SSLX101 - Pipe right modelled in shells and beams

Summarized:

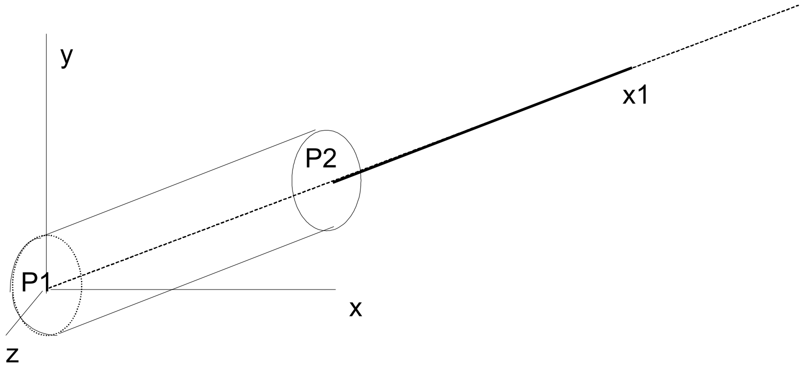
The purpose of this test is validating connection shell-beam. The pipe is embedded at an end, and subjected to 4 successive forces (tension and 3 moments) on the other end. A half of the pipe is with a grid in shells, the other is with a grid out of beams. The fixed support and the connection between the shell part and the beam are carried out by a connection shell-beam, making it possible in particular to transmit to the shell only the torsor of the forces of type beam, without generating secondary stresses.

The reference solution is analytical (strength of materials). The variation with the numerical solution (from 3 to 5%) is explained by the fact why the mesh in shells actually consists of element planes (facets). The geometry of the pipe is thus itself approximate. The solution obtained makes it possible to check that connection between the shell elements and the beam element is correct.

1 Problem of reference

1.1 Geometry

right Pipe length $80\,m$, modelled in shells enters 0 and $40\mathrm{m}$, and out of beams enters 40 and $80\mathrm{m}$.
External radius: $2\mathrm{m}$, thickness: $0.1\mathrm{m}$.
The axis of the pipe is in the plane Oxy , tilted of 30 degrees compared to Ox .



1.2 Material properties

$E=2.10^{11}\,Pa$
$\nu=0.3$

1.3 Boundary conditions and loadings

Fixed support "of standard beam" in $x=y=0$, realized by a connection shell-beam between edge $C1$ of the shell and a point $P1$ (located in O). It is this point which is blocked.

4 unit loading cases applied to the point $P2(80\times cos30\,,80\times sin30\,,0)$

Tension $Fx1=1\mathrm{N}$ along the axis $Ox1$, either $Fx=cos30.Fx$ and $Fy=sin30.Fx1$
Twisting moment $Mx1=1\mathrm{Nm}$ around $Ox1$, or $Mx=cos30.Mx1$ and $My=sin30.Mx1$
Bending moment $My1=1\mathrm{Nm}$ around $Oy1$ or $Mx=-sin30.My1$ and $My=cos30.My1$
Bending moment around Oz , or $Mz=1\mathrm{Nm}$

2 Reference solution

2.1 Method of calculating used for the analytical reference solution

Solution for each of the 4 cases of loading:

In beam theory, in the frame of the assumptions of Eulerian-Bernouilli, the solution of the problem of reference is that of a straight beam subjected to forces and moments at an end and embedded at the other end:

Tension : $\mathbf{u}_{x_1} = F_{x_1} \dfrac{x}{ES} \mathbf{e}_{x_1}$

Torsion : $\boldsymbol{\theta}_{x_1} = M_{x_1} \dfrac{x}{GJ} \mathbf{e}_{x_1}$

Bending around O_{y_1} : $\boldsymbol{\theta}_{y_1} = \dfrac{M_{y.x}}{EI_{y1}} \mathbf{e}_{y1}$

Bending around O_z : $\boldsymbol{\theta}_z = \dfrac{M_{z.x}}{EI_z} .\mathbf{e}_z$

2.2 Results of reference

Tension:

$$u_{x_1}(P_2) = F_{x_1} \frac{L}{ES}$$

donc $$u_x(P_2) = F_{x_1} \frac{L}{ES}.\cos(30)$$

$$u_y(P_2) = F_{x_1} \frac{L}{ES} \sin(30)$$

Torsion:

$$\theta_{x_1}(P_2) = M_{x_1} \frac{L}{GJ}$$

donc $$\theta_x(P_2) = M_{x_1} \frac{L}{GJ} \cos(30)$$

$$\theta_y(P_2) = M_{x_1} \frac{L}{GJ} \sin(30)$$

Bending around: O_{y_1}

$$\theta_{y_1} = M_{y_1} \frac{L}{EI_{y1}}$$

donc $$\theta_x = -\theta_{y_1}.\sin(30)$$

$$\theta_y = \theta_{y_1} \cos(30)$$

et $$u_z = -M_{y_1} \frac{L^2}{2EI_{y_1}}$$

Bending around: O_z

$$\theta_z = M_z \frac{L}{EI_z}$$

et $$u_{y_1} = M_z \frac{L^2}{2EI_z}$$

donc $$u_x = u_{y_1} \sin(30)$$

$$u_y = u_{y_1} \cos(30)$$

Note:

The use of connection shells beams for the fixed support and the loadings makes it possible to remain in the frame of the assumption of Eulerian-Bernouilli (cf [R3.03.06]). The preceding analytical solution is thus well the reference solution of the problem.

2.3 Uncertainty on the analytical

solution Solution.

3 Modelization A

3.1 Characteristic of modelization

1 nets POI1 (modelization DIS_TR), 1280 meshes QUAD4 (modelization DKT), 4 meshes SEG2 (POU_D_E). 32 meshes SEG2 on each edge of the shell.

3.2 Characteristics of the mesh

Many nodes: 4416
Number of meshes and types: 1 POI1, 4 SEG2, 1280 QUAD4

3.3 Values tested

Displacements and rotations at the point $P2$ (to be multiplied by $1.\mathrm{E}-10m$).

Loading case	Identification	Reference	*Aster*	% difference
Tension	DX	2.8273	2.7942	1.2
Tension	DY	1.6324	1.6132	1.2
Torsion	DRX	1.93195	1.8713	3.1
Torsion	DRY	1.1154	1.0804	3.1
Bending Y	DZ	– 68.64	– 64.88	5.5
Bending Y	DRX	– 0.858	– 0.827	3.7
Bending Y	DRY	1.4861	1.4319	3.7
Bending Z	DX	– 34.32	– 32.44	5.5
Bending Z	DY	59.44	56.19	5.5
Bending Z	DRZ	1.716	1.653	3.7

4 Modelization B

4.1 Characteristic of the modelization

the beam part is modelled by pipe sections . The shell part is modelled in DKT.

4.2 Characteristics of the mesh

Many nodes: 4420
Number of meshes and types:

- 1 mesh POI1 (modelization DIS_TR),
- 1344 meshes QUAD4 (modelization DKT), 32 meshes SEG2 on each edge of the shell
- 4 meshes SEG3 (PIPE)

4.3 Values tested

Displacements and rotations at the point $P2$ (to be multiplied by $1.\mathrm{E}-10m$).

Loading case	Identification	Reference	*Aster*	% difference
Tension	DX	2.8273	2.7942	1.2
Tension	DY	1.6324	1.6132	1.2
Torsion	DRX	1.93195	1.8713	3.1
Torsion	DRY	1.1154	1.0804	3.1
Bending Y	DZ	– 68.64	– 64.92	5.4
Bending Y	DRX	– 0.858	– 0.827	3.7
Bending Y	DRY	1.4861	1.4325	3.7
Bending Z	DX	– 34.32	– 32.40	5.6
Bending Z	DY	59.44	56.11	5.6
Bending Z	DRZ	1.716	1.652	3.7

5 Summary of the results

the reference solution is analytical (strength of materials). The variation with the numerical solution (from 3 to 5%) is explained by the fact why the mesh in shells actually consists of plane elements (facets). The geometry of the pipe is thus itself approximate. The solution obtained makes it possible to check that connection between the shell elements and the beam element is correct.