SSNS115 - Swelling of a flexible membrane

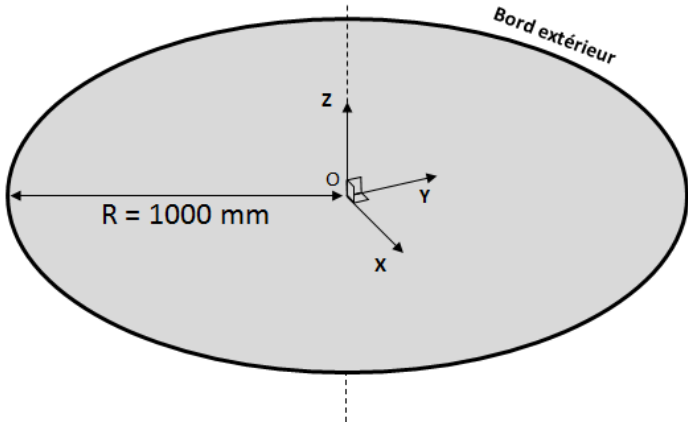
Summary:

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.

One applies a following pressure to the whole of the disc. Its value is different according to the law of behavior used. It is worth $25\,kPa$ with the use of Coming Saint Kirchhoff and $1,32\,kPa$ with the law néo-Hookéenne.

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.

2.2 Sizes and results of reference

One specifies below the vertical displacements measured at the point O in modelings of reference:

Size	Identification	Law of behavior	Reference solution
Displacement	Not O - DZ	SAinT Coming Kirchhoff	2448 mm
Displacement	Not O - DZ	Néo-Hookéenne	1047 mm

2.3 Uncertainties on the solution

The reference solution is digital.

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.

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

The grid 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

The grid 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

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

6.3 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'	1047	3%

6.4 Remarks

One used linear research (RECH_LINEAIRE) to reach convergence.

One limits the maximum pressure to 1.047 kPa because with the law of behavior néo-Hookéenne there is appearance of one *snap-through* with approximately 1.5 kPa. That involves strong non-linearities around this value who can be surmounted only by the use of piloting, incompatible with a following pressure at present.

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

The grid contains 108 elements of the type QUAD8 and 14 of type TRIA6.

7.3 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'	1047	1%

7.4 Remarks

One used linear research (RECH_LINEAIRE) to reach convergence.

One limits the maximum pressure to 1.047 kPa because with the law of behavior néo-Hookéenne there is appearance of one *snap-through* with approximately 1.5 kPa. That involves strong non-linearities around this value who can be surmounted only by the use of piloting, incompatible with a following pressure at present.

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

The grid contains 108 elements of the type QUAD9 and 14 of type TRIA7.

8.3 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'	1047	0.1%

8.4 Remarks

One used linear research (RECH_LINEAIRE) to reach convergence.

One limits the maximum pressure to 1.047 kPa because with the law of behavior néo-Hookéenne there is appearance of one *snap-through* with approximately 1.5 kPa. That involves strong non-linearities around this value who can be surmounted only by the use of piloting, incompatible with a following pressure at present.

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.