

**LAB 3. A 3D quarter model of a pressure vessel. Stress state in a thin-walled shell of revolution.**

1. Create geometry of a quarter model of the vessel shown in Fig. 1. (the model is built "from the Bottom Up"):

a) change the active coordinate system to Global Spherical: (Utility Menu > Working Plane > Change Active CS to > Global Spherical)

b) create six keypoints starting from 1 to 6 (Fig. 1) (Preprocessor > Modeling > Create > Keypoints > In Active CS).

(Type  $1000/\cos(20 \cdot 4 \cdot \text{ATAN}(1.0)/180)$  instead of  $1000/\cos 20^\circ$ )

c) create four lines between keypoints (1-2), (2-3), (4-5), (5-6) (Preprocessor > Modeling > Create > Lines > In Active Coord)

d) change the active coordinate system to Global Cartesian: (Working Plane > Change Active CS to > Global Cartesian)

e) copy keypoint 4 along X axis with the distance  $a = 100$  mm (Preprocessor > Modeling > Copy > Keypoints)

f) create lines between keypoints (3-4) and (4-7) (Preprocessor > Modeling > Create > Lines > Straight Line)

g) extrude the shell meridian (5 lines) about the axis defined by points 1 and then 6, Arc length in deg: 90, No. of area segments: 1 (Preprocessor > Modeling > Operate > Extrude > Lines > About Axis) (Fig. 2)

h) extrude the reinforcing ring (line between keypoints 4-7) about the vessel axis (1-6) (Fig. 2)

i) merge the areas, keypoints and lines: Preprocessor > NumberingCtrls > Merge Items > All,

j) save the database (Utility Menu > File > Save As..., shell\_geom.db)

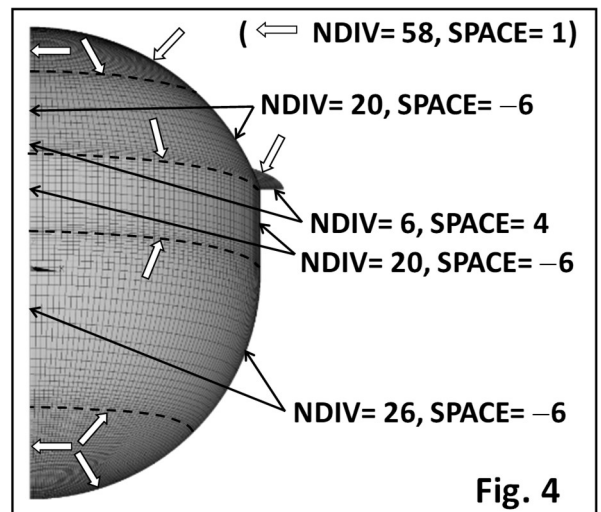
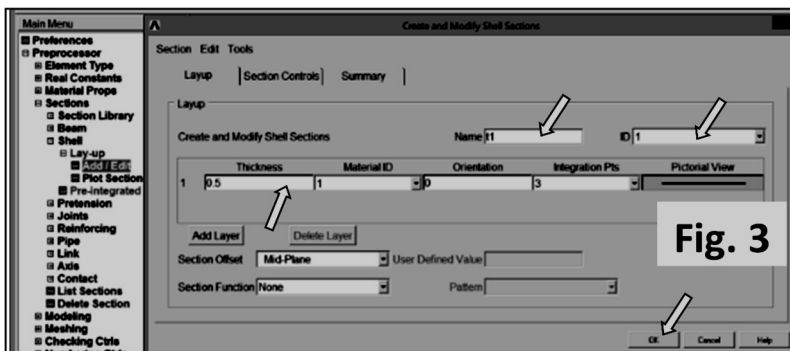
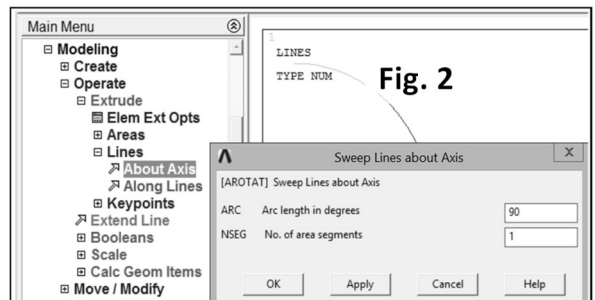
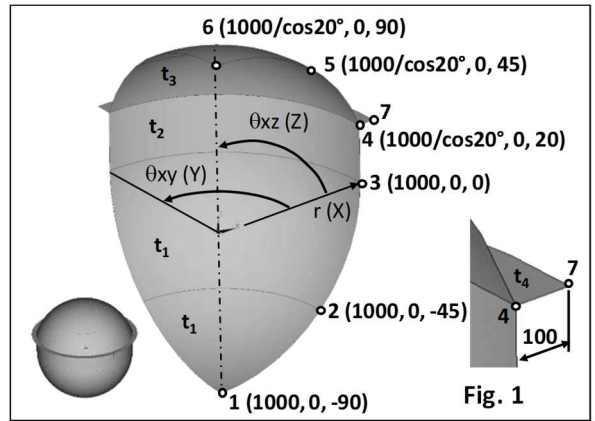
2. Choose a finite element: SHELL 281 (Shell 8 node) (Preprocessor > Element Type > Add >)

3. Define a linear elastic, isotropic material properties:  $E = 2 \cdot 10^5 \text{MPa}$  (Young's modulus) and  $\nu = 0.3$  (Poisson's ratio),

4. Create 4 shell sections (Preprocessor > Sections > Shell > Lay-up > Add/Edit, one-by-one) (Fig. 3):

$$t_1 \geq \frac{|p|R}{2\sigma_a} = 0.5 \text{ mm}; t_2 \geq \frac{\sqrt{3}|p|R}{2\sigma_a} = 0.866 \text{ mm}; t_3 \geq \frac{|p|R}{2\sigma_a \cos 20^\circ} = 0.532 \text{ mm}; t_4 \geq \frac{|p|R^2 \tan 20^\circ}{2a\sigma_a} = 1.82 \text{ mm}$$

where: pressure  $p = 0.1 \text{MPa}$ , radius  $R = 1000 \text{mm}$ , allowable stress  $\sigma_a = 100 \text{MPa}$ , the ring width  $a = 100 \text{mm}$  (thicknesses were calculated assuming that only the membrane stress exists)



5. Specify the density of discretisation on lines and create a mapped quadrilateral mesh (Fig. 4) .

6. Save the mesh as an image (Plot > Elements, PlotCtrls > Redirect Plots-> To JPEG File ...)

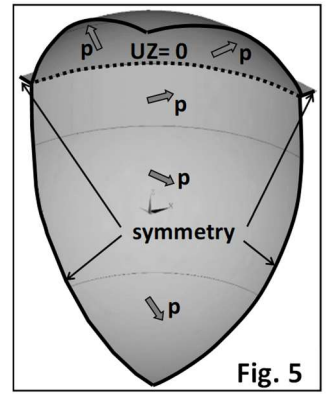
7. Note numbers of nodes and elements in Tab. 1 (Utility Menu > List > Status > Global Status)

8. Apply boundary conditions: symmetry condition on the shell meridians and displacement  $U_z = 0$  on the inner edge of the reinforcing ring, and pressure of 0.1 MPa on the shell (Fig. 5), Solution > Apply > Structural > Displacement > Symmetry B.C > On Lines, and Pressure > On Areas,

9. Solve (Solution-> Solve-> Current LS)

10. Choose the global cylindrical system for results presentation (Main Menu > General Postproc > Options for Output > [RSYS]-> Global Cylidric, [SHELL] ->Top layer) (Fig. 9).

11. Plot a contour map of the radial displacement (*Main Menu>General Postproc>Plot Results>Contour Plot> Nodal Solu> DOF Solution> X-Component of displacement, Scale Factor: Off*) (Fig. 6). Save the contour map as an image and note the minimum and maximum values of UX in Tab. 1.



12. Plot a contour map of Von Mises stress (SEQV) (*Main Menu> General Postproc> Read Results>First Set, and Main Menu>General Postproc>Plot Results>Contour Plot> Nodal Solu>Stress > Von Mises stress, Scale Factor: Off*) (Fig. 7). Save it as an image and note the maximum value of Von Mises stress in Tab. 1.

13. Select the part of the thickness  $t_1$  (*Utility Menu> Select> Entites> Areas > By Attributes > Section number > 1 -> Apply, Sele Belo*). Plot and save a contour map of Von Mises stress (Fig. 8) and note the data in Tab. 1.

14. Repeat selection for remaining parts of the vessel. Save contour maps as shown in Fig. 8 and fill Tab. 1.

*For points A and C change the system for results presentation to the Global Spherical.*

15. Select the entire vessel: (*Utility Menu> Select> Everything*) and then unselect the reinforcing ring. Define the path between cylindrical and upper spherical parts as shown in Fig 9 and map the Von Mises stress on the top, bottom and middle layer of the shell. Save the graph as an image.

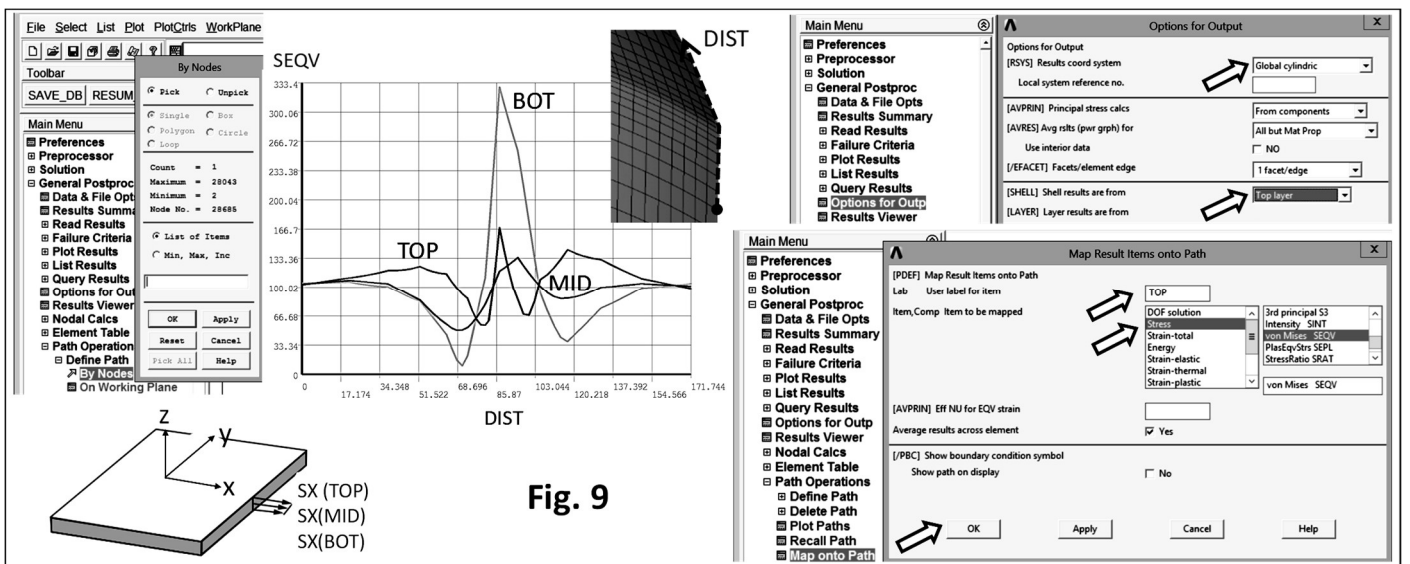
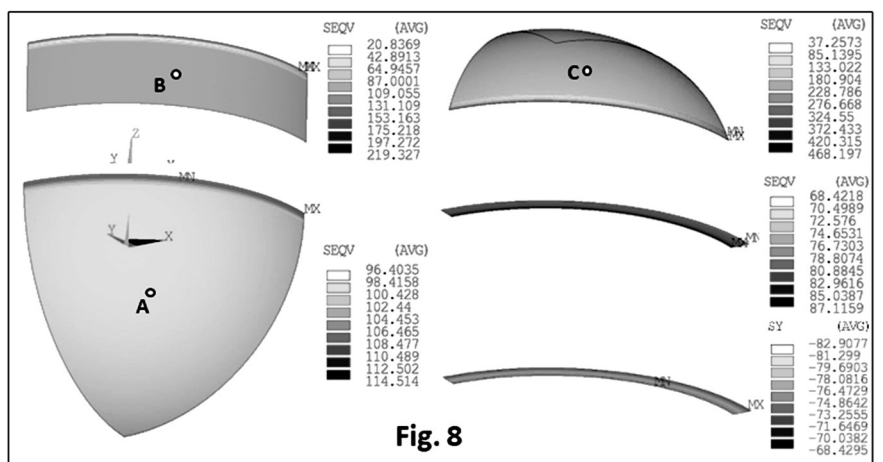
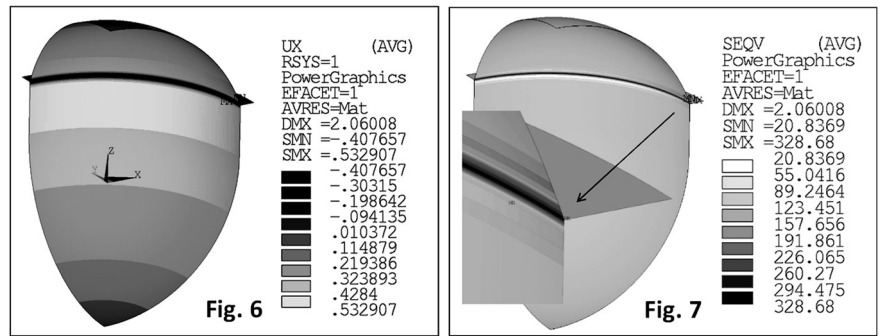
16. Set the shell thickness  $t_1$  to 0.54 mm and assume  $t_4 = 10$  mm for the reinforcing ring. Adjust  $t_2 = t_3$  values (together) until the maximum Von Mises stress in the entire vessel is less than the allowable stress ( $\sigma_0 = 100$  MPa). Save contours maps and the graph (as shown in Fig. 6 to 9) as images, and note the data in Tab. 2.

17. Change the thickness  $t_1$  to have only membrane stress state between the two shell parts of thicknesses  $t_1$  and  $t_2$  :

$$t_1 = (1-\nu) / (2-\nu) \cdot t_2.$$

Use  $t_2, t_3,$  and  $t_4$  values obtained at point 16. Solve the model. Save the two contour maps as shown on the left of Fig. 8 and note the data in Tab. 3.

18. Change the thickness of the reinforcing ring (use  $t_4$  values given in Tab. 4, and  $t_1, t_2, t_3$  from point 17). Perform analyses and save the data in Tab. 4. Show the maximum value of Von Mises stress  $SEQV_{max} = f(t_4)$  on a graph (Excel).



19. Discuss results and write conclusions.