SSNL503 - Elastoplastic ruin of a bent pipe thin

Summary:
This test consists in calculating the elastoplastic ruin of a thin bent pipe subjected to an inflection in its plan and an internal pressure with basic effect. It makes it possible to validate modeling finite elements `PIPE` (`SEG3` and `SEG4`) and `TUYAU_6M` (`SEG3`) in the quasi-static field in non-linear material.

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

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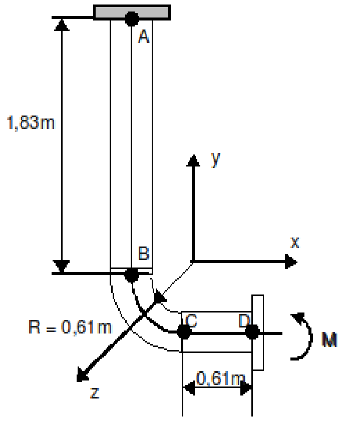
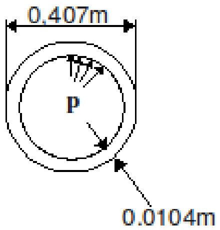
1 Problem of reference

1.1 Geometry



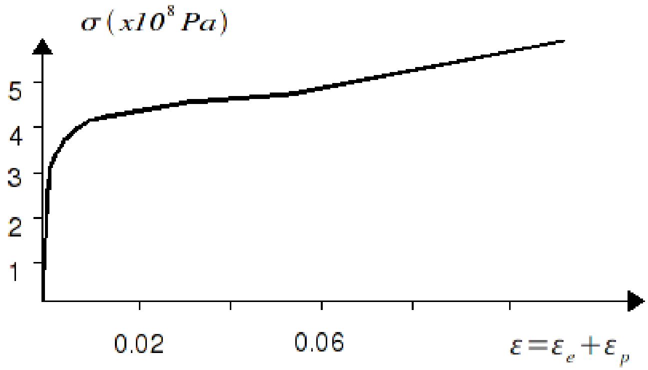


1.2 Properties of material

The properties of material constituting the pipe are:

$E=193.10^9\ Pa$ Young modulus

$\nu=0.2642$ Poisson's ratio



Constraint Pa	Deformation Plastic 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:
  - Section A embedded
  - Section D rigid (no deformation of the section)
- Loading: one seeks the successive states of balance under the following loadings:
  - Stage a: $0=t<t_1$
    - the pressure varies 0 with $3.45\,10^6\ Pa$
    - The force (basic effect) at the point D vary 0 with $4.0414\,10^5\ N$
    - the moment is null
  - Stage b: $t_1=t<t_2$
    - the pressure is constant and is worth $3.45\,10^6\ Pa$
    - the force (basic effect) at the point D is constant and is worth $4.0414\,10^5\ N$
    - the moment varies 0 with $2.534\,10^5\ N.m$

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2 Reference solution

2.1 Method of calculating used for the reference solution

The reference solution was obtained numerically with ABAQUS 5.5. The grid used consists of elements ELBOW31 with 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 direction.

2.2 Results of reference

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

2.3 Uncertainties on the solution

Lower than 2%

2.4 Bibliographical references

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

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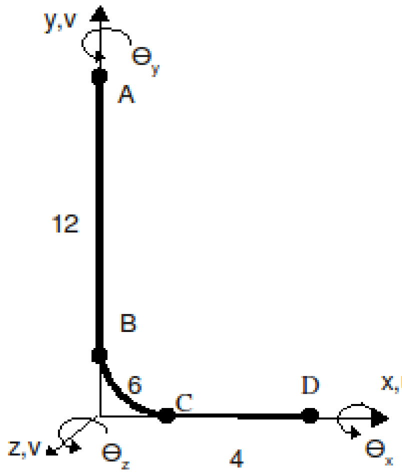
3 Modeling A

3.1 Characteristics of modeling



Modeling PIPE (SEG3)

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

Boundary conditions:
Not A :
degree of freedom of beam
$DX=DY=DZ=DRX=DRY=DRZ=0$
degree of freedom of Hull:
$Ulm=Vlm=Wlm=0(m=2,3)$
$UOm=VOm=WOm=0(m=2,3)$
$Wl1=WO1=WO=0$
Not D :
degree of freedom of hull:
$Ulm=Vlm=Wlm=0(m=2,3)$
$UOm=VOm=WOm=0(m=2,3)$
$Wl1=WO1=WO=0$

3.2 Characteristics of the grid

Many nodes: 45
Number of meshs and type: 22 SEG3

3.3 Sizes tested and results

DRZ	Identification	Moments	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

The distribution in volume of the component is also tested SIXY (tests of not-regression) of the fields SIEF_ELGA and SIGM_ELNO as well as the volume of the pipe.

3.4 Remarks

At the time of stage A, one gradually imposes the internal pressure and the effort due to the basic effect on the time interval $0<t<10$. 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 of $0.4\,rad$ with the solution obtained at the time of stage A.

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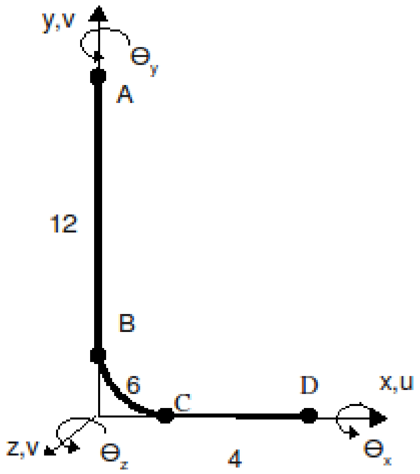
4 Modeling B

4.1 Characteristics of modeling



Modeling `TUYAU_6M` (`SEG3`)

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

Boundary conditions:
Not A :
degree of freedom of beam:
$DX=DY=DZ=DRX=DRY=DRZ=0$
degree of freedom of hull:
$Ulm=Vlm=Wlm=0(m=2,6)$
$UOm=VOm=WOm=0(m=2,6)$
$Wl1=WO1=WO=0$
Not D :
degree of freedom of hull:
$Ulm=Vlm=Wlm=0(m=2,6)$
$UOm=VOm=WOm=0(m=2,6)$
$Wl1=WO1=WO=0$

4.2 Characteristics of the grid

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

4.3 Sizes tested and results

DRZ	Identification	Moments	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 stage A, one gradually imposes the internal pressure and the effort due to the basic effect on the time interval $0<t<10$. 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 of $0.4\,rad$ with the solution obtained at the time of stage A.

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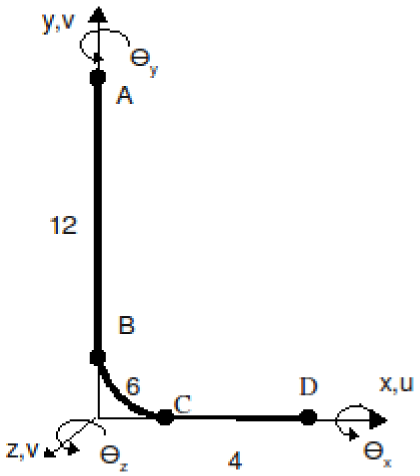
5 Modeling C

5.1 Characteristics of modeling



Modeling PIPE (SEG4)

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

Boundary conditions:
Not A :
degree of freedom of Beam:
$DX=DY=DZ=DRX=DRY=DRZ=0$
degree of freedom of Hull:
$Ulm=Vlm=Wlm=0(m=2,6)$
$UOm=VOm=WOm=0(m=2,6)$
$Wl1=WO1=WO=0$
Not D :
degree of freedom of Hull:
$Ulm=Vlm=Wlm=0(m=2,6)$
$UOm=VOm=WOm=0(m=2,6)$
$Wl1=WO1=WO=0$

5.2 Characteristics of the grid

Many nodes: 67
Number of meshs and type: 22 SEG4

5.3 Sizes tested and results

DRZ	Identification	Moments	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 stage A, one gradually imposes the internal pressure and the effort due to the basic effect on the time interval $0<t<10$. 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 of $0.4\,rad$ with the solution obtained at the time of stage A.

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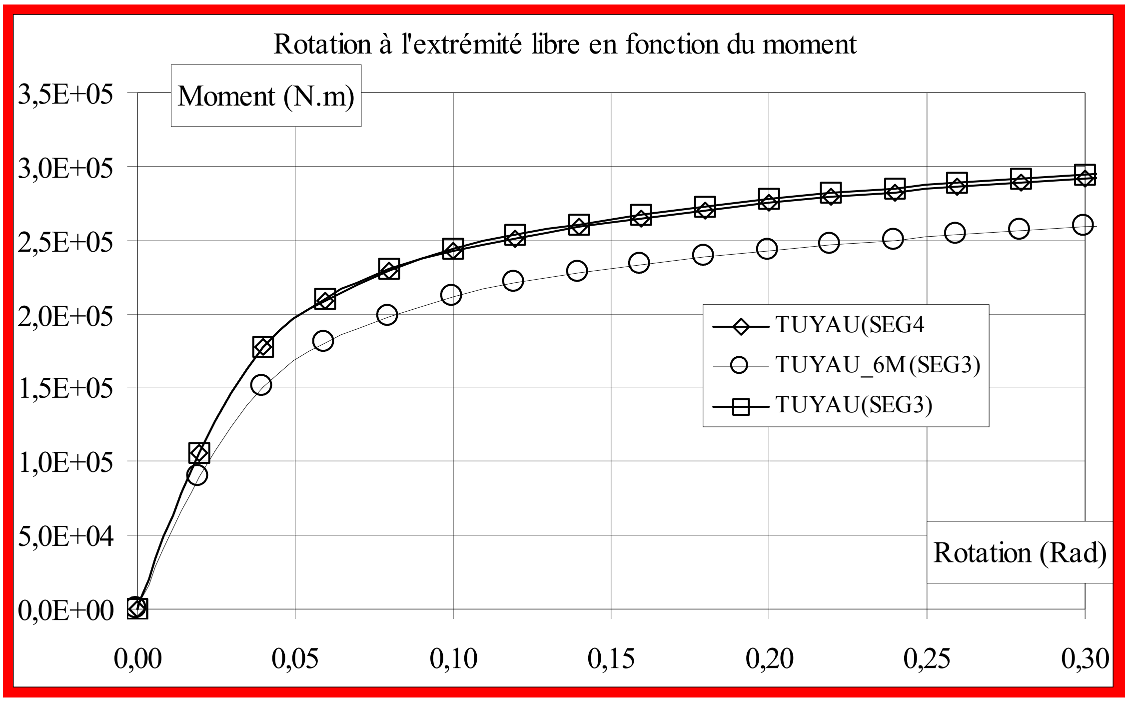
6 Summary of the results



Results got for modeling PIPE (SEG3 and SEG4) are rather far away from the reference solution, (error of 20%). On the other hand, they are better for modeling TUYAU_6M (error of 6%).
The deformation of the transverse section in the elbow is represented better by modeling TUYAU_6M, adapted better to the modeling of the thin pipes. In this modeling, displacements of the average surface of the pipe are broken up into Fourier series until order 6, instead of 3 for modeling PIPE. The modeling of reference uses a decomposition in Fourier series until order 6.

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