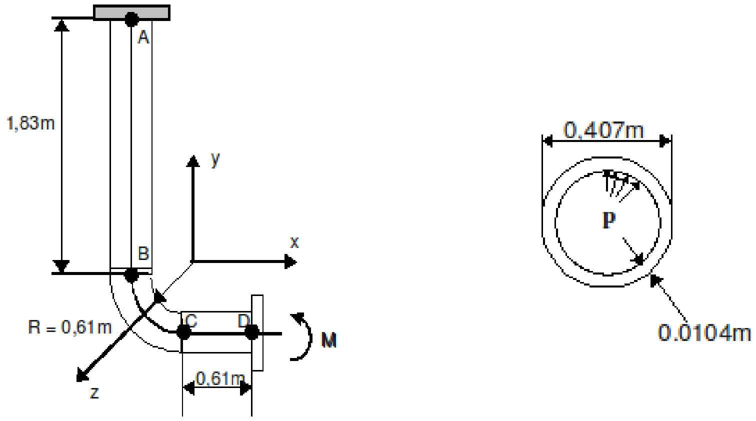
SSNL503 - Elastoplastic failure of a Summarized thin

pipe elbow:
This test consists in calculating the elastoplastic failure of a thin pipe elbow subjected to a bending in its plane and an internal pressure with basic effect. It makes it possible to validate modelization finite elements PIPE (SEG3 and SEG4) and TUYAU_6M (SEG3) in the quasi-static field in nonlinear material.

The got results are compared with a numerical reference solution obtained with the computer code ABAQUS.

1 Problem of reference

1.1 Geometry

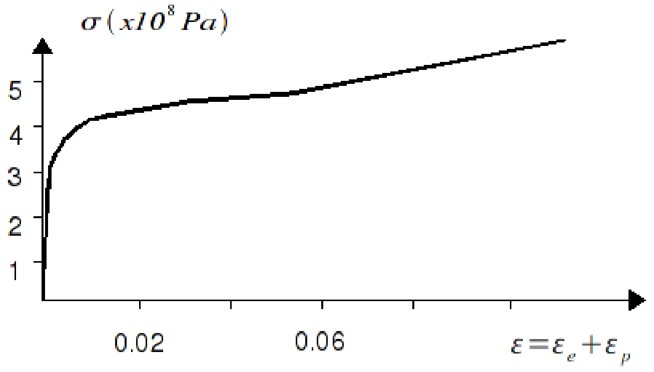


1.2 Properties of the material

the properties of the material constituting the pipe are:

$E=193.10^9\ Pa$ Modulus Young

$\nu=0.2642$ Poisson's ratio



Forced Pa	Plastic strain ε_p
2.72E+08	0.00000
3.46E+08	0.00473
3.79E+08	0.01264
4.04E+08	0.02836
4.24E+08	0.04910
5.28E+08	0.10500

1.3 Boundary conditions and loadings

- Boundary conditions:
  clamped A ◦Section
  rigid D ◦Section (no strain of the section)
- Loading: one seeks the successive states of equilibrium under the following loadings:
  ◦Étape a: $0=t<t_1$
  - la pressure varies from 0 with $3.45\ 10^6\ Pa$
  - La force (basic effect) at the point D varies from 0 with $4.0414\ 10^5\ N$
  - le moment is null

  ◦Étape b: $t_1=t<t_2$
  - la pressure is constant and is worth $3.45\ 10^6\ Pa$
  - la force (basic effect) at the point D is constant and is worth $4.0414\ 10^5\ N$
  - le moment varies from 0 with $2.534\ 10^5\ N.m$

2 Reference solution

2.1 Method of calculating used for the reference solution

the reference solution was obtained numerically with ABAQUS 5.5. The mesh used consists of elements ELBOW31 to 2 nodes with 6 modes of Fourier. The discretization used is the following one:

- Part AB : 24 elements,
- Part BC : 8 elements,
- Part CD : 12 elements.

Integration in the section is the following one:

- 7 layers in the thickness,
- 18 sectors in the circumferential meaning.

2.2 Results of reference

Moment limits = $253.4\,10^{3}\,N.m$ for a rotation around z $0.22\,rad$ to the point D .

2.3 Uncertainties on the solution

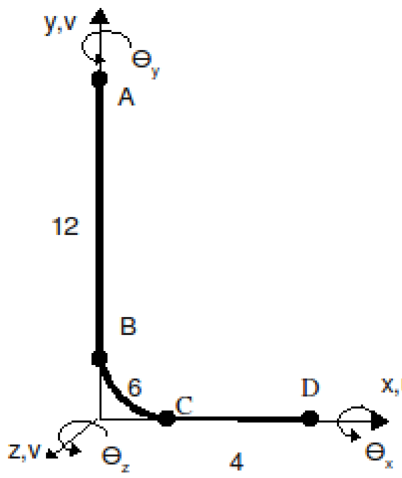
Lower than 2%

2.4 bibliographical References

[ABAQUS/Standard Version 5.5: Example Problems Manual Volume 2, pp 4.2.2-1.

3 Modelization A

3.1 Characteristic of the modelization



Modelization `PIPE` (`SEG3`)

Cutting for numerical integration
Many layers: 7
Many sectors: 18

Boundary conditions:
Point: A
degree of freedom of beam
$DX=DY=DZ=DRX=DRY=DRZ=0$
degree of freedom of Shell:
$Ulm=Vlm=Wlm=0(m=2,3)$
$UOm=VOm=WOm=0(m=2,3)$
$Wl1=WO1=WO=0$
Point: D
degree of freedom of shell:
$Ulm=Vlm=Wlm=0(m=2,3)$
$UOm=VOm=WOm=0(m=2,3)$
$Wl1=WO1=WO=0$

3.2 Characteristics of the mesh

Many nodes: 45
Number of meshes and type: 22 `SEG3`

3.3 Quantities tested and results

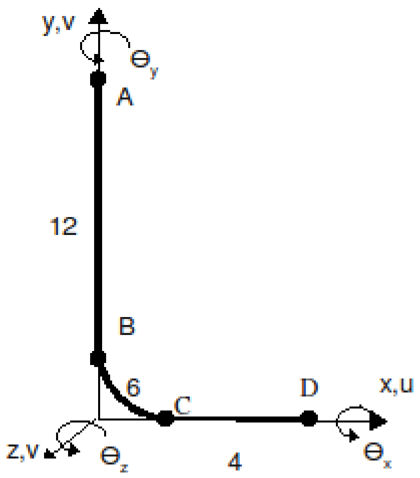
DRZ	**Identification**	**Times**	**Reference**	***Aster***	**% difference**
0.32	ETA_PILOTAGE	18.1.0		1.1699	16.99
0.34	ETA_PILOTAGE	18.5	1.0	1.1787	17.87
0.36	ETA_PILOTAGE	19.1.0		1.1869	18.69
0.38	ETA_PILOTAGE	19.5	1.0	1.1946	19.46
0.40	ETA_PILOTAGE	20.1.0		1.2020	20.20

3.4 Remarks

At the time of the stage A, one gradually imposes the internal pressure and the force due to the basic effect on the interval of time $0<t<10$. Then (stage B), one gradually imposes the bending moment on the time interval $10<t<20$. To solve, one B forces at the time of the stage an increase in rotation DRZ in $0.4\,rad$ on the solution obtained at the time of stage A.

4 Modélisation B

4.1 Characteristic of the modelization



Modelization `TUYAU_6M` (`SEG3`)

Cutting for numerical integration
Many layers: 7
Many sectors: 18

Boundary conditions:
Point: A
degree of freedom of beam:
$$DX=DY=DZ=DRX=DRY=DRZ=0$$
degree of freedom of shell:
$$Ulm=Vlm=Wlm=0\,(m=2,6)$$
$$UOm=VOm=WOm=0\,(m=2,6)$$
$$Wl1=WO1=WO=0$$
Point: D
degree of freedom of shell:
$$Ulm=Vlm=Wlm=0\,(m=2,6)$$
$$UOm=VOm=WOm=0\,(m=2,6)$$
$$Wl1=WO1=WO=0$$

4.2 Characteristics of the mesh

Many nodes: 45
Number of meshes and type: 22 `SEG3`

4.3 Quantities tested and results

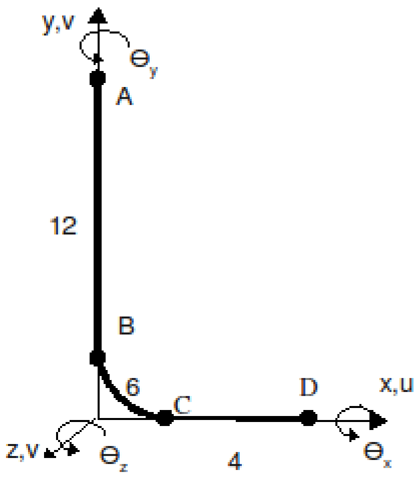
DRZ	Identification	Times	Reference	Aster	% difference
0.32	ETA_PILOTAGE	18.1.0		1.0296	2.96
0.34	ETA_PILOTAGE	18.5	1.0	1.0379	3.79
0.36	ETA_PILOTAGE	19.1.0		1.0456	4.56
0.38	ETA_PILOTAGE	19.5	1.0	1.0528	5.28
0.40	ETA_PILOTAGE	20.1.0		1.0597	5.97

4.4 Remarks

At the time of the stage A, one gradually imposes the internal pressure and the force due to the basic effect on the interval of time $0<t<10$. Then (stage B), one gradually imposes the bending moment on the time interval $10<t<20$. To solve, one B forces at the time of the stage an increase in rotation DRZ in $0.4\,rad$ on the solution obtained at the time of stage A.

5 Modélisation C

5.1 Characteristic of the modelization



Modelization `PIPE` (`SEG4`)

Cutting for numerical integration
Many layers: 7
Many sectors: 18

Boundary conditions:
Point: A
degree of freedom of Beam:
$DX=DY=DZ=DRX=DRY=DRZ=0$
degree of freedom of Shell:
$Ulm=Vlm=Wlm=0(m=2,6)$
$UOm=VOm=WOm=0(m=2,6)$
$Wl1=WO1=WO=0$
Point: D
degree of freedom of Shell:
$Ulm=Vlm=Wlm=0(m=2,6)$
$UOm=VOm=WOm=0(m=2,6)$
$Wl1=WO1=WO=0$

5.2 Characteristics of the mesh

Many nodes: 67
Number of meshes and type: 22 `SEG4`

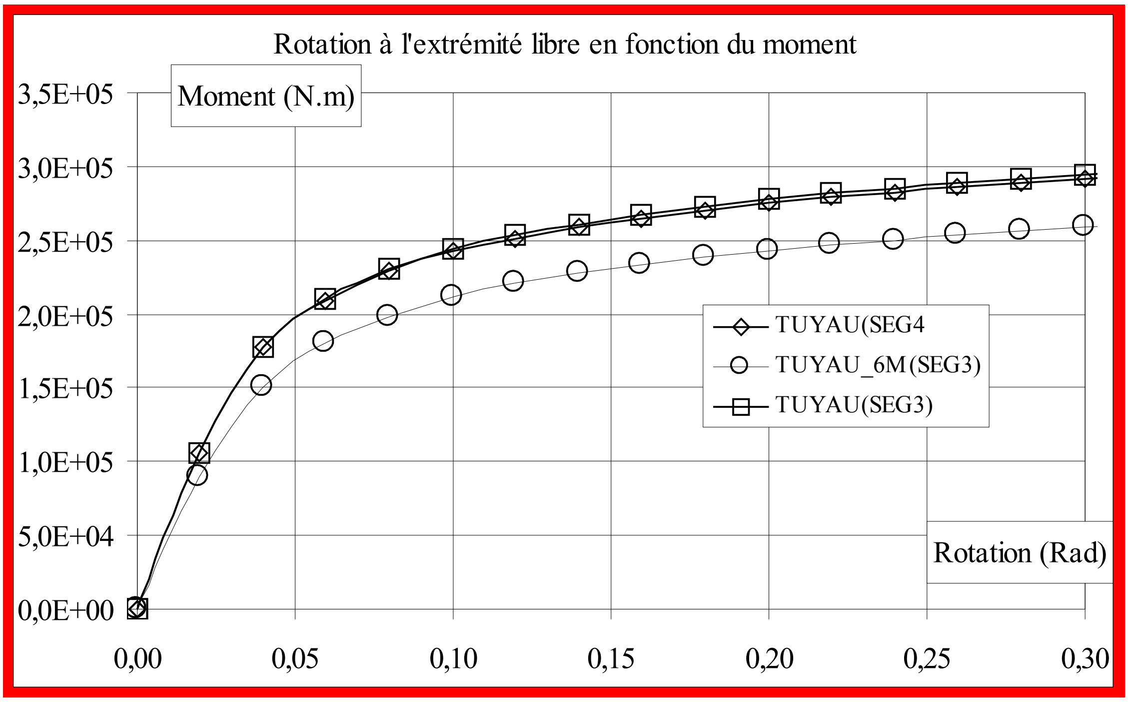
5.3 Quantities tested and results

DRZ	Identification	Times	Reference	*Aster*	$\%$ difference
0.32	ETA_PILOTAGE	18.1.0		1.1681	16.81
0.34	ETA_PILOTAGE	18.5	1.0	1.1678	16.78
0.36	ETA_PILOTAGE	19.1.0		1.1758	17.58
0.38	ETA_PILOTAGE	19.5	1.0	1.1834	18.34
0.40	ETA_PILOTAGE	20.1.0		1.1905	19.05

5.4 Remarks

At the time of the stage A, one gradually imposes the internal pressure and the force due to the basic effect on the interval of time $0<t<10$. Then (stage B), one gradually imposes the bending moment on the time interval $10<t<20$. To solve, one forces at the time of the stage B an increase in rotation DRZ in $0.4\,rad$ the solution obtained at the time of stage A.

6 Synthèse of the results



the results got for the modelization `PIPE` (`SEG3` and `SEG4`) are rather far away from the reference solution, (error of 20%). On the other hand, they are better for modelization `TUYAU_6M` (error of 6%).
The strain of the cross-sectional area in the elbow is represented better by modelization `TUYAU_6M`, adapted better to the modelization of the thin pipes. In this modelization, displacements of the mean surface of the pipe are broken up into Fourier series until order 6, instead of 3 for the modelization `PIPE`. The modelization of reference uses a decomposition in Fourier series until order 6.