SSLL101 - Piping: Problem of HOVGAARD

Summary:

It is about a linear elastic test, in statics, of a noncoplanar three-dimensional piping comprising elbows. There exists a test in dynamics of same structure (SDLX02) [V2.05.002].

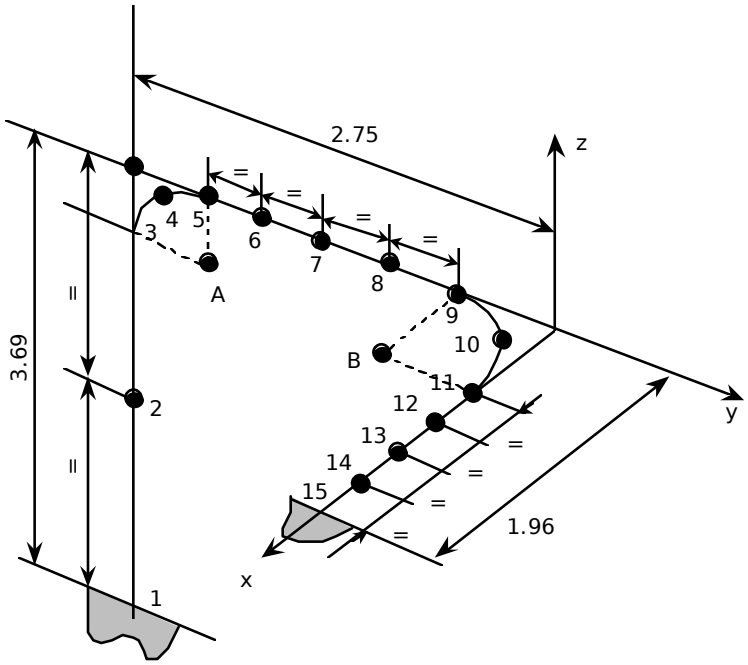
The elements are tested POU_D_T, PIPE (SEG3 and SEG4) and TUYAU_6M (SEG3) via 5 modelings:
- modeling a: 92 elements POU_D_T (40 for an elbow), calculation with MECA_STATIQUE,
- modeling C: 28 elements PIPE (SEG3) (5 for an elbow), calculation with MECA_STATIQUE,
- modeling D: 28 elements TUYAU_6M (SEG3) (5 for an elbow), calculation with MECA_STATIQUE,
- modeling E: 28 elements PIPE (SEG4) (5 for an elbow), calculation with MECA_STATIQUE,

The loadings are of type:
- gravity,
- thermics,
- nodal forces.

1 Problem of reference

1.1 Geometry

Geometry, as well as the points of modeling are represented on the following figure:



A	0. –1.828 –0.922
B	0.922 –0.922 0.

Lengths in meters

- diameter external of the pipe: $0.185\,m$
- thickness of the pipe: $6.12\,mm$
- radius of curvature of the elbows: $0.922\,m$
- piping full of water

1.2 Material properties

$E = 1.658\,E+11\,Pa$
$\nu = 0.3$
$\rho = 13404.10\,kg/m^3$
$\alpha = 0.1288\,E-4/C°$

1.3 Boundary conditions and loadings

- Items 1 (group of node T1) and 15 (group of node T15) embedded,
  - Loading:
    1. Gravity according to $-z$,
    2. Uniform rise in temperature of $472.22\,C°$,
    3. Nodal forces.

Groups of node	T2	T3	T4, T10	T5, T9	T6, T7, T8	T11	T12, T13	T14
Fz (N)	– 624,897	– 788,724	– 327,654	– 214,839	– 102.5145	– 222,687	– 117,720	– 176,580

2 Reference solution

2.1 Method of calculating used for the reference solution

Reference solutions adopted to check modelings *Code_Aster* are the following ones:

- for modelings BEAM : comparison with the codes: POUX , ADL and TITUS-T [1], using a modeling of type beam,
- for modelings PIPE : comparison with the code ABAQUS , using a modeling of type pipe. The number of mode of Fourier (M) used during the calculation of the reference is identical to that used at the time as of calculations with *Code_Aster*.
- for modelings beams, one also defines a moment equivalent to the point $T1$ like $M_{eq}=\sqrt{(MT^2+MFY^2+MFZ^2)}$. The value of reference is that obtained with the hand with the results of modeling A (reference AUTRE_ASTER).

2.2 Results of reference

Cas de Chargement	Displacement as in point 3 (group of node T3)	Modeling Beam (POUX , ADL , TITUS)	Modeling Pipe: $M=3$ (ABAQUS)	Modeling Pipe: $M=6$ (ABAQUS)
Actual weight	DX	– 0.1658E-3	– 0.16517E-3	– 0.16512E-3
	DY	– 0.2040E-4	– 0.13870E-4	– 0.13946E-4
	DZ	– 0.8010E-5	– 0.80376E-5	– 0.80369E-5
Nodal force	DX	– 0.1651E-3	– 0.16445E-3	– 0.16441E-3
	DY	– 0.2080E-4	– 0.14245E-4	– 0.14320E-4
	DZ	– 0.9516E-5	– 0.10047E-4	– 0.10047E-4
Dilation	DX	– 6.1418E-3	– 6.3277E-3	– 6.3236E-3
	DY	– 13.090E-3	– 13.092E-3	– 13.093E-3
	DZ	16.799E-3	16.798E-3	16.798E-3

Case of loading	Moment are equivalent to the point $T1$	Reference AUTRE_ASTER (modeling A)
Actual weight	M_{eq}	189.76886594440944

2.3 Uncertainty on the solution

Uncertainty on the reference solution is fixed at 2% .

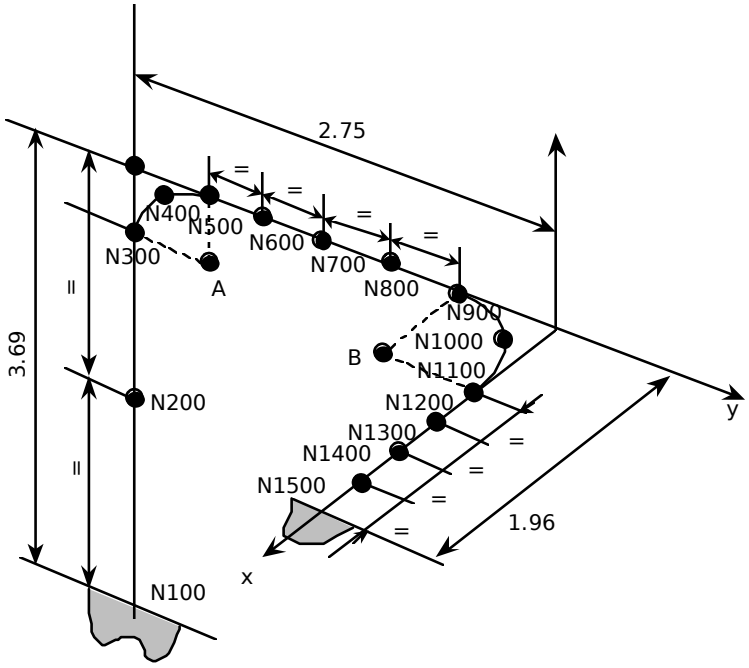
2.4 Bibliographical references

[1] M.W. KELLOG Co. Design of Piping Systems. New York, 1956 - Problem n°5.9

3 Modeling A

3.1 Characteristics of modeling

The curved elements are modelled by right elements.
A half curved element is modelled by 20 right elements.



Lengths in meters

3.2 Characteristics of the grid

Many nodes: 93
Number of meshs and type: 92 POU_D_T

3.3 Sizes tested and results

Identification	Displacement		Type of reference	Value of reference	Precision (%)
Actual weight	$T3$	DX	'SOURCE_EXTERNE'	– 0.1658E-3	0.1
		DY	'SOURCE_EXTERNE'	– 0.2040E-4	0.1
		DZ	'SOURCE_EXTERNE'	– 0.8010E-5	0.1
Nodal force	$T3$	DX	'SOURCE_EXTERNE'	– 0.1651E-3	0.1
		DY	'SOURCE_EXTERNE'	– 0.2080E-4	0.1
		DZ	'SOURCE_EXTERNE'	– 0.9516E-5	0.1
Dilation	$T3$	DX	'SOURCE_EXTERNE'	– 6.1418E-3	0.1
		DY	'SOURCE_EXTERNE'	– 13.090E-3	0.1
		DZ	'SOURCE_EXTERNE'	16.799E-3	0.1

Identification	Type of reference	Value of reference	Precision (%)
Not $T1$ - $X1$ Field UT01_ELNO	'AUTRE_ASTER'	189.76886594440944	0.1

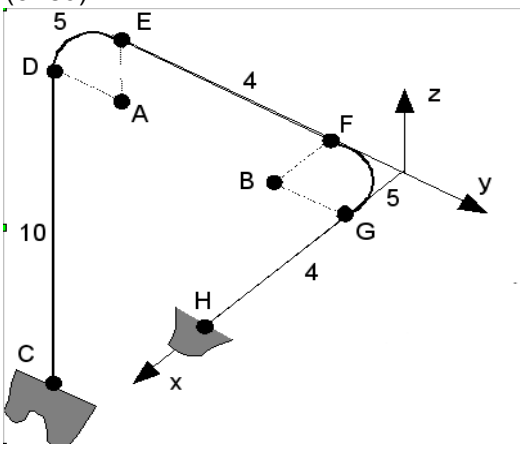
3.4 Notice

Differences between the results *Aster* and the reference solution beam are all lower than 0.05% .

4 Modeling C

4.1 Characteristics of modeling

Modeling PIPE (SEG3)



Lengths in meters

Boundary conditions: points C and H

- DDL beam: $DX=DY=DZ=DRX=DRY=DRZ=0$
- DDL hull:
  - $UIm=VIm=WIm=0 (m=2,3)$
  - $UOm=VOm=WOm=0 (m=2,3)$
  - $WI1=WO1=WO=0$

4.2 Characteristics of the grid

Many nodes:	57
Number of meshs and type:	28 SEG3

4.3 Values tested

Identification	Displacement	Reference pipe ($M=3$)	%
	Not D DX	– 0.16517E-3	– 0.93
Actual weight	DY	– 0.13870E-4	– 9.80
	DZ	– 0.80376E-5	– 0.24
	Not D DX	– 0.16445E-3	– 0.94
Nodal force	DY	– 0.14245E-4	– 9.61
	DZ	– 0.10047E-4	– 0.20
	Not D DX	– 6.3277E-3	1.99
Dilation	DY	– 13.092E-3	0.08
	DZ	16.798E-3	– 0.93

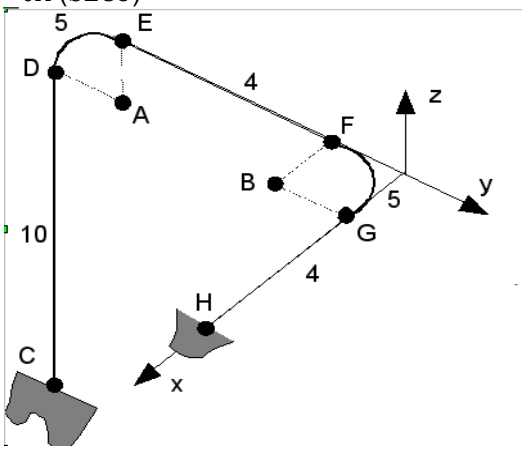
4.4 Notice

Results got with *Code_Aster* are similar to those of ABAQUS by elements pipes except for displacement DY (actual weight and nodal force) where the variation is about 10%.

5 Modeling D

5.1 Characteristics of modeling

Modeling TUYAU_6M (SEG3)



Lengths in meters

Boundary conditions: points C and H

- DDL beam: $DX=DY=DZ=DRX=DRY=DRZ=0$
- DDL hull:
  - $UIm=VIm=WIm=0(m=2,6)$
  - $UOm=VOm=WOm=0(m=2,6)$
  - $WI1=WO1=WO=0$

5.2 Characteristics of the grid

Many nodes:	57
Number of meshs and type:	28 SEG3

5.3 Sizes tested and results

Identification	Displacement	Reference pipe ($M=6$)	%
	Not D DX	– 0.16512E-3	– 0.93
Actual weight	DY	– 0.13946E-4	– 9.78
	DZ	– 0.80369E-5	– 0.24
	Not D DX	– 0.16441E-3	– 0.94
Nodal force	DY	– 0.14320E-4	– 9.58
	DZ	– 0.10047E-4	– 0.21
	Not D DX	– 6.3236E-3	1.99
Dilation	DY	– 13.093E-3	0.08
	DZ	16.798E-3	0.49

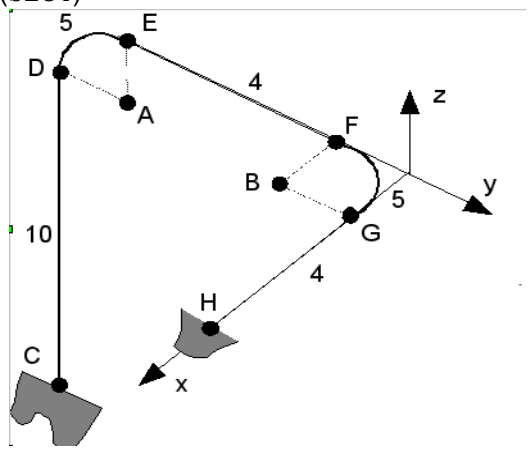
5.4 Notice

Results got with *Code_Aster* are similar to those of ABAQUS for elements pipes except for displacement DY (actual weight and nodal force) where the variation is about 10%.

6 Modeling E

6.1 Characteristics of modeling

Modeling PIPE (SEG4)



Lengths in meters

Boundary conditions: points C and H

- DDL beam: $DX=DY=DZ=DRX=DRY=DRZ=0$
- DDL hull:
  - $UIm=VIm=WIm=0(m=2,3)$
  - $UOm=VOm=WOm=0(m=2,3)$
  - $WI1=WO1=WO=0$

6.2 Characteristics of the grid

Many nodes:	85
Number of meshs and type:	28 SEG4

6.3 Sizes tested and results

Identification	Displacement	Reference pipe ($M=3$)	%
Actual weight	Not D DX	– 0.16517E-03	– 0.22
	DY	– 0.13870E-04	– 4.73
	DZ	– 0.80376E-05	– 0.18
Nodal force	Not D DX	– 0.16445E-03	– 0.37
	DY	– 0.14245E-04	– 1.74
	DZ	– 0.10047E-04	– 0.50
Dilation	Not D DX	– 6.3277E-03	0.02
	DY	– 13.092E-03	0.10
	DZ	16.798E-03	0.27

6.4 Remarks

Grid in SEG4 is obtained starting from a grid SEG3 with the order CREA_MAILLAGE, MODI_MAILLE with the option 'SEG3_4'. It is important that the node medium of SEG3 that is to say well in the medium, it *Code_Aster* check this condition with a tolerance.
Results got with *Code_Aster* are similar to those of ABAQUS with elements pipes except for displacement DY (actual weight and nodal force) or the variation is about 5% and 2%.

7 Summary of the results

This CAS-test makes it possible to test a noncoplanar piping.

Modeling beam:
The results are similar to the reference solution (modeling beam: average of results of 3 codes).

Modeling pipe:
Results *Code_Aster* are similar to those of ABAQUS (for elements pipes), except for displacement DY and for the loadings actual weight and nodal forces where the variation with the reference solution is more important with the meshs SEG3 (10%) that with the meshs SEG4 (5%).
The thermal loading of dilation gives similar results.