# SSNL117 - Bend in bending in elastoplasticity

**Summarized:**
This test validates the modelization of the phenomena of ovalization in the pipework in the elastoplastic field with the elements PIPE: an elbow, prolonged by right pipes is subjected to a bending in its plane. The pipework is thick (of size similar to the elbows of the primary education circuits). The reference solution is numerical: it is obtained with *Code_Aster* using a mesh $3D$ of the elbow.

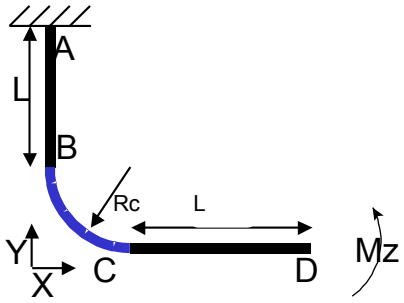
The two modelizations make it possible to validate A the elements PIPE (with right and bent elements with 3 nodes for the modelization and of the right and bent elements with 4 nodes for the modelization B) in elastoplasticity.

Into the modelization B, a term of “total” rotation, developed by EDF, French atomic energy agency and FRAMATOME [bib2], for the pipework under seisme, is introduced via a macro-command Python.

# 1 Problem of reference

## 1.1 Geometry

Pipework bent in the plane $XY$. The right parts have as a length $L=1\,m$.
The elbow has as a radius of curvature: $Rc=1.25\mathrm{m}$




The tubular section has for average radius $R=395.5\mathrm{mm}$ and a thickness $e=77\mathrm{mm}$.

## 1.2 Properties of the materials

the material is elastoplastic with isotropic linear hardening.

$E=2.\mathrm{E}11\,Pa$

$\nu=0.3$

Elastic limit $SIGY=200.10^{6}\,Pa$

Hardening modulus $\mathrm{D\_SIGM\_EPSI}=2.10^{10}\,Pa$

## 1.3 Boundary conditions and loadings

Fixed support in $A$ (degrees of freedom of beam blocked, but free degrees of freedom of ovalization).

Moment $MZ$ imposed while $D$ growing:

Increment 1 $Mz=3086702.1520853\,Nm$

10 equal increments until:

Increment 11 $Mz=7091146.5935484\,Nm$

## 1.4 Initial conditions

Without object.

# 2 Reference solution

## 2.1 Method of calculating used for the reference solution

Comparison to other numerical results got with *Code_Aster* (version 4.3 [bib1]) with a mesh $3D$ of the elbow and right parts, connected at the ends with straight beams. This mesh $3D$ comprises 1024 meshes HEXA20. A modelization of the elbow in elements COQUE_3D gave results comparable to computation $3D$ (see [§2.2]).

## 2.2 Results of reference

For one applied moment $Mz$ in $D$, the displacement $DY$ of the same point $D$ is worth [bib1]:

| Moment | $Dy$ not $D$ $(m)$ (3D) | $Dy$ not $D$ $(m)$ (COQUE_3D) |
|---|---|---|
| 0. | 0. | 0. |
| 3.08670D+06 | 1.09349D-02 | 1.08875D-02 |
| 3.48715D+06 | 1.23536D-02 | |
| 3.88759D+06 | 1.37891D-02 | 1.37381D-02 |
| 4.28804D+06 | 1.52727D-02 | |
| 4.68848D+06 | 1.68128D-02 | |
| 5.08892D+06 | 1.84085D-02 | |
| 5.48937D+06 | 2.01272D-02 | |
| 5.88981D+06 | 2.20836D-02 | |
| 6.29026D+06 | 2.43502D-02 | |
| 6.69070D+06 | 2.70438D-02 | |
| 7.09115D+06 | 3.04756D-02 | |

## 2.3 Accuracy on the results of reference

Owing to the fact that the reference solution is numerical, one can evaluate the accuracy according to [§2.2] with $2\%$ by comparison of the solutions 3D and COQUE_3D.

## 2.4 References bibliographical

[1 J.M. PROIX, A. BEN HAJ YEDDER: “Project CACIP: study of a pipework bent in bending”. Note EDF/DER HI-75/98/001/0

[] C. CHURN (SEPTEN), MN. BERTON, N. BLAY (FRENCH ATOMIC ENERGY AGENCY), F. LE BRETON (FRAMATOME - ANP): “Project of new coding of the criteria of seismic design of the pipework”. Note EDF/SEPTEN E-N-ES-MS/01-01004-A.

# 3 Modelization A

## 3.1 Characteristic of the modelization

the structure is with a grid in elements pipes (meshes SEG3, modelization PIPE).

## 3.2 Characteristics of the mesh

20 meshes SEG3 (The mesh are regular: 10 elements in the elbow, 5 in each right pipe)

## 3.3 Quantities tested and Increment

| results of load | $DY$ of the point $D$ | Reference | % difference |
|---|---|---|---|
| 1: $Mz=3.08670\mathrm{D}+06\mathrm{Nm}$ | $DY\ (m)$ | 1.09349E-02 | 2.3 |
| 8: $Mz=5.88981\mathrm{D}+06\mathrm{Nm}$ | $DY\ (m)$ | 2.20836E-02 | 2.75 |

# 4 Modelization B

## 4.1 Characteristic of the modelization

the structure is with a grid in elements pipes with 4 nodes (meshes SEG4, modelization PIPE).

## 4.2 Characteristics of the mesh

11 meshes SEG4 (5 elements in the elbow, 3 in each right pipe)

## 4.3 Computation of the term of "Total" Rotation

This term of "total" rotation were developed in the frame of a tripartite action EDF - French atomic energy agency - FRAMATOME [bib2], for a future integration in the code of design RCC-M.
It is expressed starting from rotations of two points representative of the elbow (entered and left), by:

$$R_G = \sqrt{\Delta R_x^2 + \Delta R_y^2 + \Delta R_z^2}$$

where

$$\Delta R_x = DRX_{sortiecoude} - DRX_{entréecoude}$$
$$\Delta R_y = DRY_{sortiecoude} - DRY_{entréecoude}$$
$$\Delta R_z = DRZ_{sortiecoude} - DRZ_{entréecoude}$$

This term is calculated by the macro-command Python MACR_ROTA_GLOBALE which is integrated in the body of the command file. Result of this macro-command is a function Aster of total rotation according to time. A test of NON-regression comes to validate this function.

## 4.4 Quantities tested and Increment

| results of load | $DY$ of the point $D$ | Reference | % difference |
|---|---|---|---|
| 1: $Mz = 3.08670\text{D}+06\text{Nm}$ | $DY\ (m)$ | 1.09349D-02 | 0.3 |
| 8: $Mz = 5.88981\text{D}+06\text{Nm}$ | $DY\ (m)$ | 2.20836D-02 | 1.1 |

Test of NON-regression for total rotation:

| Urgent | *Aster* |
|---|---|
| 5.88981E+06 | 9.26451E-03 |

Tests of non regression for the options of CALC_CHAMP or POST_CHAMP :

| Component | option | Does not net | | Subpoint | Sequence number | *Aster* |
|---|---|---|---|---|---|---|
| SIEQ_ELGA | VMIS | M1 | 2 | 61 | 1 | 4.675554583E+07 |
| SIEQ_ELGA | VMIS | M1 | 3 | 55 | 3 | 5.608141169E+07 |
| EPEQ_ELGA | INVA_2 | M1 | 1 | 77 | 4 | 2.590281477E-04 |
| EPEQ_ELGA | INVA_2 | M1 | 1 | 8 | 5 | 1.769279362E-04 |

| Component | Component | Option | Does not net | | Sequence number | Aster |
|---|---|---|---|---|---|---|
| SIEQ_ELGA | VMIS/MAX | VAL | M1 | 1 | 1 | 8.84099E+07 |
| SIEQ_ELGA | VMIS/MIN | VAL | M1 | 1 | | 5.88318E+06 |
| SIEQ_ELGA | VMIS/MAX | NUCOU | m2 | 2 | 1 | 1.00000E+00 |
| SIEQ_ELGA | VMIS/MIN | NUCOU | m3 | 3 | 1 | 1.00000E+00 |
| SIEQ_ELGA | VMIS/MAX | NUSECT | M4 | 1 | 1 | 1.20000E+01 |
| SIEQ_ELGA | VMIS/MIN | NUSECT | M5 | 2 | 1 | 1.60000E+01 |
| SIEQ_ELGA | VMIS/MAX | POSIC | M6 | 3 | 1 | 1.00000E+00 |
| SIEQ_ELGA | VMIS/MIN | POSIC | M7 | 1 | 1 | 2.00000E+00 |
| SIEQ_ELGA | VMIS/MAX | POSIS | M8 | 2 | 1 | 3.00000E+00 |
| SIEQ_ELGA | VMIS/MIN | POSIS | M9 | 3 | 1 | 3.00000E+00 |
| SIEQ_ELGA | VMIS/MAX | VAL | M1 | 2 | 4 | 1.27695E+08 |
| SIEQ_ELGA | VMIS/MIN | VAL | M5 | 3 | 5 | 2.20755E+07 |

# 5 Summary of the results

the reference solution not being analytical, but numerical (obtained by a modelization 3D), the noted variations (of 1% with 3% ) can be regarded as reasonable. 3D to obtain a better correspondence of the solutions and PIPE, it would be advisable to model the right parts over a bigger length, and to adopt a finer mesh for each modelization. This was not done in the frame of this test, to keep reasonable execution times.