SSLX101 - Pipe right modelled in hulls and in beams

Summary:

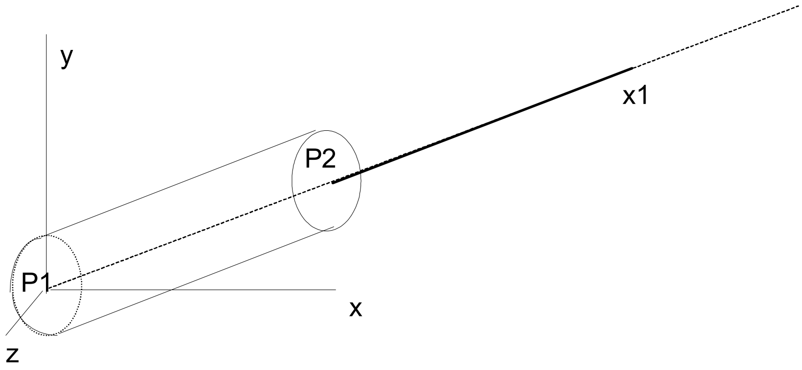
The purpose of this test is to validate the connection hull-beam. The pipe is embedded at an end, and subjected to 4 successive efforts (traction and 3 moments) on the other end. A half of the pipe is with a grid in hulls, the other is with a grid in beams. Embedding and the connection between the hull part and the beam are carried out by a connection hull-beam, allowing in particular to transmit to the hull only the torque of the efforts of type beam, without generating secondary stresses.

The reference solution is analytical (resistance of materials). The variation with the digital solution (from 3 to 5%) is explained by the fact why the grid in hulls actually consists of element plans (facets). The geometry of the pipe is thus itself approximate. The solution obtained makes it possible to check that connection between the elements of hull and the element of beam is correct.

1 Problem of reference

1.1 Geometry

Right pipe length $80\,m$, modelled in hulls enters 0 and 40m , and in beams enters 40 and 80m .
External ray: 2m , thickness: 0.1m .
The axis of the pipe is in the plan 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

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

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

Traction $Fx1=1\text{N}$ along the axis $Ox1$, that is to say $Fx=cos30.Fx$ and $Fy=sin30.Fx1$
Torque $Mx1=1\text{Nm}$ around $Ox1$, that is to say $Mx=cos30.Mx1$ and $My=sin30.Mx1$
Bending moment $My1=1\text{Nm}$ around $Oy1$ that is to say $Mx=-sin30.My1$ and $My=cos30.My1$
Bending moment around Oz , that is to say $Mz=1\text{Nm}$

2 Reference solution

2.1 Method of calculating used for the reference solution

Analytical solution for each of the 4 cases of loading:

In theory of beams, within the framework as of assumptions of Euler-Bernouilli, the solution of the problem of reference is that of a right beam subjected to efforts and moments at an end and embedded at the other end:

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

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

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

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

2.2 Results of reference

Traction:

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

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

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

Torsion:

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

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

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

Inflection 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 $u_z = -M_{y_1} \dfrac{L^2}{2EI_{y_1}}$

Inflection 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 the connection hulls beams for embedding and the loadings makes it possible to remain within the framework of the assumption of Euler-Bernouilli (cf [R3.03.06]). The preceding analytical solution is thus well the reference solution of the problem.

2.3 Uncertainty on the solution

Analytical solution.

3 Modeling A

3.1 Characteristics of modeling

1 mesh POI1 (modeling `DIS_TR`), 1280 meshs QUAD4 (modeling `DKT`), 4 meshs SEG2 (`POU_D_E`). 32 meshs SEG2 on each edge of the hull.

3.2 Characteristics of the grid

Many nodes: 4416
Many meshs 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
Traction	DX	2.8273	2.7942	1.2
Traction	DY	1.6324	1.6132	1.2
Torsion	DRX	1.93195	1.8713	3.1
Torsion	DRY	1.1154	1.0804	3.1
Inflection Y	DZ	– 68.64	– 64.88	5.5
Inflection Y	DRX	– 0,858	– 0,827	3.7
Inflection Y	DRY	1.4861	1.4319	3.7
Inflection Z	DX	– 34.32	– 32.44	5.5
Inflection Z	DY	59.44	56.19	5.5
Inflection Z	DRZ	1,716	1,653	3.7

4 Modeling B

4.1 Characteristics of modeling

The beam part is modelled by elements of PIPE. The hull part is modelled in DKT.

4.2 Characteristics of the grid

Many nodes: 4420
Many meshs and types:
- 1 mesh POI1 (modeling DIS_TR),
- 1344 meshs QUAD4 (modeling DKT), 32 meshs SEG2 on each edge of the hull
- 4 meshs SEG3 (PIPE)

4.3 Values tested

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

Loading case	Identification	Reference	*Aster*	% difference
Traction	DX	2.8273	2.7942	1.2
Traction	DY	1.6324	1.6132	1.2
Torsion	DRX	1.93195	1.8713	3.1
Torsion	DRY	1.1154	1.0804	3.1
Inflection Y	DZ	– 68.64	– 64.92	5.4
Inflection Y	DRX	– 0,858	– 0,827	3.7
Inflection Y	DRY	1.4861	1.4325	3.7
Inflection Z	DX	– 34.32	– 32.40	5.6
Inflection Z	DY	59.44	56.11	5.6
Inflection Z	DRZ	1,716	1,652	3.7

5 Summary of the results

The reference solution is analytical (resistance of materials). The variation with the digital solution (from 3 to 5%) is explained by the fact why the grid in hulls actually consists of elements plans (facets). The geometry of the pipe is thus itself approximate. The solution obtained makes it possible to check that connection between the elements of hull and the element of beam is correct.