SSNL136 - Great displacements of the arc with aperture 45°

Summary

This test makes it possible to validate the element of beam multifibre POU_D_TGM in the geometrical non-linear field of great displacements and great rotations. An additional modeling with POU_D_T_GD (model geometrically exact of beams in great displacements) allows to compare the two elements.
One studies an arc plan of opening $45°$ embedded at an end and subjected to a bending stress perpendicular to its plan at the other end. This test, very severe, gives results in concord with the results already got by other researchers in the literature.

1 Problem of reference

1.1 Geometry

An arc is considered AB of ray $100\,cm$, of center C and of opening $45°$

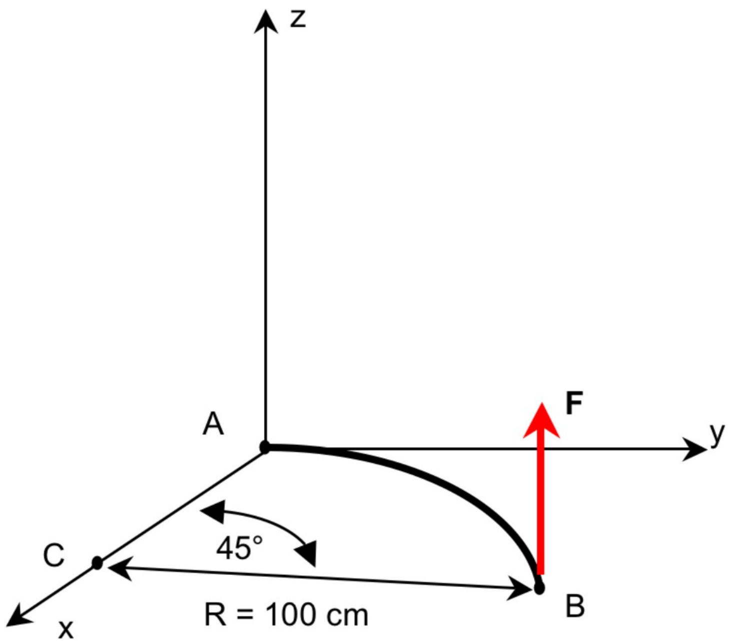


Illustration 1.1.1 : geometry of the arc

Coordinates of the points (in cm):

	A	B	C
x	0	29.3	100
y	0	70.7	0
z	0	0	0

1.2 Characteristics of the section

The arc is with square section of $1\,cm$ by $1\,cm$.

$$A=1\,cm^2$$
$$I_y=I_z=0.0833\,cm^4$$
$$A_y=A_z=1.2$$

1.3 Properties of material

$$E=1\,MPa$$
$$\nu=0.0$$

1.4 Boundary conditions and loading

1) Boundary conditions are imposed on the point A (embedding of the arc):

$$DX=DY=DZ=DRX=DRY=DRZ=0$$

2) One imposes at the loose lead at the point B, a top-load (perpendicular to the plan of the arc) growing until $600\mathrm{N}$:

$$FZ=600\times t$$

2 Reference solution

2.1 Method used for calculation of the reference solution

The first results of reference for this problem are the results got by Bathe and Bolourchi [1] in 1979 with a modeling beam. Bathe appreciably got the same results in 1990 with a modeling 3D, completely different thus from the model beam, this is why its results are largely accepted by the scientific community like value of reference.
Since, several other researchers attacked this problem. One thus chooses to compare our results with an average of 8 codes.

2.2 Results of reference

One is interested in the coordinates in the total reference mark of the point B for $t=0.5$ (either $F=300\text{N}$) and $t=1.0$ ($F=600\text{N}$).
One presents below a summary table of the results got by various researchers since the introduction of the problem as well as the average of these results and the maximum change to this average. It is the average, illustrated in **fat** , which is selected like reference for each test.

Load	$F=300\text{N}$			$F=600\text{N}$		
	X	Y	Z	X	Y	Z
ADINA-1 (1979)	22.5	59.2	39.5	15.9	47.2	53.4
ADINA-2 (1990)	22.2	58.5	40.4	15.7	46.8	53.6
NACS-1 (1993)	22.6	59.2	39.5	15.9	47.2	53.4
NACS-2 (1993)	22.3	58.6	40.3	15.7	46.7	53.6
Cardona and Geradin (1988)	22.14	58.64	40.35	15.55	47.04	53.5
Crisfield (1990)	22.16	58.53	40.35	15.61	46.84	53.71
Crivelli and Felippa (1993)	22.31	58.85	40.08	15.75	47.25	53.37
Shakourzadeh (1994)	21.99	58.4	40.49	15.24	46.91	53.55
Average	**22.28**	**58.74**	**40.12**	**15.67**	**46.99**	**53.52**
Maximum variation	1.44	0.78	1.55	2.74	0.62	0.36

ADINA are the results got by Bathe in [1], one will be able to find the other results in [2].

2.3 Uncertainty on the solution

Between 1 and 3% (maximum variation relative to the average of the results).

2.4 Bibliographical references

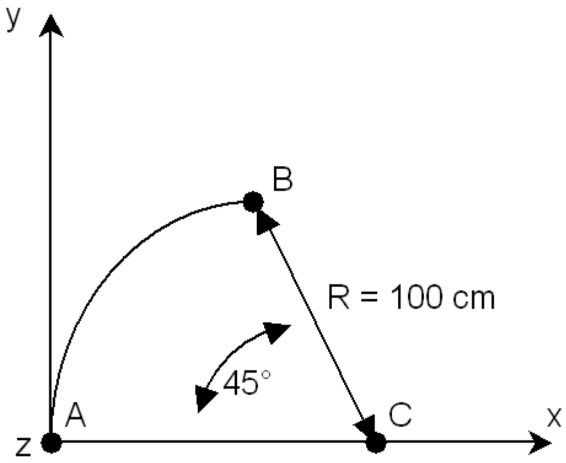
[1] Bathe KJ, Bolourchi S. Large displacement analysis of three-dimensional beam structures. Int J Numer Meth Eng 1979; 14:961-86.

[2] H. Shakourzadeh. Modeling of the three-dimensional structure-beams with thin walls and simulation of the geometrical and elastoplastic nonlinear behavior. Doctorate, University of Compiegne, Compiegne (1994).

3 Modeling A

3.1 Characteristics of modeling

Modeling POU_D_TGM



Cutting: 8 elements in the length of the arc

3.2 Characteristics of the grid

Many nodes: 9
Many meshs and types: 8 SEG2

3.3 Characteristics of the grid of the transverse section

Many fibres: 49 (cutting in 7 on each side)
Many meshs and types: 49 QUA4

3.4 Remarks

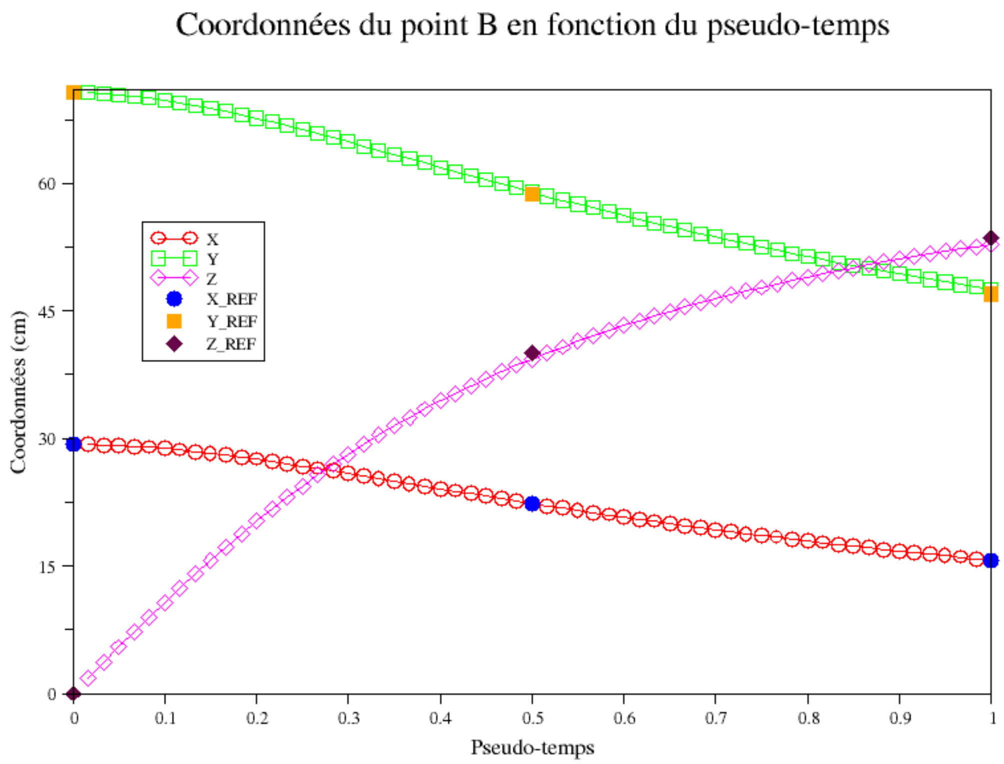
The element POU_D_TGM have an additional degree of freedom compared to a classical element of beam, warping in line with the section. One chooses not to model it here while imposing $JG=0$ (worthless constant of warping) on the one hand because it is negligible (full square section) and on the other hand because the results of reference one has do not take account of it.

3.5 Sizes tested and results

The loading is applied in 60 pas de charges.

Loading	Coordinates	Reference	Type of reference	Tolerance
$F=300\,N$	X	22.28	'SOURCE_EXTERNE'	1 %
	Y	58.74	'SOURCE_EXTERNE'	1%
	Z	40.12	'SOURCE_EXTERNE'	2%
$F=600\text{N}$	X	15.67	'SOURCE_EXTERNE'	2 %
	Y	46.99	'SOURCE_EXTERNE'	1%
	Z	53.52	'SOURCE_EXTERNE'	2%

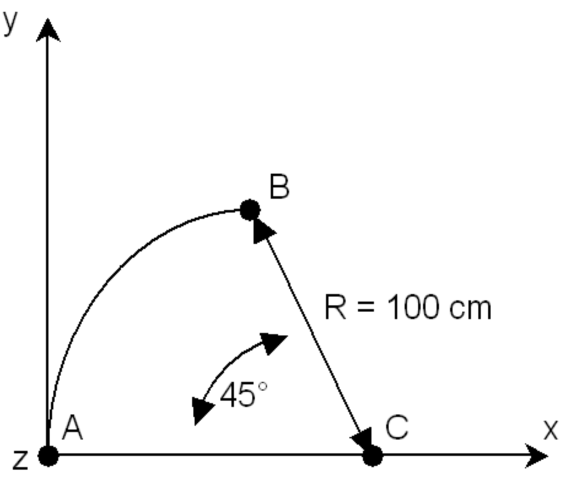
3.6 Graphic results of modeling A



4 Modeling B

4.1 Characteristics of modeling

Modeling POU_D_T_GD



Cutting: 8 elements in the length of the arc

4.2 Characteristics of the grid

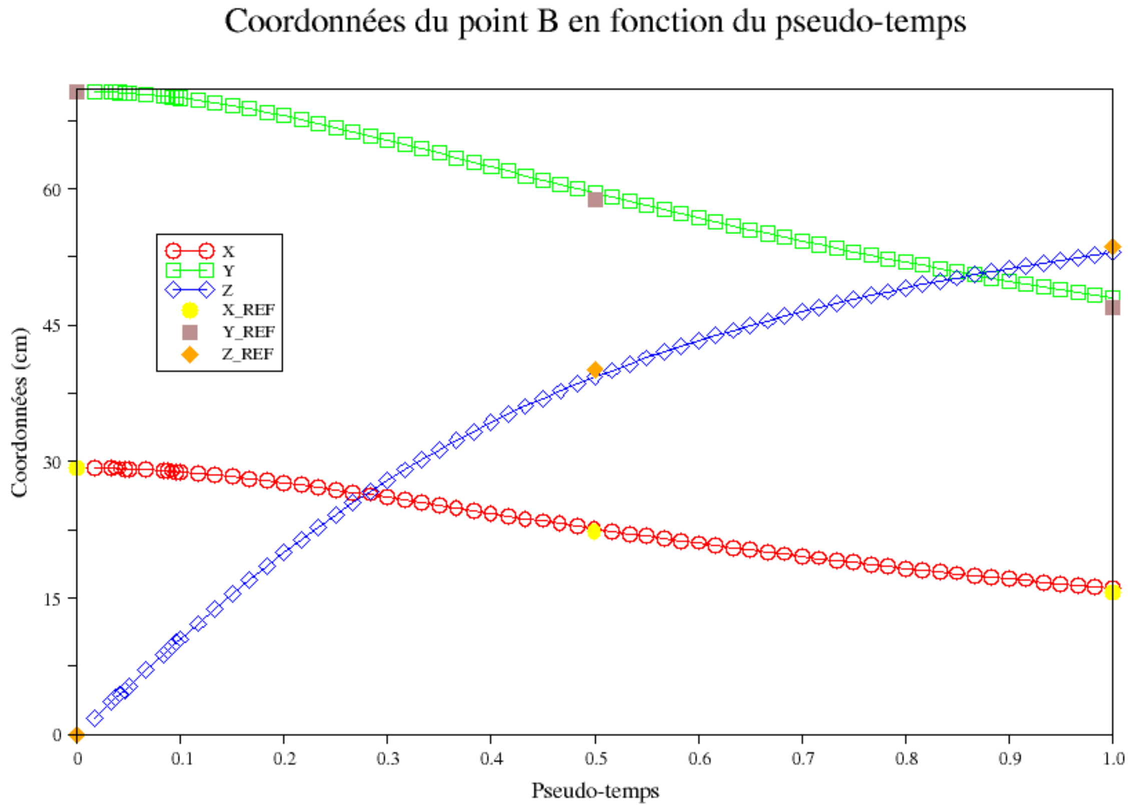
Many nodes: 9
Many meshs and types: 8 SEG2

4.3 Sizes tested and results

The loading is applied in 60 pas de charges.

Loading	Coordinates	Reference	Type of reference	Tolerance
$F=300\,N$	X	22.28	'SOURCE_EXTERNE'	2 %
	Y	58.74	'SOURCE_EXTERNE'	2 %
	Z	40.12	'SOURCE_EXTERNE'	3%
$F=600\text{N}$	X	15.67	'SOURCE_EXTERNE'	3 %
	Y	46.99	'SOURCE_EXTERNE'	3 %
	Z	53.52	'SOURCE_EXTERNE'	1%

4.4 Graphic results of modeling B


Coordonnées du point B en fonction du pseudo-temps
Coordonnées (cm)
Pseudo-temps
X
Y
Z
X_REF
Y_REF
Z_REF
0
15
30
45
60
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

5 Summary of the results

The got results are in very good agreement with the reference and this, whatever the element of beam used. One can notice that the element multifibre obtains better tolerances that the element of beam in great rotations, however this last requires in practice to carry out much less step of loading.

Moreover, in spite of an arched structure, discretized in only 8 elements and undergoing great rotations, the continuity of the degrees of freedom to the nodes of the elements is well ensured for two modelings.