

## SSNV144 - Elbow in inflection in great displacements

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### Summary:

This test validates the modeling of the phenomena of inflection of hull in great displacements in the elastic range or elastoplastic: an elbow of piping, prolonged by right pipes is subjected to an inflection in its plan. Piping is thick (of size similar to the elbows of the primary education circuits). The reference solution is digital: it is obtained with *Code\_Aster* using a grid 3D elbow.

Modeling is carried out with elements `COQUE_3D` in great 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 as an average radius  $R = 395.5\text{mm}$  and for thickness  $e = 77\text{mm}$ .

### 1.1 Properties of materials

The material is elastoplastic with isotropic linear work hardening.

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

$$\nu = 0.3$$

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

$$\text{Module of work hardening } D - SIGM - EPSI = 2.10^{10} \text{ Pa}$$

### 1.2 Boundary conditions and loadings

Embedding in  $A$  (corresponding to the section of named piping  $CERCLE1$ ).

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

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

In the case of calculation 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 digital results got with *Code\_Aster* on a grid 3D elbow and right parts, connected at the ends with right beams. This grid 3D comprise 1024 meshes HEXA20. A modeling COQUE\_3D give close results.

### 2.2 Results of reference

For one moment applied  $Mz$  in  $D$ , displacement  $DY$  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

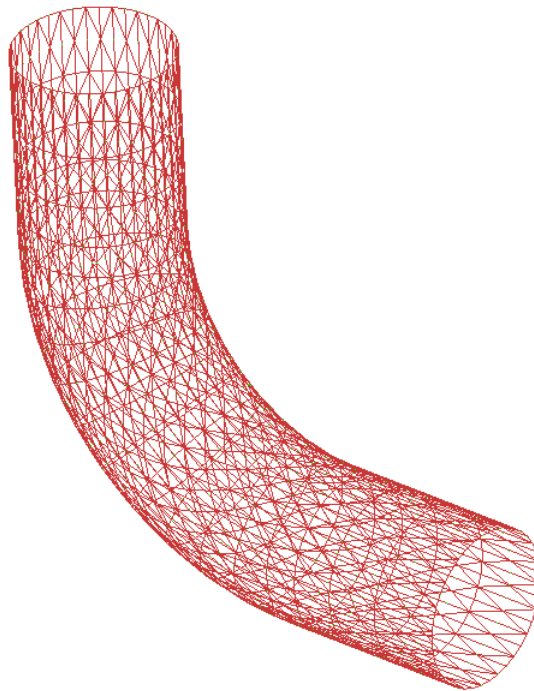
### 2.3 Uncertainty on the solution

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

## 3 Modeling A

### 3.1 Characteristics of modeling

COQUE\_3D



### 3.2 Characteristics of the grid

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

### 3.3 Sizes tested and results of modeling 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` ).

$$\frac{\text{Increment of load}}{Mz = 3.08670D + 06Nm} \quad \frac{DY \text{ point } D}{DY (m)}$$

Linear calculation:

Site	Value to be tested	Type of 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	-9.39844E-05	NON_REGRESSION	6.63E- 06%

Elastoplastic calculation (not regression)

Site	Value to be tested	Type of 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 not-regression the full number of iterations of Newton:

Parameter	Value to be tested	Type of test	Tolerance
EVOL_NOLI - ITER_GLOB	1	NON_REGRESSION	0

Calculation great displacements (not regression):

Site	NUME_ORDRE	Value to be tested	Type of 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 not-regression the full number of iterations of Newton:

Parameter	Value to be tested	Type of 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 the elements COQUE\_3D into linear and nonlinear geometrical for a real geometry having two curves. The results are close (difference lower than 1% ) digital reference in elasticity.