# SSLX102 - Piping bent in inflection

**Summary:**

This test validates the modeling of the phenomena of ovalization in pipings: an elbow, prolonged by right pipes is subjected to one bending moment. This one causes in the elbow an ovalization which is propagated and diminishes in the right parts, and which modifies the rigidity of the whole of piping. To check the exactitude of the results, one tests the flexibility of the whole of piping (value of displacement at the end for one imposed moment) and the elements of hulls DKT.

The case test comprises six modelings:

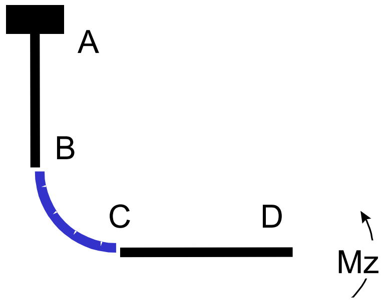
- For modeling A, the elbow is with a grid in hulls (modeling DKT), modeling pipe is used for the right parts, the connection is ensured by a connection COQUE_TUYAU.
- For modelings B and C, modeling PIPE is assigned to the whole of piping: TUYAU_3M for B and TUYAU_6M for C ( $M$ = modes of Fourier).
- In modeling D, piping is with a grid in hulls (elements COQUE_3D), the ends are with a grid in beams to apply the loadings.
- Modeling E: Modeling PIPE (3 modes of Fourier) is assigned to the whole of piping.
- For modeling F, the elbow is with a grid in voluminal meshs, the right parts in elements PIPE and the connection is ensured by a connection 3D_TUYAU.

Modeling A makes it possible to validate the good transmission of ovalization (mode 2) between the elements PIPE, and the connection validates COQUE_TUYAU, two modelings B and C make it possible to validate the elements PIPE (with 3 and 6 modes of Fourier) in linear elasticity and last modeling makes it possible to validate the good transmission of ovalization (mode 2) between the elements PIPE, and the connection validates 3D_TUYAU.

# 1 Problem of reference

## 1.1 Geometry

Piping bent in the plan $XY$. The right parts have as a length $L=1200\,mm$.
The elbow has as a radius of curvature: $Rc=305\mathrm{mm}$




The tubular section has as an average radius $R=105.5\mathrm{mm}$ and for thickness $e=8.18\mathrm{mm}$

## 1.2 Properties of materials

$E=200000\,MPa$
$\nu=0.3$

## 1.3 Boundary conditions and loadings

Embedding in $A$

2 loading cases:

1) Moment $MZ$ imposed in $D$ : $MZ=17000\,Nm$ (cross-bending).
2) Inflection except plan: moment $My$ imposed in $D$
$My=17000\,Nm$

## 1.4 Initial conditions

Without object.

# 2 Reference solution

## 2.1 Method of calculating used for the reference solution

Comparison with other digital results got with grids 3D or hulls (within the framework in particular of the tripartite Card 3455 of the ECA, (see references), and with a calculation COQUE_3D rather fine (modeling D).

## 2.2 Results of reference

For one moment applied $MZ$ in $D$ of $17000\,Nm$ , displacement $DY$ same point $D$ is worth:

| **Type of calculation** | $Dy$ **not** $D$ **(** $mm$ **)** |
|---|---|
| Calculation ECA (hulls + Victus) | 0.02 |
| Calculation COQUE_3D | 0.02012 (modeling D) |

We choose for reference the value $Dy=0.02\,mm$ .

For the inflection except plan, the value of reference (calculation COQUE_3D end) is worth $-1.5657\,10^{-2}\,mm$ .

## 2.3 Precision on the results of reference

Owing to the fact that the reference solution is digital, one can evaluate the precision according to [§2.2] to 2%.

## 2.4 References bibliographical

1) M.N. BERTON: “Elastoplastic calculations of pipings with CASTEM 2000. Formulation VICTUS. Synthesis of card 3455”. Note CEA/LDM 96/6036

2) J.M. PROIX, A. BEN HAJ YEDDER: “Project CACIP: study of a piping bent in inflection”. Note EDF/DER HI-75/98/001/0

# 3 Modeling A

## 3.1 Characteristics of modeling

The elbow is with a grid in hulls (meshs QUAD4, modeling DKT). All the right parts are with a grid in elements pipes (meshs SEG3, modeling PIPE).

## 3.2 Characteristics of the grid

320 meshs QUAD4
8 meshs SEG3
32 meshs SEG2 (edges of hulls).

## 3.3 Values tested

| Loading case | Displacement of the point $D$ | Reference | *Aster* | % diff |
|---|---|---|---|---|
| $Mz=17000\,Nm$ | $DY(mm)$ | 0.02 | 0.01941 | 3.0 |
| $My=17000\,Nm$ | $DZ(mm)$ | – 0.015657 | – 0.0157 | 0.3 |

# 4 Modeling B

## 4.1 Characteristics of modeling

The whole of piping is with a grid with elements `PIPE`, rights or bent.

## 4.2 Characteristics of the grid

86 meshs SEG3

## 4.3 Values tested

| Loading case | Displacement of the point $D$ | Reference | *Aster* | % diff |
|---|---|---|---|---|
| $Mz=17000\,Nm$ | $DY(mm)$ | 0.02 | 0.0186 | 6.8 |
| $My=17000\,Nm$ | $DZ(mm)$ | – 0.015657 | – 0.0154 | 1.9 |

# 5 Modeling C

## 5.1 Characteristics of modeling

All piping is modelled in `TUYAU_6M` (6 modes of Fourier).

## 5.2 Characteristics of the grid

86 meshs SEG3

## 5.3 Values tested

| Loading case | Displacement of the point $D$ | Reference | *Aster* | % diff |
|---|---|---|---|---|
| $Mz=17000\,Nm$ | $DY\,(mm)$ | 0.02 | 0.0199 | 0.01 |
| $My=17000\,Nm$ | $DZ\,(mm)$ | – 0.015657 | – 0.01598 | 2 |

# 6 Modeling D

## 6.1 Characteristics of modeling

- Piping is with a grid in hulls (elements hulls 3D).
- The ends are with a grid in beams (`POU_D_T`) to be able to apply the boundary conditions easily.
- This modeling constitutes a reference solution for modelings A, B and C in particular for the inflection except plan where one does not have results published.

## 6.2 Characteristics of the grid

680 meshs QUAD8
2 meshs SEG2

## 6.3 Values tested

| Loading case | Displacement of the point $D$ | Reference | *Aster* | % diff |
|---|---|---|---|---|
| $Mz=17000\,Nm$ | $DY(mm)$ | 0.02 | 0.0192 | 0.6 |
| $My=17000\,Nm$ | $DZ(mm)$ | – 0.015657 | – 0.015601 | 0.4 |

# 7 Modeling E

## 7.1 Characteristics of modeling

The whole of piping is with a grid with elements PIPE, rights or bent, being pressed on meshs with 4 nodes.

## 7.2 Characteristics of the grid

18 meshs SEG4 (10 in the elbow, 4 in each right part).

## 7.3 Values tested

| Loading case | Displacement of the point $D$ | Reference (MOD B) | *Aster* | % diff |
|---|---|---|---|---|
| $Mz=17000\,Nm$ | $DY(mm)$ | 0.0186 | 0.01854 | 0.4 |
| $My=17000\,Nm$ | $DZ(mm)$ | – 0.0154 | – 0.0153 | 0.2 |

# 8 Modeling F

## 8.1 Characteristics of modeling

The two right parts of piping are with a grid with elements PIPE bent, being pressed on meshs with 3 nodes. The elbow is with a grid with voluminal meshs HEXA20.

This modeling thus makes it possible to validate the good transmission of ovalization (mode 2) between the elements PIPE on the right parts and the elbow in 3D, and the connection validates 3D_TUYAU.

## 8.2 Characteristics of the grid

234 meshs SEG3.
512 meshs HEXA20.

## 8.3 Values tested

| Loading case | Displacement of the point $D$ | Reference | *Aster* | % diff |
|---|---|---|---|---|
| $Mz=17000\,Nm$ | $DY(mm)$ | 0.0200 | 0.01922 | 4.4 |
| $My=17000\,Nm$ | $DZ(mm)$ | – 0.015657 | – 0.01561 | 0.0 |

# 9 Summary of the results

This test not having reference solutions analytical, but digital, the noted variations (lower than 2% except a value) can be regarded as reasonable.

More precisely, for modeling A (elbow with a grid in hulls DKT and right beams in PIPE) one can estimate that the solution obtained (2.7% of variation in cross-bending, and 0.4% in inflection except plan, compared to the reference: grid all in hulls of modeling D) makes it possible to validate the good performance of connection coque_tuyau.

For modeling B (elements PIPE, 3 modes of Fourier), the important variation on cross-bending (6.8%) is due to the fact that piping is relatively thin, therefore that ovalization in the elbow reveals of the modes of Fourier of a nature higher than 3.

In fact, modeling C (PIPE, 6 modes of Fourier) is very close to the reference (0.01% in cross-bending, and 2% in inflection except plan). The element pipe is thus validated in elasticity for these loadings, compared to a solution in hulls (modeling D).

Modeling E (elements PIPE to 4 nodes) gives results identical to modeling B, at a cost of weaker calculation due to a less fine grid.