SSNS115 - Swelling of a flexible membrane

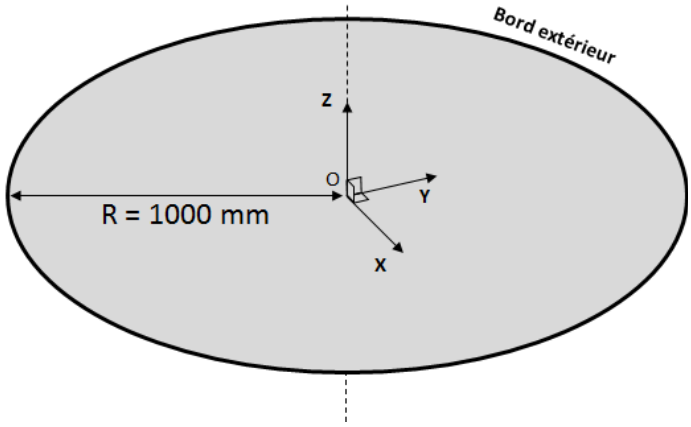
Summary:

The objective of this test is to validate the operation of the element MEMBRANE in great deformations for two hyperelastic laws of behavior and different standard from meshs (linear, quadratic and biquadratic). One thus considers the swelling of a disc subjected to a following pressure and one compares the results with solutions drawn from the literature.

1 Problem of reference

1.1 Geometry

A disc of ray is considered $1000\,mm$ in the plan $(0, X, Y)$.



The thickness of the membrane is indicated in AFFE_CARA_ELEM via the keyword THICK and is worth $1\,mm$.

1.2 Properties of material

The material is hyperelastic isotropic whose properties are:

- $E=2\,Mpa$
- $\nu=0,3$

One validates two laws of behavior, the law of Coming Saint Kirchhoff and the law néo-Hookéenne.

1.3 Boundary conditions and loadings

One embeds the edge external of the membrane. A pressure is applied uniform on the whole of the disc.

For the law of Coming Saint Kirchhoff the pressure is of $25\,kPa$. It is applied in 2 increments.

For the law Néo-Hookéenne, one controls the pressure via displacement at the point O according to Z , noted W , in order to continue calculation beyond the limiting load. Calculation is then continued after the maximum pressure is reached. Piloting is carried out in 10 increments, until $W=2500\,mm$. The pressure of controlled reference is of $1\,Pa$. Size ETA_PILO corresponds then to the value of pressure in N/m^2 .

1.4 Initial conditions

One informs an initial tension of $1\,Pa$ in AFFE_CARA_ELEM via the keyword N_INIT. This tension disappears after the first increment from Newton.

2 Reference solution

2.1 Method of calculating

We do not have exact analytical solution to this problem. The reference solutions are drawn from the literature (cf. 1, p.262). They are digital solutions obtained by calculations finite elements.

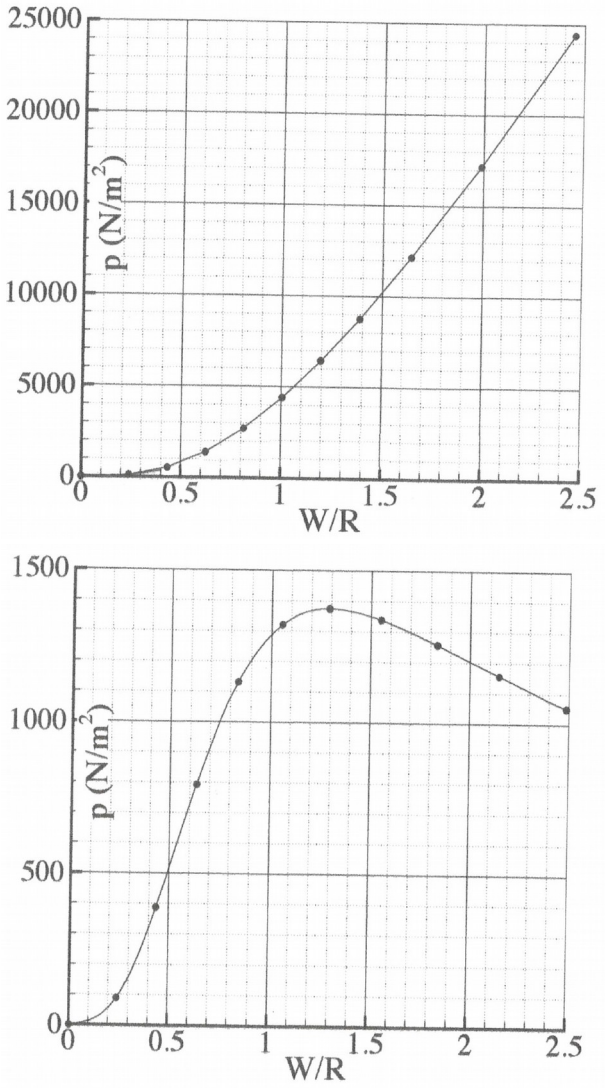


Figure 2.1-a: Curves of references for the laws of Coming saint Kirchhoff (on the left) and Néo-Hookéenne (on the right).

2.2 Sizes and results of reference

Pour the law of Coming Saint Kirchhoff, ON test vertica displacementL at the point O at the final moment. Displacement is obtained on the curve of left of the figure 2.1-a:

Size	Identification	Law of behavior	Reference solution
Displacement	Moment 1.0 - Point O - DZ	SAinT Coming Kirchhoff	2448 mm

For the law of Néo-Hookéenne behavior, pressures are interpolated with each moment of calculation on the curve of right-hand side figure 2.1-a:

Size	Identification	Law of behavior	Reference solution
Pressure	Moment 0.1 - ETA_PILO	Néo-Hookéenne	109.55 N/m^2
Pressure	Moment 0.2 - ETA_PILO	Néo-Hookéenne	531.73 N/m^2
Pressure	Moment 0.3 - ETA_PILO	Néo-Hookéenne	995.8 N/m^2
Pressure	Moment 0.4 - ETA_PILO	Néo-Hookéenne	1276.2 N/m^2
Pressure	Moment 0.5 - ETA_PILO	Néo-Hookéenne	1366.9 N/m^2
Pressure	Moment 0.6 - ETA_PILO	Néo-Hookéenne	1344.7 N/m^2
Pressure	Moment 0.7 - ETA_PILO	Néo-Hookéenne	1280.6 N/m^2
Pressure	Moment 0.8 - ETA_PILO	Néo-Hookéenne	1203.0 N/m^2
Pressure	Moment 0.9 - ETA_PILO	Néo-Hookéenne	1124.4 N/m^2
Pressure	Moment 1.0 - ETA_PILO	Néo-Hookéenne	1049.0 N/m^2

2.3 Uncertainties on the solution

The reference solution is digital. The grid of reference is composed of 196 elements of the type QUAD8.

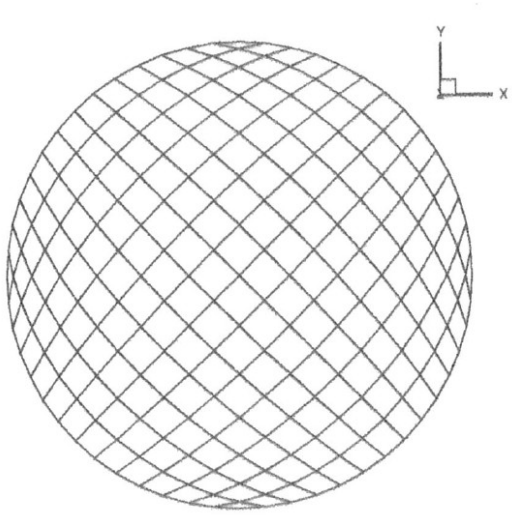


Figure 2.3- has: Grid of the reference solution.

Certain variations on the solutions obtained can be explained by differences in grids. Moreover, the statement of the values was done via the software *G3Data Analyzer Graph* on a scan of a graph contained in the reference book. Uncertainty is thus directly related on the quality and the precision of impression of the work, like with the precision of the pointings carried out.

2.4 Bibliographical references

1 A. THE VAN: Hulls and membranes, base of the nonlinear approach. Technosup (2014).

3 Modeling A

3.1 Characteristics of modeling

A modeling is used MEMBRANE into largeS deformationS (DEFORMATION=' GROT_GDEP') with the law of behavior of Coming Saint Kirchhoff (RELATION=' ELAS_MEMBRANE_SV'). Linear elements are used.

3.2 Characteristics of the grid

The grid contains 108 elements of the type QUAD4 and 14 of type TRIA3.

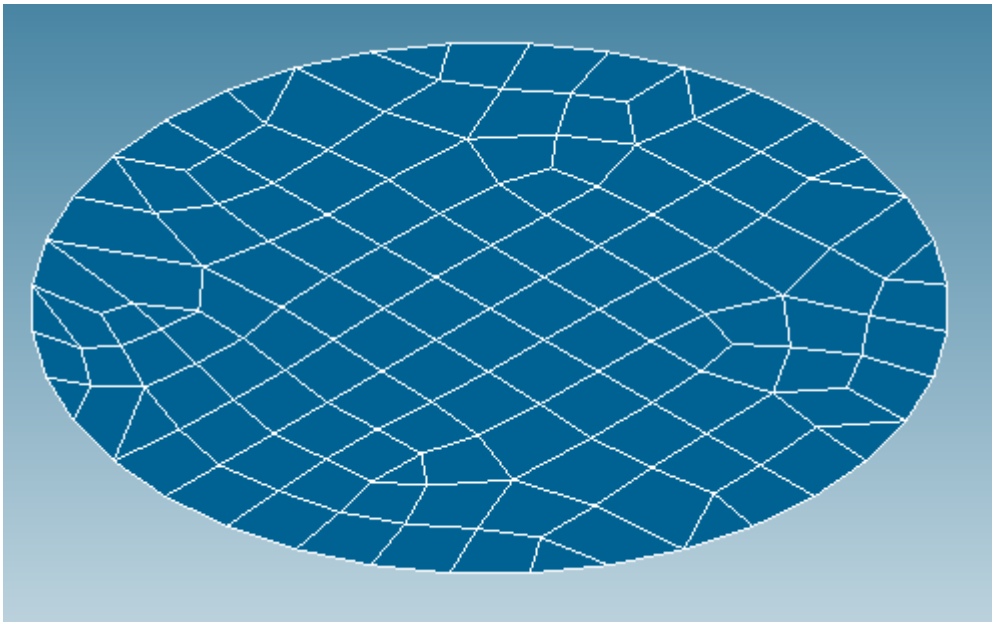


Figure 3.2- has: Grid of the membrane.

3.3 Sizes tested and results

One tests displacement in the center of the disc, out of O.

Identification	Type of reference	Value of reference (mm)	Precision
Not O - DZ	'SOURCE_EXTERNE'	2448	1.5%

3.4 Remarks

One used linear research (RECH_LINEAIRE) to reach convergence.

4 Modeling B

4.1 Characteristics of modeling

A modeling is used MEMBRANE into largeS deformationS (DEFORMATION=' GROT_GDEP') with the law of behavior of Coming Saint Kirchhoff (RELATION=' ELAS_MEMBRANE_SV'). Quadratic elements are used.

4.2 Characteristics of the grid

Grid is the same one as for modeling A but into quadratic. It contains 108 elements of the type QUAD8 and 14 of type TRIA6.

4.3 Sizes tested and results

One tests displacement in the center of the disc, out of O.

Identification	Type of reference	Value of reference (mm)	Precision
Not O - DZ	'SOURCE_EXTERNE'	2448	2%

4.4 Remarks

One used linear research (RECH_LINEAIRE) to reach convergence.

5 Modeling C

5.1 Characteristics of modeling

A modeling is used MEMBRANE into largeS deformationS (DEFORMATION=' GROT_GDEP') with the law of behavior of Coming Saint Kirchhoff (RELATION=' ELAS_MEMBRANE_SV'). Biquadratic elements are used.

5.2 Characteristics of the grid

Grid is the same one as for modeling B but into biquadratic. It contains 108 elements of the type QUAD9 and 14 of type TRIA7.

5.3 Sizes tested and results

One tests displacement in the center of the disc, out of O.

Identification	Type of reference	Value of reference (mm)	Precision
Not O - DZ	'SOURCE_EXTERNE'	2448	1.5%

5.4 Remarks

One used linear research (RECH_LINEAIRE) to reach convergence.

6 Modeling D

6.1 Characteristics of modeling

A modeling is used MEMBRANE into largeS deformationS (DEFORMATION=' GROT_GDEP') with the law of behavior néo-Hookéenne (RELATION=' ELAS_MEMBRANE_NH'). Linear elements are used.

6.2 Characteristics of the grid

Grid is the same one as for the MODelisation A.

6.3 Sizes tested and results

L is testedpressure applied during the loading has.

Identification	Type of reference	Value of reference	Precision
Moment 0.1 - ETA_PILO	'SOURCE_EXTERNE'	109.55 N/m^2	7%
Moment 0.2 - ETA_PILO	'SOURCE_EXTERNE'	531.73 N/m^2	3%
Moment 0.3 - ETA_PILO	'SOURCE_EXTERNE'	995.8 N/m^2	2%
Moment 0.4 - ETA_PILO	'SOURCE_EXTERNE'	1276.2 N/m^2	3%
Moment 0.5 - ETA_PILO	'SOURCE_EXTERNE'	1366.9 N/m^2	3%
Moment 0.6 - ETA_PILO	'SOURCE_EXTERNE'	1344.7 N/m^2	4%
Moment 0.7 - ETA_PILO	'SOURCE_EXTERNE'	1280.6 N/m^2	5%
Moment 0.8 - ETA_PILO	'SOURCE_EXTERNE'	1203.0 N/m^2	6%
Moment 0.9 - ETA_PILO	'SOURCE_EXTERNE'	1124.4 N/m^2	6%
Moment 1.0 - ETA_PILO	'SOURCE_EXTERNE'	1049.0 N/m^2	7%

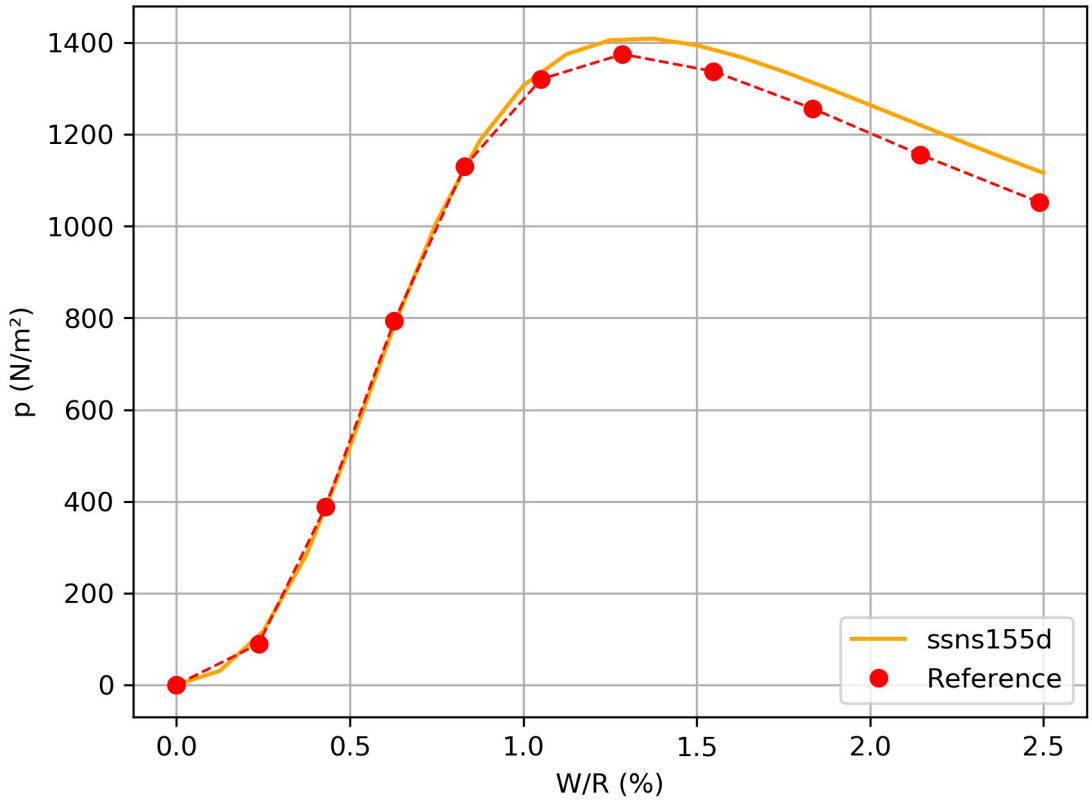


Figure 6.2- has: Results of modeling D vs reference digital of the figure 2.1- has.

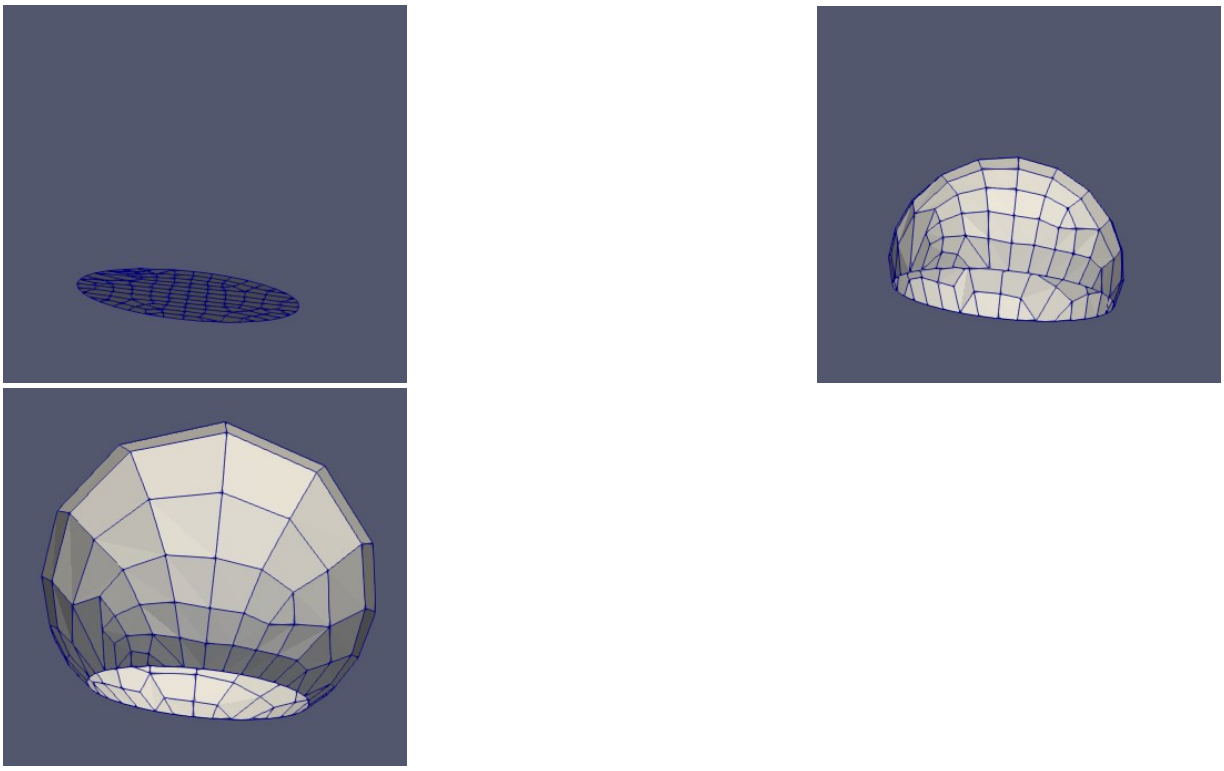


Figure 6.2-B : State initial (on the left), deformed at moment 0.5 (in the center) and deformed in a final state (on the right).

6.4 Remarks

One used piloting in displacement (SUIV_PILO) to reach convergence. L law of behavior néo-Hookéenne has fact of appearing one *snap- through* to approximately 1, 4 kPa. That involves strong non-linearities around this value that one can surmount via the piloting of the following pressure .

The grid is approximately 2 times coarser than that of the reference and the meshs are linear and nonquadratic. That explains the variations observed vis-a-vis the reference solution for this modeling.

7 Modeling E

7.1 Characteristics of modeling

A modeling is used MEMBRANE into largeS deformationS (DEFORMATION=' GROT_GDEP') with the law of behavior néo-Hookéenne (RELATION=' ELAS_MEMBRANE_NH'). Quadratic elements are used.

7.2 Characteristics of the grid

Grid is the same one as for modeling B.

7.3 Sizes tested and results

L is testedpressure applied during the loading has.

Identification	Type of reference	Value of reference	Precision
Moment 0.1 - ETA_PILO	'SOURCE_EXTERNE'	109.55 N/m^2	7%
Moment 0.2 - ETA_PILO	'SOURCE_EXTERNE'	531.73 N/m^2	3%
Moment 0.3 - ETA_PILO	'SOURCE_EXTERNE'	995.8 N/m^2	1%
Moment 0.4 - ETA_PILO	'SOURCE_EXTERNE'	1276.2 N/m^2	1%
Moment 0.5 - ETA_PILO	'SOURCE_EXTERNE'	1366.9 N/m^2	0.4%
Moment 0.6 - ETA_PILO	'SOURCE_EXTERNE'	1344.7 N/m^2	0.4%
Moment 0.7 - ETA_PILO	'SOURCE_EXTERNE'	1280.6 N/m^2	0.3%
Moment 0.8 - ETA_PILO	'SOURCE_EXTERNE'	1203.0 N/m^2	0.1%
Moment 0.9 - ETA_PILO	'SOURCE_EXTERNE'	1124.4 N/m^2	0.1%
Moment 1.0 - ETA_PILO	'SOURCE_EXTERNE'	1049.0 N/m^2	0.1%

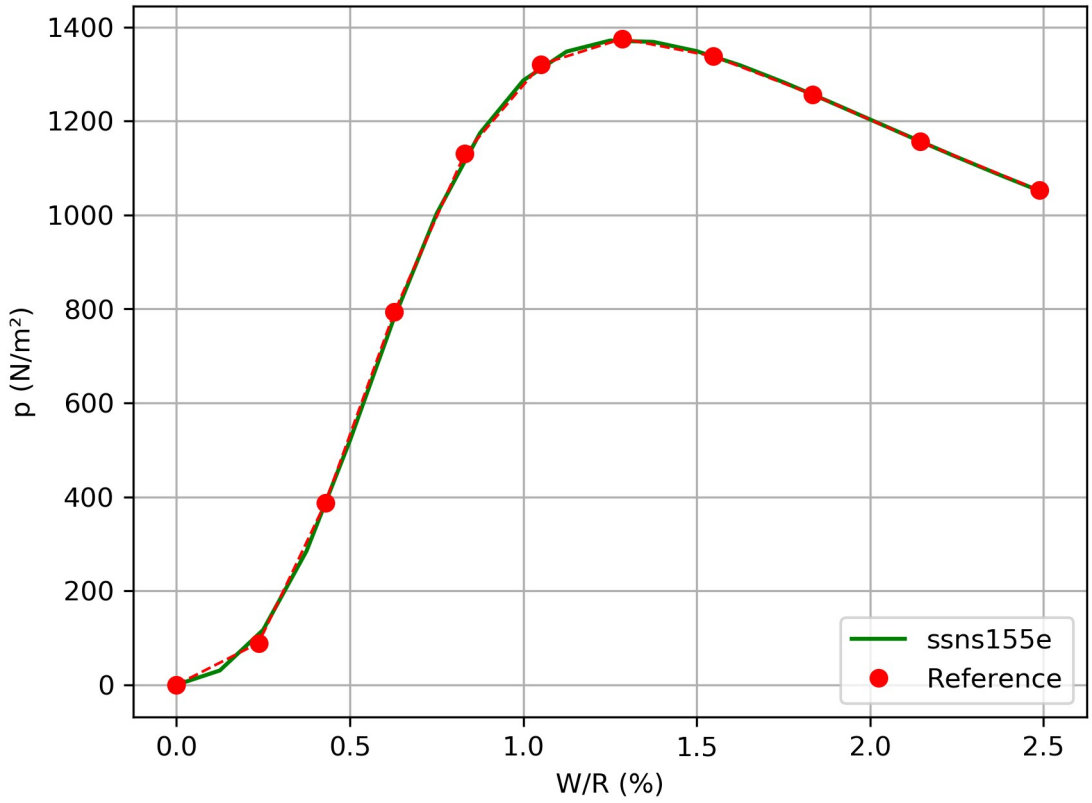


Figure 6.2- has: Results of modeling E vs reference digital of the figure 2.1- has.

7.4 Remarks

One used piloting in displacement (SUIV_PILO) as for modeling D.

Contrary to modeling D, the meshs are quadratic, therefore in the same way standard than for the reference solution. It is noticed that the results are then much more precise compared to the reference solution, which is very satisfactory taking into account owing to the fact that E grid is approximately 2 times coarser.

8 Modeling F

8.1 Characteristics of modeling

A modeling is used MEMBRANE into largeS deformationS (DEFORMATION=' GROT_GDEP') with the law of behavior néo-Hookéenne (RELATION=' ELAS_MEMBRANE_NH'). Biquadratic elements are used.

8.2 Characteristics of the grid

Grid is the same one as for modeling C.

8.3 Sizes tested and results

L is testedpressure applied during the loading has.

Identification	Type of reference	Value of reference	Precision
Moment 0.1 - ETA_PILO	'SOURCE_EXTERNE'	109.55 N/m^2	8%
Moment 0.2 - ETA_PILO	'SOURCE_EXTERNE'	531.73 N/m^2	2%
Moment 0.3 - ETA_PILO	'SOURCE_EXTERNE'	995.8 N/m^2	2%
Moment 0.4 - ETA_PILO	'SOURCE_EXTERNE'	1276.2 N/m^2	2%
Moment 0.5 - ETA_PILO	'SOURCE_EXTERNE'	1366.9 N/m^2	0.7%
Moment 0.6 - ETA_PILO	'SOURCE_EXTERNE'	1344.7 N/m^2	0.6%
Moment 0.7 - ETA_PILO	'SOURCE_EXTERNE'	1280.6 N/m^2	0.4%
Moment 0.8 - ETA_PILO	'SOURCE_EXTERNE'	1203.0 N/m^2	0.3%
Moment 0.9 - ETA_PILO	'SOURCE_EXTERNE'	1124.4 N/m^2	0.1%
Moment 1.0 - ETA_PILO	'SOURCE_EXTERNE'	1049.0 N/m^2	0.1%

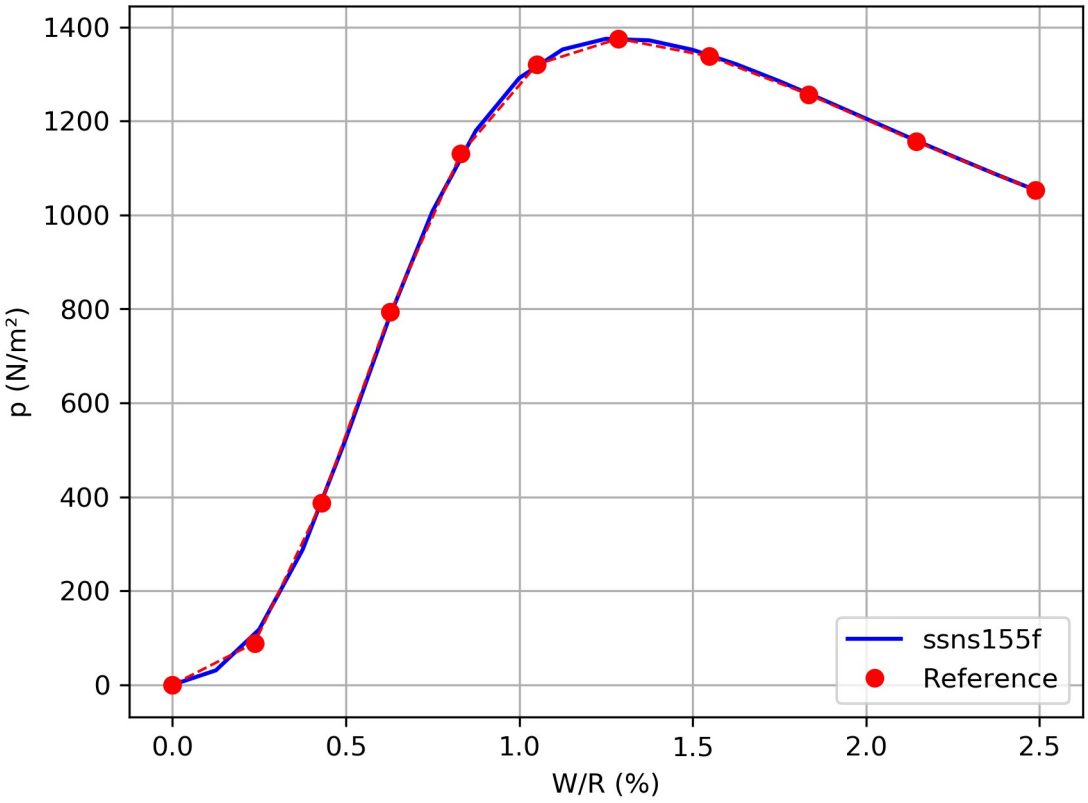


Figure 6.2- has: Results of modeling D vs reference digital of the figure 2.1- has.

8.4 Remarks

One used piloting in displacement (SUIV_PILO) as for modeling D.

With biquadratic meshs, therefore of a nature higher than the reference solution, the results remain as satisfactory as with the quadratic meshs of modeling E.

9 Summary of the results

This document validates the element of MEMBRANE in great deformations, for:
- laws of behavior of Coming Saint Kirchhoff and néo-Hookéenne,
- linear, quadratic and biquadratic elements.

This validation is based on the comparison with results resulting from the literature and is supplemented by several tests of not-regression. The elements of literature being used as reference were also used for to establish the element of membrane into largeS deformationS in code_aster, the good one is thus checked establishment element in the code with respect to the sources used.

Being given uncertainty on the results of reference, it is not possible to conclude as for the relevance to use higher elements of order to get more precise results with identical grid. One can on the other hand conclude that all these elements give satisfactory results here, which that is the law of behavior used.

It is noted in addition that the element of membrane in great deformations is strongly nonlinear and requires a certain number iterations of Newton (sometimes more 100) to reach initial balance.