SSNS501 - Great displacements of a panel cylindrical simply supported

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Summary:

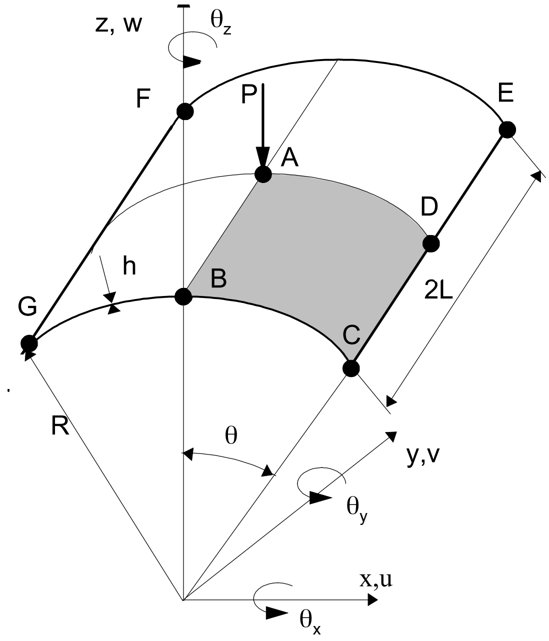
This test represents a calculation of stability of a cylindrical panel simply supported subjected to an effort concentrated in its center. The behavior of the panel changes completely and clearly shows points of return in load and displacement "snap-through/snap-back". In this case a piloting in displacement diverges and a piloting in length of arc must be selected.

It makes it possible to validate modeling finite elements `COQUE_3D` with meshs TRIA7 and QUAD9 in the geometrical non-linear quasi-static field in the presence of strong instabilities.

Displacements and the critical load are compared with a digital reference solution.

1 Problem of reference

1.1 Geometry



L = 0.254 m
R = 2.54 m
h = 0.00635 m
θ = 0.1 rd

1.2 Properties of material

The properties of material constituting the plate are:

$E=3.10275\times 10^9\,Pa$	Young modulus
$\nu=0.3$	Poisson's ratio

1.3 Boundary conditions and loadings

- Boundary conditions: panel simply supported on the sides CE and GF (worthless displacements, free rotations)

- One seeks the successive states of balance under a load P imposed on the point A.

1.4 Initial conditions

Without object

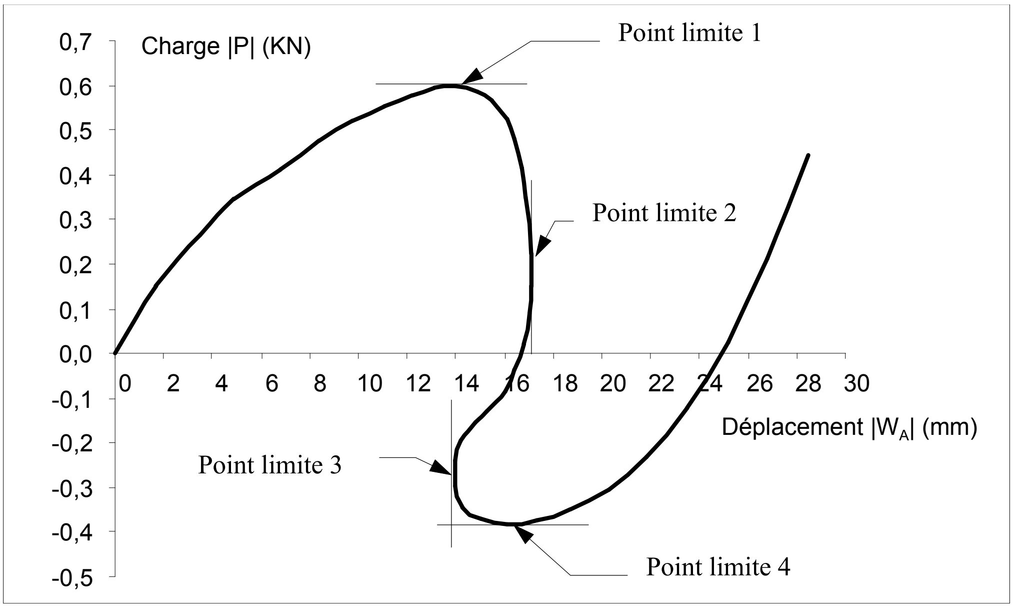
2 Reference solution

2.1 Method of calculating used for the reference solution

The reference solution was obtained with a finite element of hull DKT24 (grid 4x6) to 4 nodes with 6 degrees of freedom per node in Total Lagrangian Formulation. This solution is described in details in [bib2].

2.2 Results of reference

W_A $\times 10^{-3}$m	Load P (KN)	Load P/Pma	W_A $\times 10^{-3}$m	Load P (KN)	Load $P/Pmax$	W_A $\times 10^{-3}$m	Load P (KN)	Load $P/Pmax$
0.0	0,000	0.0000	– 16.4	0,480	0.8000	– 14.0	– 0,295	– 0.4916
– 1.7	0,150	0.2500	– 16.7	0,415	0.6916	– 14.3	– 0,345	– 0.5750
– 3.5	0,265	0.4416	– 16.9	0,350	0.5833	– 15.0	– 0,370	– 0.6166
– 4.9	0,345	0.5750	– 17.0	0,290	0.4833	– 16.1	– 0,380	– 0.6333
– 6.8	0,410	0.6833	– 17.1	0,225	0.3750	– 17.3	– 0,375	– 0.6250
– 8.4	0,475	0.7916	– 17.1	0,150	0.2500	– 18.7	– 0,350	– 0.5833
– 9.8	0,520	0.8666	– 17.0	0,090	0.1500	– 20.3	– 0,305	– 0.5083
– 11.1	0,555	0.9250	– 16.8	0,020	0.0333	– 21.8	– 0,230	– 0.3833
– 12.2	0,580	0.9666	– 16.4	– 0,035	– 0.0583	– 23.5	– 0,120	– 0.2000
– 13.1	0,595	0.9916	– 16.0	– 0,085	– 0.1416	– 25.2	0,025	0.0416
– 14.0	0,600	1.0000	– 15.3	– 0,130	– 0.2166	– 26.8	0,210	0.3500
– 14.9	0,585	0.9750	– 14.8	– 0,155	– 0.2583	– 28.5	0,445	0.7416
– 15.5	0,565	0.9416	– 14.2	– 0,195	– 0.3250			
– 16.1	0,525	0.8750	– 14.0	– 0,240	– 0.4000			



2.3 Uncertainties on the solution

Lower than 2%, digital solution

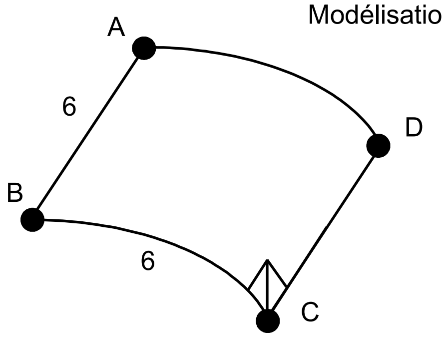
2.4 Bibliographical references

1) HAMMADI Fodil: Formulation and evaluation of finite elements with C° continuity of the geometry for the linear and non-linear analysis of the hulls.

2) JAAMEI S.: Study of various Lagrangian formulations for the nonlinear analysis of plates and thin hulls elastoplastic in great displacements and great rotations, Doctorate, University of Technology of Compiegne 1986.

3 Modeling A

3.1 Characteristics of modeling



Modélisation COQUE_3D (TRIA7)

Conditions aux limites :
- Côté CD : u = v = w = 0

Conditions de symétrie :
- Côté AB : u = θ_y = θ_z = 0
- Côté AD : v = θ_x = θ_z = ▯

On modélise un quart de la plaque.

Les états successifs d'équilibre sont obtenus grâce à une méthode de pilotage par longueur d'arc.

Dans ce cas, **`ETA_PILOTAGE`** = $\frac{p}{p_{\max}}$

3.2 Characteristics of the grid

Many nodes: 241
Number of meshs and type: 72 TRIA7

3.3 Values tested

Identification	Moments	Reference	*Aster*	% difference
Boundary point n°1				
`DZ`	1.03	– 0.0140	– 0.01322	– 5,573
`Eta_PILOTAGE`	1.03	1.0	0.9729	– 2,471
Boundary point n°2				
`DZ`	1.78	– 0.0171	– 0.01696	– 0,847
`Eta_PILOTAGE`	1.78	0,375 0,250	0.07513	– 75.96
Boundary point n°3				
`DZ`	2.3	– 0.0140	– 0.01458	4,176
`Eta_PILOTAGE`	2.3	– 0,400 – 0,492	– 0,533	19.67
Boundary point n°4				
`DZ`	2.48	– 0.0161	– 0.01617	0,452
`Eta_PILOTAGE`	2.48	– 0,633	– 0.6442	1,717

3.4 Remarks

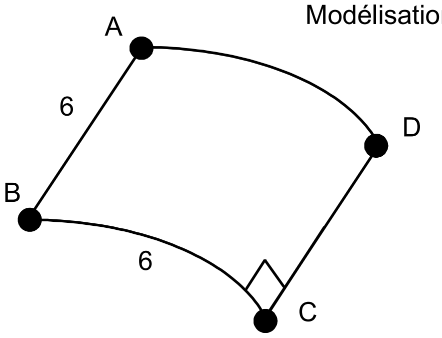
The strategy of calculation used breaks up into two stages:

- calculation in loading imposed until $P=582.\mathrm{N}$ correspondent with 97% of the critical load,
- calculation in "imposed displacement": then, one imposes a displacement imposed by using the technique length of arc imposed on all the structure (option `LONG_ARC` in `STAT_NON_LINE`).

The use of the technique length of arc makes difficult the definition of the value of reference to be introduced into the order `TEST_RESU`, since these values cannot be imposed. To define the values of reference, we searched the values of DZ closest possible to those listed in the table of [§2.2] and we deferred the values of the parameter of piloting which one was to obtain for the values of DZ in question.

4 Modeling B

4.1 Characteristics of modeling



Modélisation COQUE_3D (QUAD9)

Conditions aux limites :
- Côté CD : $u = v = w = 0$

Conditions de symétrie :
- Côté AB : $u = \theta_y = \theta_z =$ ▯
- Côté AD : $v = \theta_x = \theta_z =$ ▯

4.2 Characteristics of the grid

Many nodes: 169
Number of meshs and type: 36 QUAD9

4.3 Values tested

Identification	Moments	Reference	*Aster*	% difference
Boundary point n°1				
`DZ`	1.03	– 0.0140	– 0.01318	– 5,886
`Eta_PILOTAGE`	1.03	1.0	0.9724	– 2,760
Boundary point n°2				
`DZ`		– 0.0171	– 0.01702	– 0,462
`Eta_PILOTAGE`		0,375 0,250	0,101	– 67.69
Boundary point n°3				
`DZ`		– 0.0140	– 0.01446	3,269
`Eta_PILOTAGE`		– 0,400 – 0,492	– 0,558	25,177
Boundary point n°4				
`DZ`		– 0.0161	– 0.0161	– 0,007
`Eta_PILOTAGE`		– 0,633	– 0,640	1,120

4.4 Remarks

The strategy of calculation used breaks up into two stages:

- calculation in loading imposed until $P=582.\mathrm{N}$ correspondent with 97% of the critical load,
- calculation in imposed displacement: then, one imposes a displacement imposed by using the technique length of arc imposed (option `LONG_ARC` in `STAT_NON_LINE`).

The use of the technique length of arc makes difficult the definition of the value of reference to be introduced into the order `TEST_RESU`, since these values cannot be imposed. To define the values of reference, we searched the values of DZ closest possible to those listed in the table of [§2.2] and we deferred the values of the parameter of piloting which one was to obtain for the values of DZ in question.

5 Summary of the results

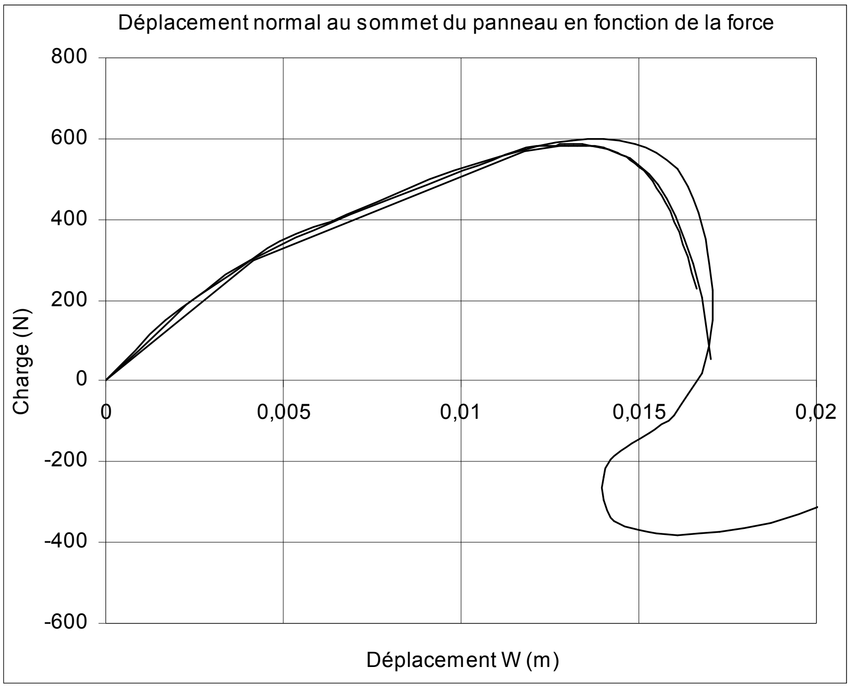


Figure 7-a: Normal displacement at the top of the panel according to the force applied. Enlarging around boundary point 1

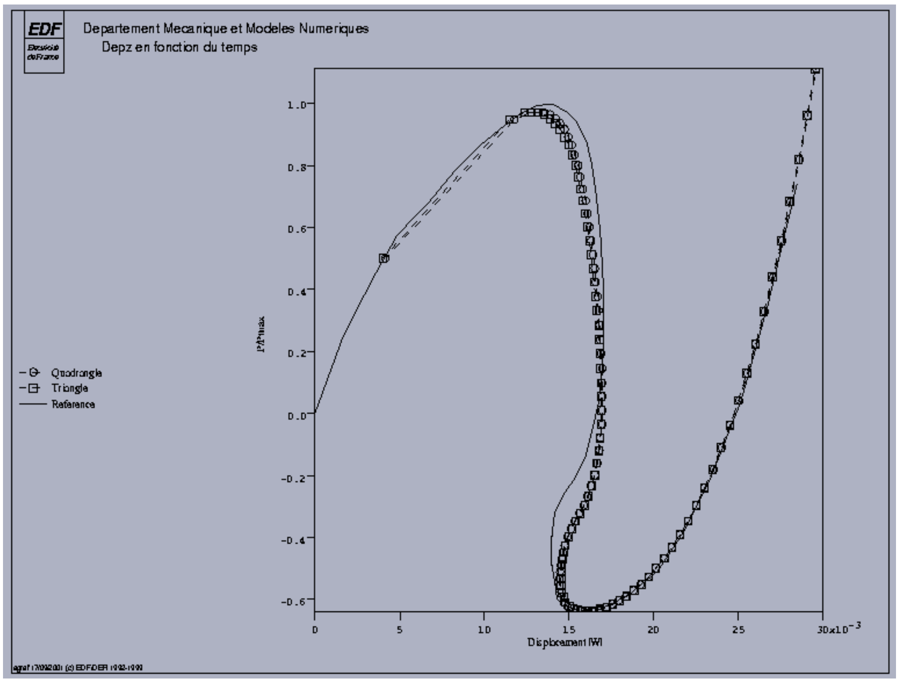


Figure 7-b: Normal displacement at the top of the panel according to the force applied standardized by its maximum value

The results for the two limiting loads 1 and 4 are correct. The maximum error is of 2.5% for mesh TRIA3 and 2.8% for mesh QUAD9. On the other hand, the error on vertical displacement is more important. It is of 5.6% for mesh TRIA7 and 5.9% for mesh QUAD9.

The results between the two limiting loads 1 and 4 are qualitatively correct. One detects well boundary points 2 and 3. Quantitatively the values of displacements for these points are good with less than 1% for boundary point 2 and with less than 5% for boundary point 3. On the level of the corresponding loads, the load as in boundary point 2 is very strongly underestimated (about 70%) and that as in boundary point 3 strongly over-estimated (about 20%).

Whatever the mesh, the behavior pre-buckling is correctly evaluated. The pace in post - buckling makes it possible to determine correctly displacements as in boundary points 2 and 3. The loads obtained are further away from the reference solution. From boundary point 4, one finds a good agreement between the reference and our solution.

The coefficient of correction of transverse shearing `A_CIS` was put at 0.833 , corresponding to the thick hulls. The value ($2500=10^6 \times H/L$) who should have been taken into account does not allow to carry out calculations, because of a bad conditioning of the matrices of rigidity.