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## SSNV144 - Bend in bending in large displacements

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### Summarized:

This test validates the modelization of the phenomena of bending of shell in large displacements in the elastic domain or elastoplastic: an elbow of pipework, 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 modelization is carried out with elements `COQUE_3D` in large displacements or elastoplasticity.

## 1 Problem of reference

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the elbow has as a radius of curvature:  $R_c = 1.25\text{m}$

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

### 1.1 Properties of the materials

the material is elastoplastic with isotropic linear hardening.

$$E = 2.E11 \text{ Pa}$$

$$\nu = 0.3$$

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

$$\text{Hardening modulus } D - SIGM - EPSI = 2.10^{10} \text{ Pa}$$

### 1.2 Boundary conditions and loadings

Fixed support in  $A$  (corresponding to the section of named pipework  $CERCLE1$ ).

Moment  $MZ$  imposed in  $D$  (corresponding with  $CERCLE2$ ) growing until:

$$\text{Increment 1} \quad Mz = 308670215.2 \text{ Nm}$$

In the case of computation into large displacement,  $Mz$  is reached in 10 equal increments

### 1.3 Initial conditions

Without object.

## 2 Reference solution

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### 2.1 Method of calculating used for the reference solution

In linear elasticity, cf [V6.02.117] one carries out a comparison with other numerical results got with *Code\_Aster* on 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 COQUE\_3D gives close results.

### 2.2 Results of reference

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

Moment	$DY$ not $D$ ( m ) (3D)	$DY$ not $D$ ( m ) (COQUE_3D)
3.08670D+08	1.09349D-02	1.08875D-02

### 2.3 Uncertainty on the solution

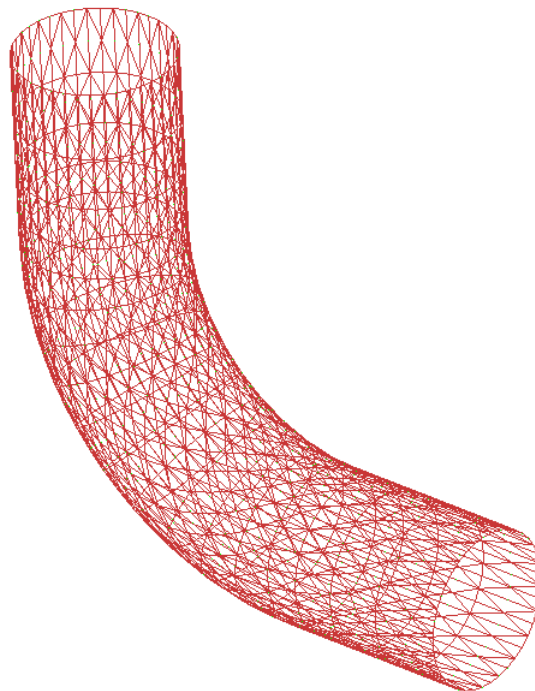
Owing to the fact that the reference solution is numerical, one can evaluate the accuracy according to [§2.2] with 2% by comparison of the solutions 3D and COQUE\_3D.

## 3 Modelization A

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### 3.1 Characteristic of modelization

COQUE\_3D



### 3.2 Characteristics of the mesh

Many nodes: 1480  
Number of meshes and type: 360 QUAD9

### 3.3 Quantities tested and results of the modelization A

to compare the results of the linear elastic design ( `MECA_STATIQUE` ) with the reference solution, one compares displacements of 4 nodes of the section of the tube corresponding to the point *D* ( *CERCLE2* ).

Increment of load	$DY$ of the point <i>D</i>
$Mz = 3.08670D + 06Nm$	$DY ( m )$

linear Computation:

Site	Value to test	Standard test	Tolerance
N1157 - DX	6.51271E-04	NON_REGRESSION	6.49E- 06%
N1104 - DX	1.28830E-04	NON_REGRESSION	1.88E- 04%
N1109 - DX	4.01834E-04	NON_REGRESSION	1.61E- 05%
N1099 - DX	4.01834E-04	NON_REGRESSION	1.61E- 05%
N1157 - DY	1.08154E-03	NON_REGRESSION	9.44E- 05%
N1104 - DY	1.09424E-03	NON_REGRESSION	3.15E- 04%
N1109 - DY	1.08427E-03	NON_REGRESSION	2.92E- 04%
N1099 - DY	1.08427E-03	NON_REGRESSION	2.92E- 04%
N1157 - DZ	0.00000E+00	NON_REGRESSION	1.00E- 08%
N1104 - DZ	0.00000E+00	NON_REGRESSION	1.00E- 08%
N1109 - DZ	6.34660E-06	NON_REGRESSION	8.70E- 06%
N1099 - DZ	-6.34660E-06	NON_REGRESSION	8.69E- 06%
N1157 - DRX	0.00000E+00	NON_REGRESSION	1.00E- 08%
N1104 - DRX	0.00000E+00	NON_REGRESSION	1.00E- 08%
N1109 - DRX	-8.06992E-06	NON_REGRESSION	7.78E- 06%
N1099 - DRX	8.06992E-06	NON_REGRESSION	7.78E- 06%
N1157 - DRY	0.00000E+00	NON_REGRESSION	1.00E- 08%
N1104 - DRY	0.00000E+00	NON_REGRESSION	1.00E- 08%
N1109 - DRY	-4.85229E-05	NON_REGRESSION	5.35E- 05%
N1099 - DRY	4.85229E-05	NON_REGRESSION	5.35E- 05%
N1157 - DRZ	5.84655E-04	NON_REGRESSION	6.51E- 05%
N1104 - DRZ	6.81747E-04	NON_REGRESSION	5.81E- 05%
N1109 - DRZ	-9.39844E-05	NON_REGRESSION	6.63E- 06%
N1099 - DRZ	elastoplastic	-9.39844E-05	NON_REGRESSION 6.63E-

06% Computation (non regression)

Site	Value to test	Standard test	Tolerance
N1157 - DX	6.51271E-04	NON_REGRESSION	0.160%
N1104 - DX	1.28830E-04	NON_REGRESSION	0.028%
N1109 - DX	4.01834E-04	NON_REGRESSION	0.149%
N1099 - DX	4.01834E-04	NON_REGRESSION	0.149%
N1157 - DY	1.08154E-03	NON_REGRESSION	0.209%
N1104 - DY	1.09424E-03	NON_REGRESSION	0.206%
N1109 - DY	1.08427E-03	NON_REGRESSION	0.208%
N1099 - DY	1.08427E-03	NON_REGRESSION	0.208%
N1157 - DZ	0.00000E+00	NON_REGRESSION	1.00000 E 08%
N1104 - DZ	0.00000E+00	NON_REGRESSION	1.00000 E 08%
N1109 - DZ	6.34660E-06	NON_REGRESSION	0.022%
N1099 - DZ	-6.34660E-06	NON_REGRESSION	0.022%
N1157 - DRX	0.00000E+00	NON_REGRESSION	1.00000 E 08%
N1104 - DRX	0.00000E+00	NON_REGRESSION	1.00000 E 08%
N1109 - DRX	-8.06992E-06	NON_REGRESSION	0.382%
N1099 - DRX	8.06992E-06	NON_REGRESSION	0.382%
N1157 - DRY	0.00000E+00	NON_REGRESSION	1.00000 E 08%
N1104 - DRY	0.00000E+00	NON_REGRESSION	1.00000 E 08%
N1109 - DRY	-4.85229E-05	NON_REGRESSION	0.533%
N1099 - DRY	4.85229E-05	NON_REGRESSION	0.533%
N1157 - DRZ	5.84655E-04	NON_REGRESSION	0.173%
N1104 - DRZ	6.81747E-04	NON_REGRESSION	0.224%
N1109 - DRZ	-9.39844E-05	NON_REGRESSION	0.533%
N1099 - DRZ	-9.39844E-05	NON_REGRESSION	0.533%

One also tests in NON-regression the nombre total of iterations of Newton:

Parameter	Value to test	Standard test	Tolerance
EVOL_NOLI - ITER_GLOB	1	NON_REGRESSION	0

Computation large displacements (non regression):

Site	NUME_ORDRE	Value to test	Standard test	Tolerance
N1157 - DX	10	6.51271E-04	NON_REGRESSION	0.16 1%
N1104 - DX	10	1.28830E-04	NON_REGRESSION	0.274%
N1109 - DX	10	4.01834E-04	NON_REGRESSION	0.169%
N1099 - DX	10	4.01834E-04	NON_REGRESSION	0.169%
N1157 - DY	10	1.08154E-03	NON_REGRESSION	0.164%
N1104 - DY	10	1.09424E-03	NON_REGRESSION	0.115%
N1109 - DY	10	1.08427E-03	NON_REGRESSION	0.139%
N1099 - DY	10	1.08427E-03	NON_REGRESSION	0.139%
N1157 - DZ	10	0.00000E+00	NON_REGRESSION	1.00000 E 08%
N1104 - DZ	10	0.00000E+00	NON_REGRESSION	1.00000 E 08%
N1109 - DZ	10	6.34660E-06	NON_REGRESSION	4.398%
N1099 - DZ	10	-6.34660E-06	NON_REGRESSION	4.398%
N1157 - DRX	10	0.00000E+00	NON_REGRESSION	1.00000 E 08%
N1104 - DRX	10	0.00000E+00	NON_REGRESSION	1.00000 E 08%
N1109 - DRX	10	-8.06992E-06	NON_REGRESSION	0.423%
N1099 - DRX	10	8.06992E-06	NON_REGRESSION	0.423%
N1157 - DRY	10	0.00000E+00	NON_REGRESSION	1.00000 E 08%
N1104 - DRY	10	0.00000E+00	NON_REGRESSION	1.00000 E 08%
N1109 - DRY	10	-4.85229E-05	NON_REGRESSION	0.565%
N1099 - DRY	10	4.85229E-05	NON_REGRESSION	0.565%
N1157 - DRZ	10	5.84655E-04	NON_REGRESSION	0.265%
N1104 - DRZ	10	6.81747E-04	NON_REGRESSION	0.021%
N1109 - DRZ	10	-9.39844E-05	NON_REGRESSION	1.456%
N1099 - DRZ	10	-9.39844E-05	NON_REGRESSION	1.456%

One also tests in NON-regression the nombre total of iterations of Newton:

Parameter	Value to test	Standard test	Tolerance
EVOL_NOLI - ITER_GLOB	2	NON_REGRESSION	0

## 4 Summary of the results

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This test makes it possible to validate elements COQUE\_3D into linear and nonlinear geometrical for a real geometry having two curvatures. The results are close (difference lower than 1%) to the numerical reference in elasticity.