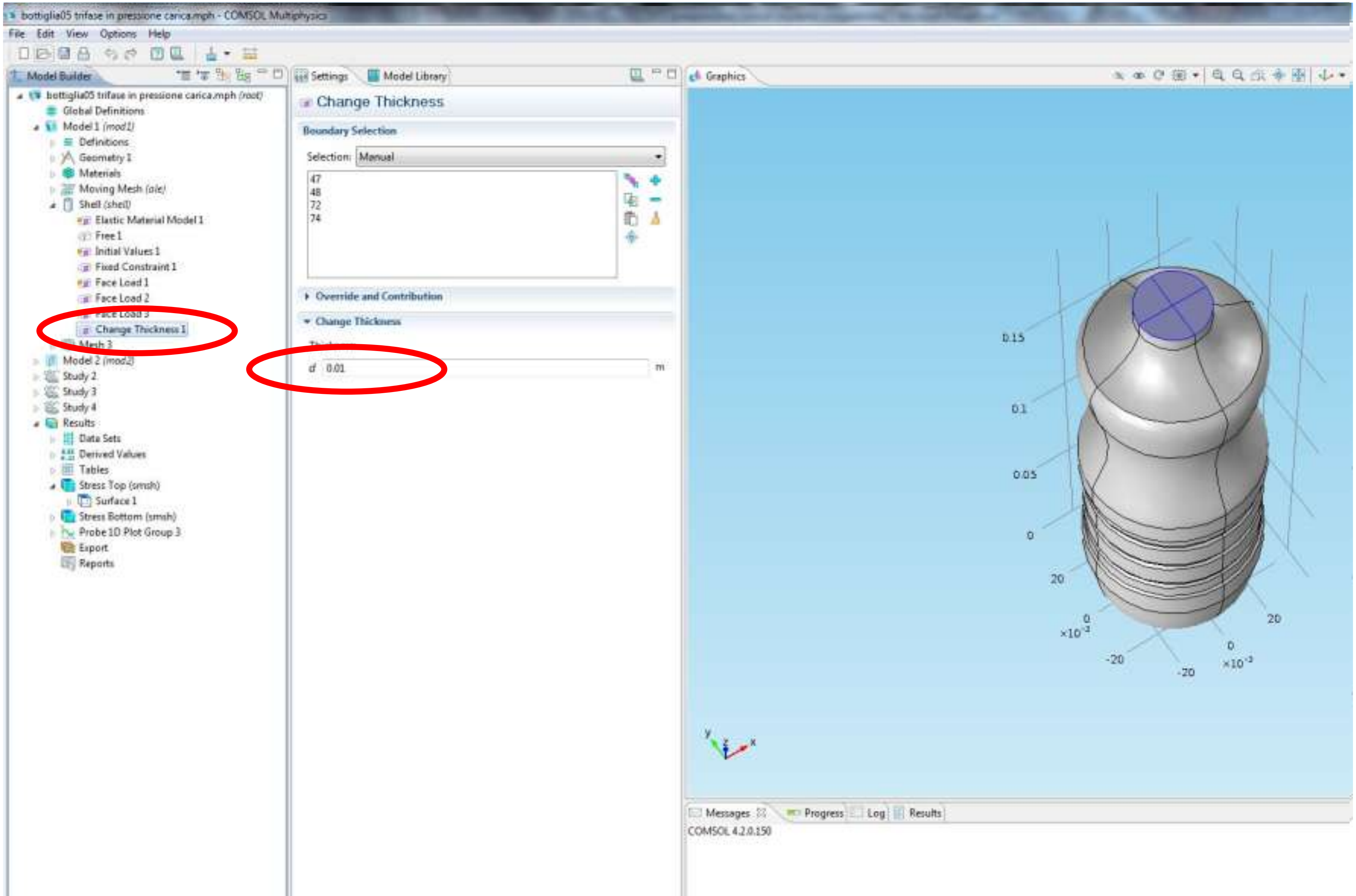
$d/D=2,5*10^{-3} << 1$



- Fluid phases:

MOVING MESH MODULE

# SHELL Module

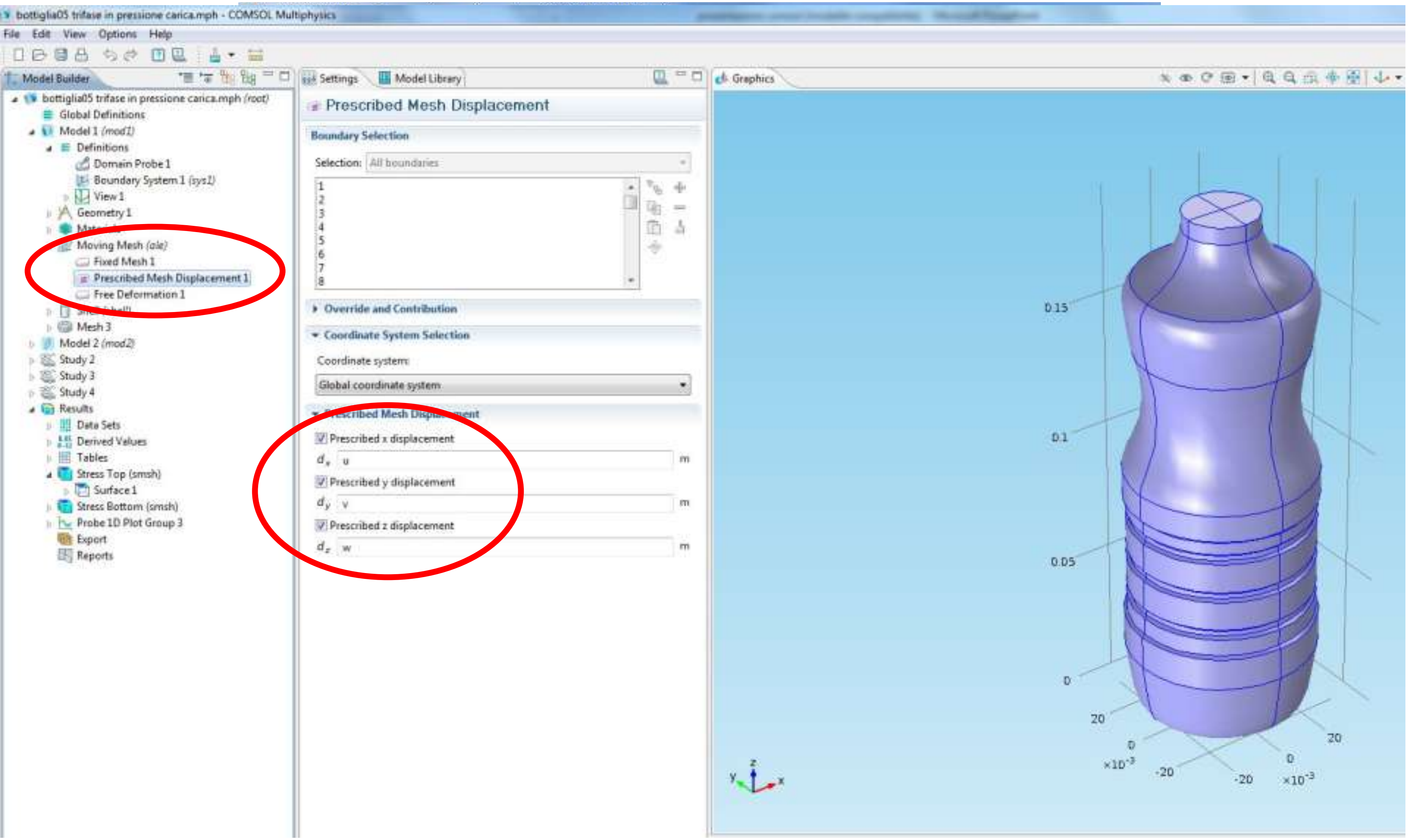


# MOVING MESH Module

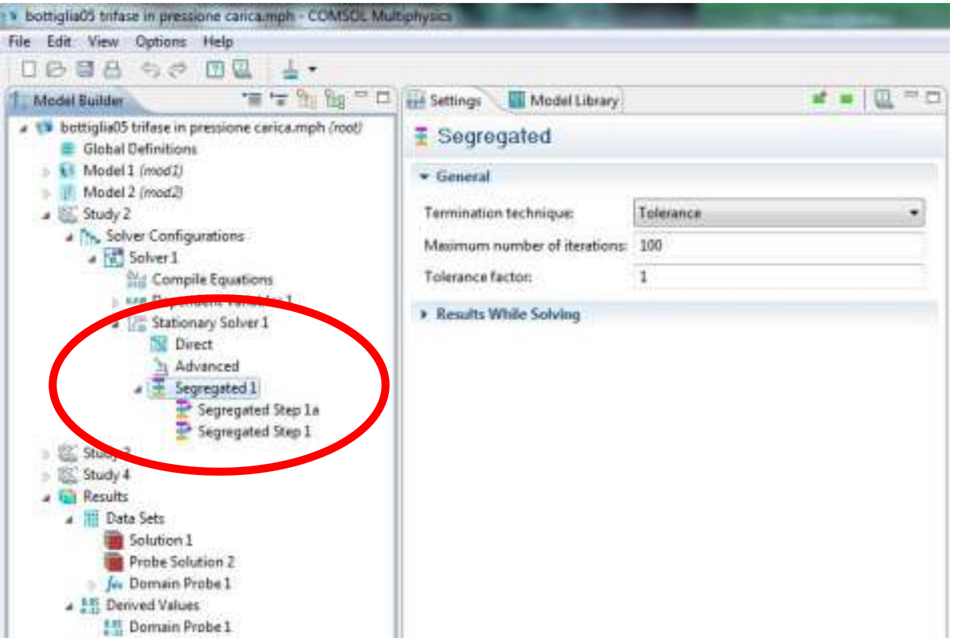
- Since water is incompressible, a change in its pressure does not affect its volume.
- As a consequence, the volume taken by the air is equal to the difference between the deformed shape of the bottle and the volume of the water.
- The volume of the bottle is evaluated by means of a "probe" defined as the integral of the unit over the volumetric mesh.
- The relative pressure of air is linked to the volume of the bottle by the following relationship:

$$p = pi * \left( \frac{V_{i,gas}}{V_{bottle} - V_{water}} \right)^{1,4}$$

# MOVING MESH Module



# Solver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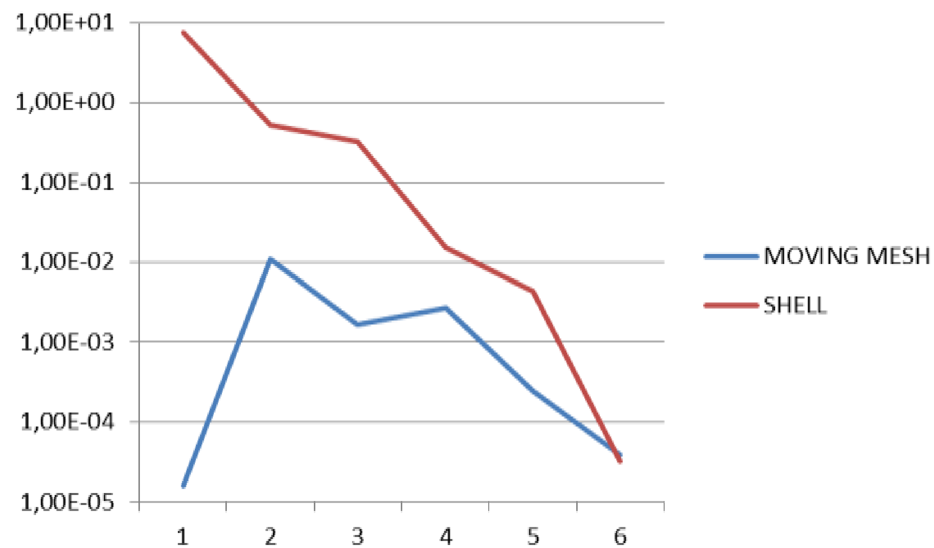
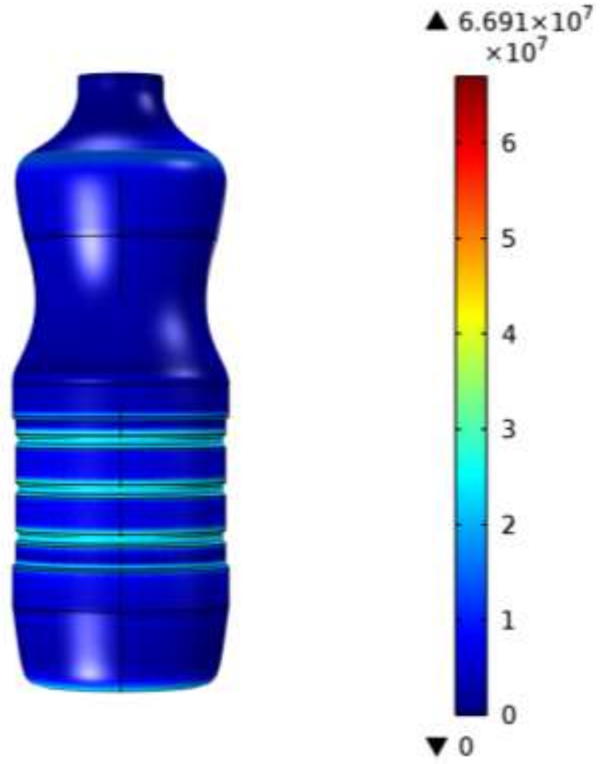
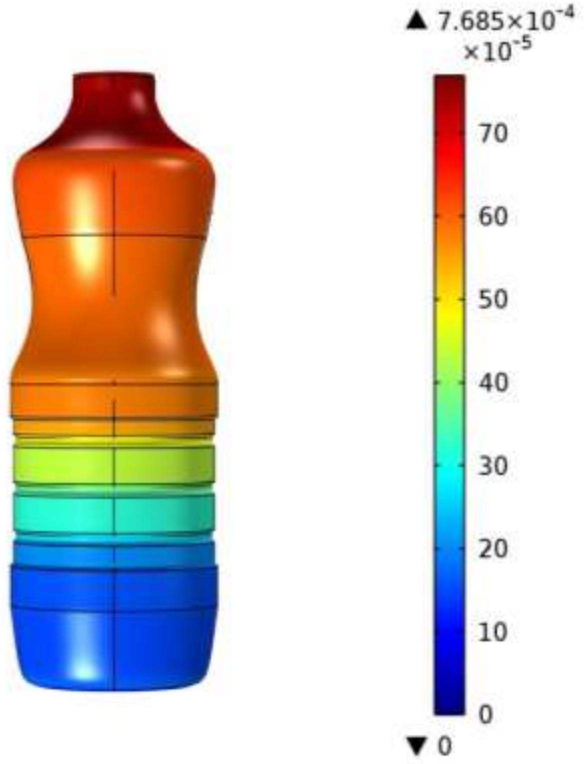
File Edit View Options Help
Model Builder
bottiglia05 trifase in pressione carica.mph (root)
Global Definitions
Model 1 (mod1)
Model 2 (mod2)
Study 2
Solver Configurations
Solver 1
Compile Equations
Stationary Solver 1
Direct
Advanced
Segregated 1
Segregated Step 1a
Segregated Step 1
Study 4
Results
Data Sets
Solution 1
Probe Solution 2
Domain Probe 1
Derived Values
Domain Probe 1
Settings
Model Library
Segregated
General
Termination technique:
Tolerance
Maximum number of iterations:
100
Tolerance factor:
1
Results While Solving


1,00E+01
1,00E+00
1,00E-01
1,00E-02
1,00E-03
1,00E-04
1,00E-05
1
2
3
4
5
6
MOVING MESH
SHELL

# Results (without load)

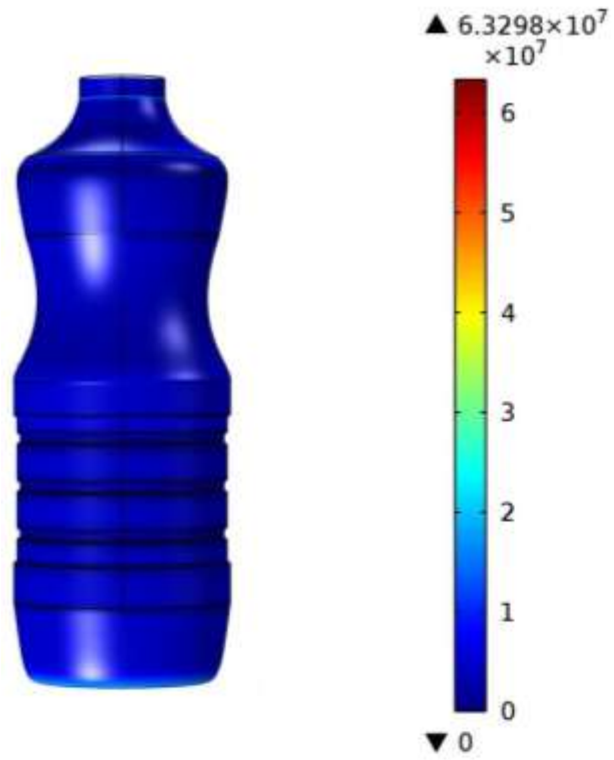



Von Mises stresses [Pa]

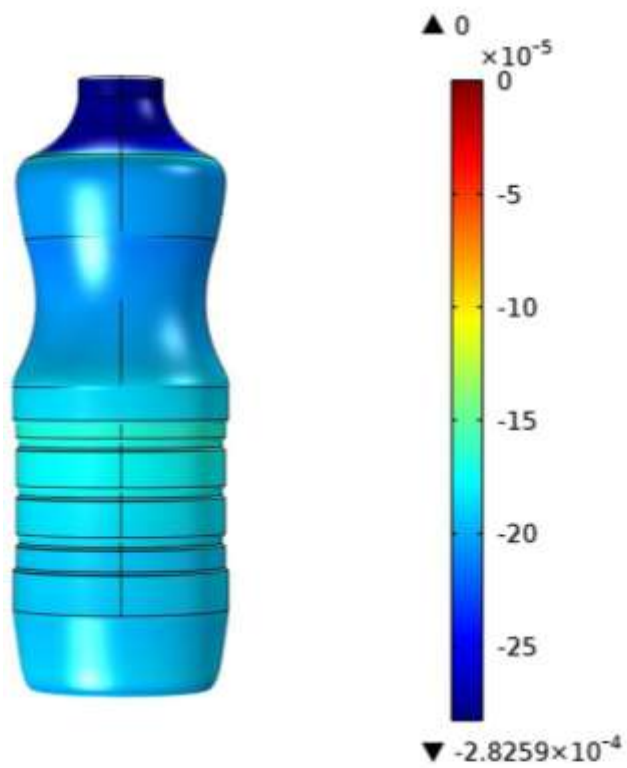



Displacement field, axial component [m]

# Results (with load)

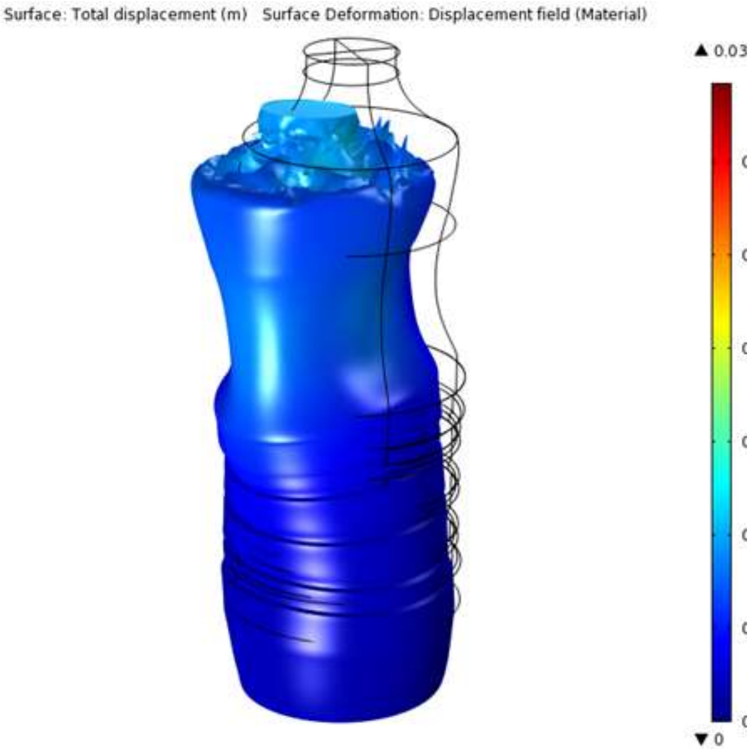


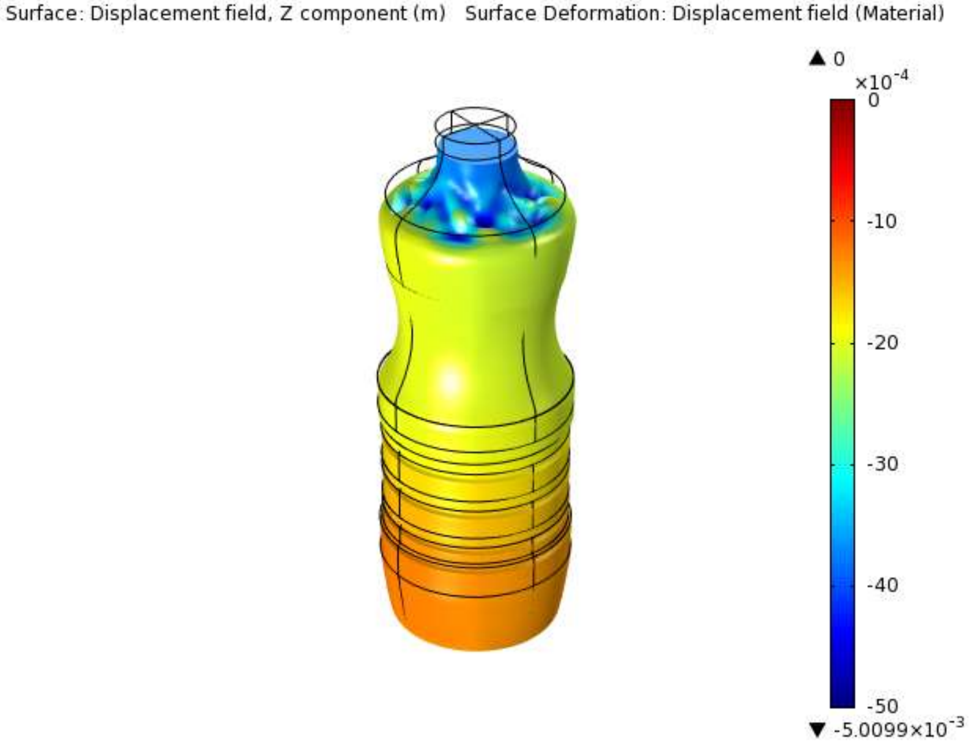

Von Mises stresses [Pa]



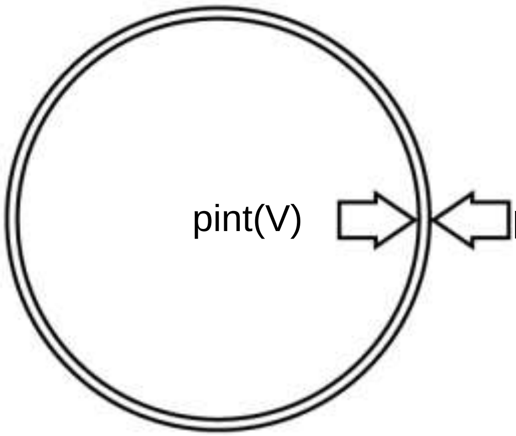

Displacement field, axial component [m]

# Results (buckling)



# A test case: analytical solution



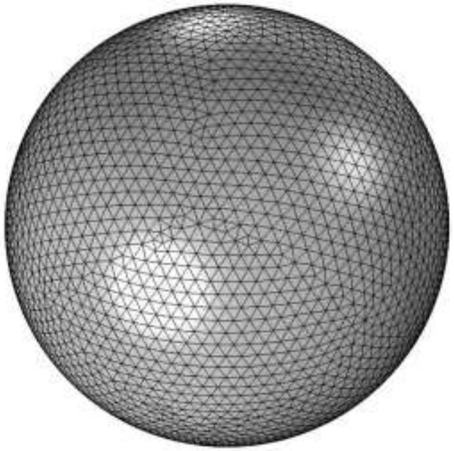

Diameter $r_0$=1 m
Thickness s=1 mm
$p_{int,0}$= 6 bar
$p_e$= 3 bar
E = 200 GPa
v= 0,29

$$r_i = r_0 + \frac{(p_{int,i} - p_e) * r_0^2}{2Es}(1 - \upsilon)$$

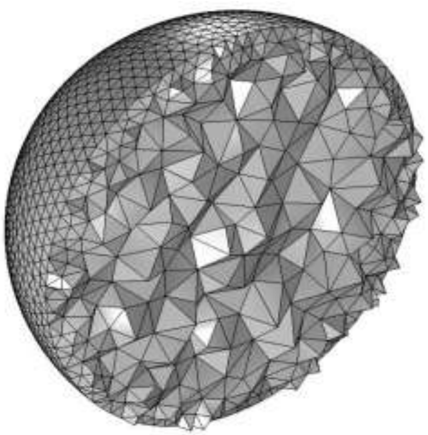
$$p_{int,i} = p_{int,1} * \left(\frac{V_1}{V_i}\right)^{\gamma}$$

$r_i$-$r_0$=0,53487 mm
$p_{int,i}$=601366 Pa

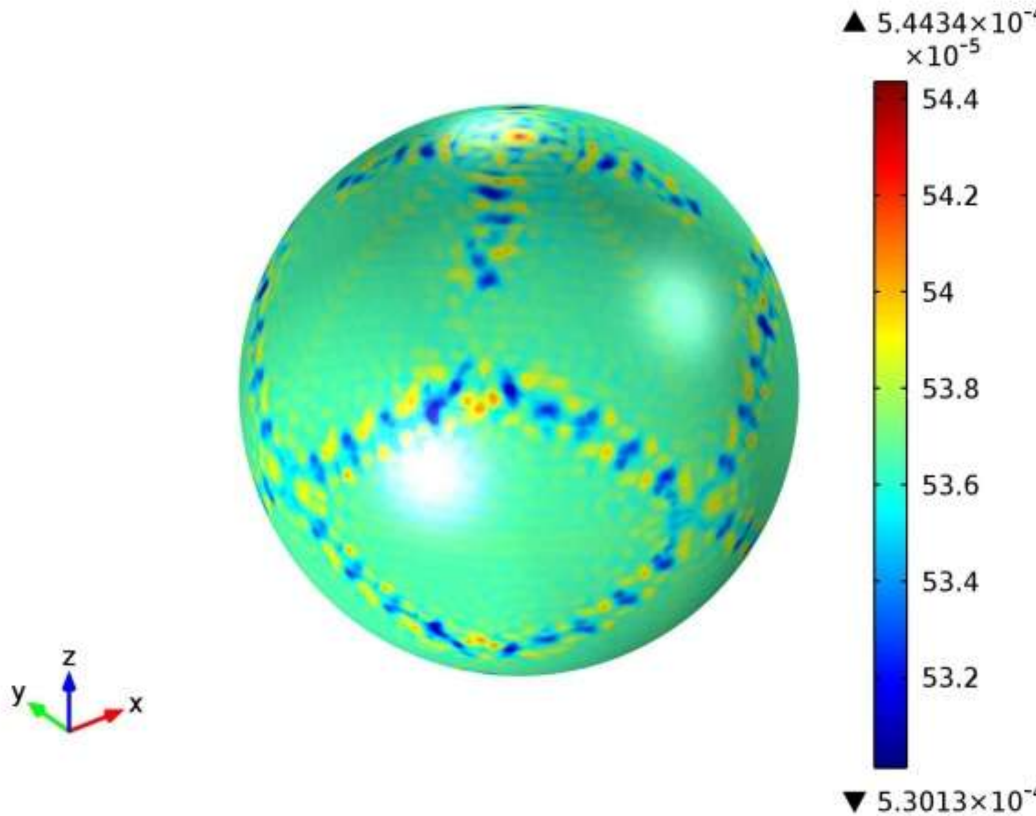
# A test case: numerical solution



7000 triangles



37000 tetrahedra



Any questions?