SSNL136 - Large displacements of the arc with aperture 45°

Summarized

This test makes it possible to validate beam element multifibre POU_D_TGM in the geometrical nonlinear field of large displacements and large rotations. An additional modelization with POU_D_T_GD (geometrically models exact beams in large displacements) makes it possible to compare the two elements.
One studies a plane arc of opening $45°$ embedded at an end and subjected to a bending stress perpendicular to his plane 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

One considers an arc AB of radius $100\,cm$, center C and opening $45°$

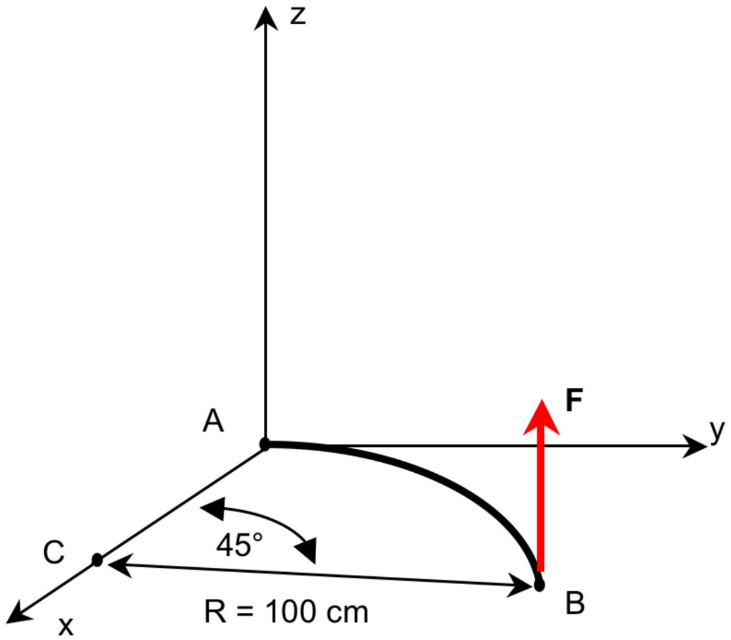


Illustration 1.1.1 : geometry of the arc

Coordinated 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 from $1\,cm$ $1\,cm$.

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

1.3 Properties of the material

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

1.4 Boundary conditions and loading

1) Boundary conditions are imposed on the point A (fixed support 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 plane of the arc) growing until $600\mathrm{N}$:

$$FZ = 600 \times t$$

2 Reference solution

2.1 Method used for computation 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 beam modelization. Bathe appreciably got the same results in 1990 with a modelization 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 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.

Charge	$F=300\text{N}$			$F=600\text{N}$		
	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 others 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

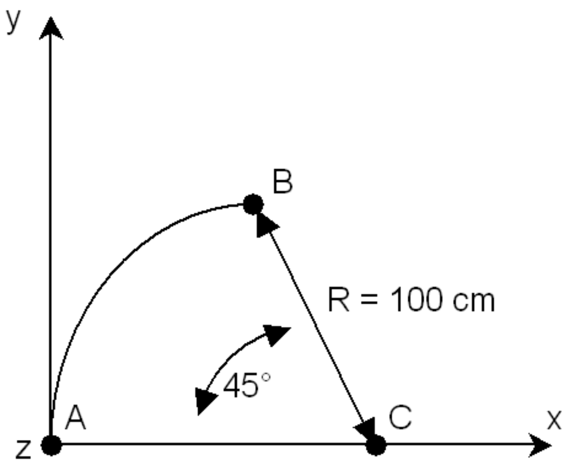
[1] Bathe KJ, Bolourchi S. Large displacement analysis of three-dimensional beam structures. Int J Numer Meth Eng 1979; 14:961-86.

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

3 Modelization A

3.1 Characteristic of the modelization

Modelization POU_D_TGM



Cutting: 8 elements in the length of the arc

3.2 Characteristics of the mesh

Many nodes: 9
Number of meshes and types: 8 SEG2

3.3 Characteristics of the mesh of the cross-sectional area

Many fibers: 49 (cutting in 7 on each side)
Number of meshes and types: 49 QUA4

3.4 Remarks

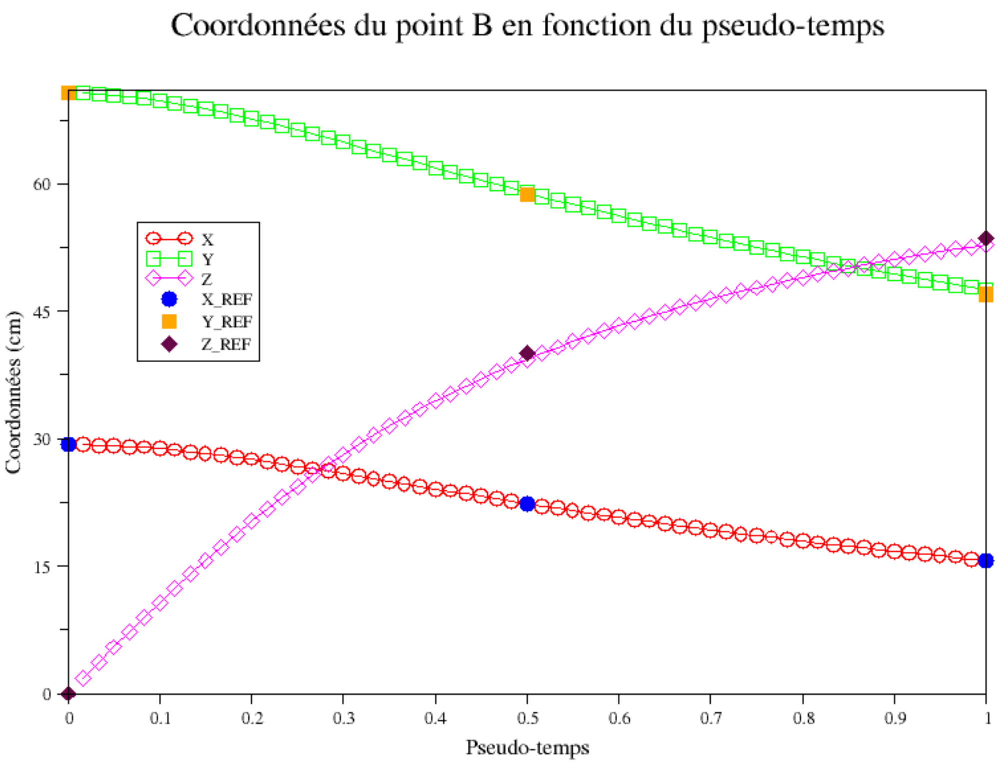
element POU_D_TGM have an additional degree of freedom compared to a classical beam element, warping in line with the section. One chooses not to model it here while imposing $JG=0$ (warping constant null) on the one hand because it is negligible (full square section) and on the other hand because the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

3.5 Quantities tested and results

the loading is applied in 60 steps of load.

Loading	Coordinated	Standard	Reference 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%

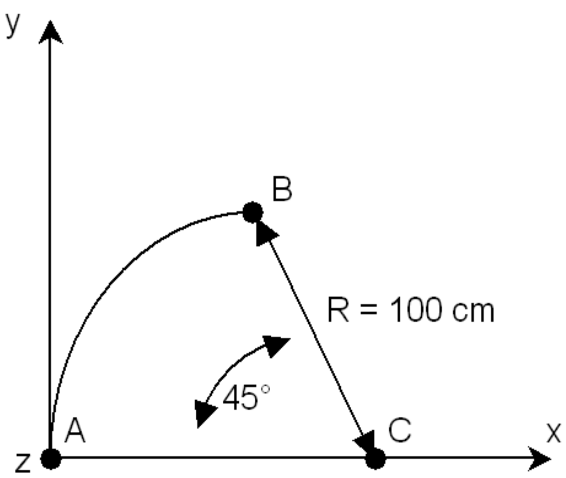
3.6 graphic Results of the modelization A



4 Modelization B

4.1 Characteristic of the modelization

Modelization POU_D_T_GD



Cutting: 8 elements in the length of the arc

4.2 Characteristics of the mesh

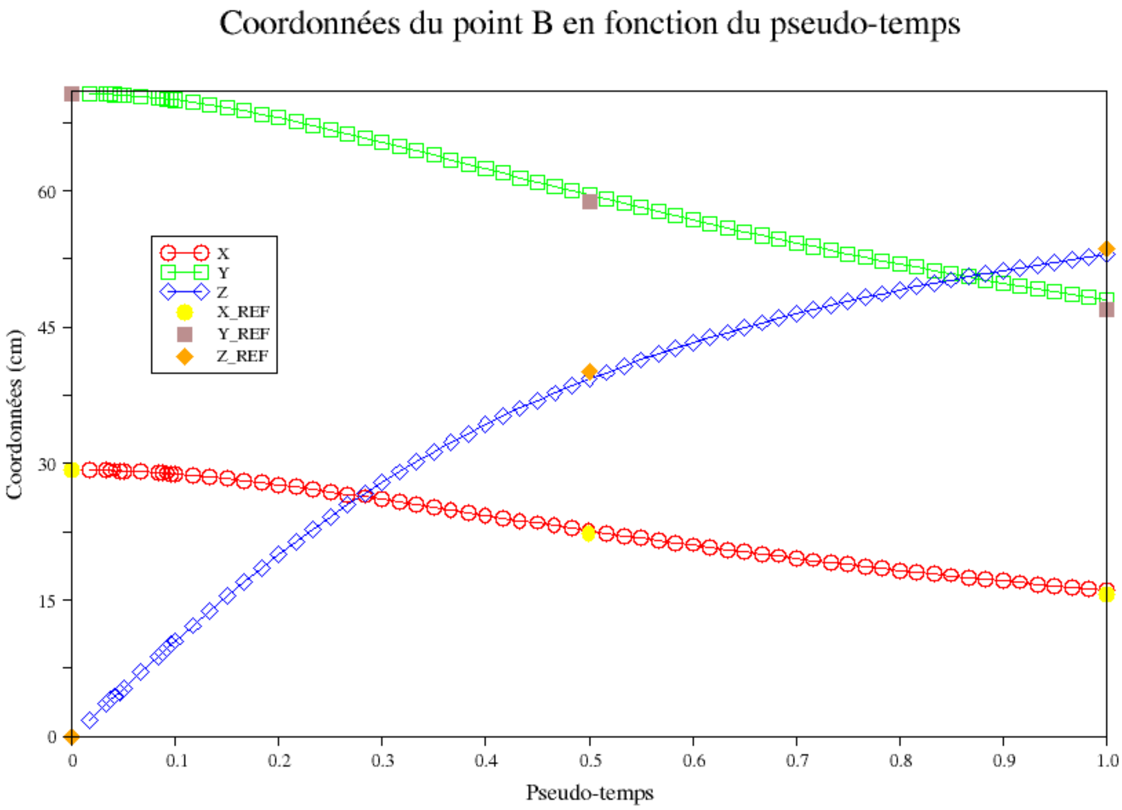
Many nodes: 9
Number of meshes and types: 8 SEG2

4.3 Quantities tested and results

the loading is applied in 60 steps of load.

Loading	Coordinated	Standard	Reference 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 the modelization 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 beam element used. One can notice that the element multifibre obtains better tolerances that the beam element in large 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 large rotations, the continuity of the degrees of freedom to the nodes of the elements is well ensured for the two modelizations.