SDLS109 - Eigen frequencies of a ring cylindrical thick

Summary:

This test is inspired by a vibratory study carried out on collector VVP of the N4 slices. This collector is thick and present a maximum report thickness on average radius of 0.13. This value, being able to be typical of an industrial structure, is slightly higher than the limiting value of validity usually recognized for the plates and hulls. In this study, the modeling of the collector in hulls is then evaluated by comparison with a voluminal model on a ring.

This test makes it possible to evaluate the operator of search for eigenvalues CALC_MODES [U4.52.02] with the matrices of rigidity and mass corresponding to following modelings:

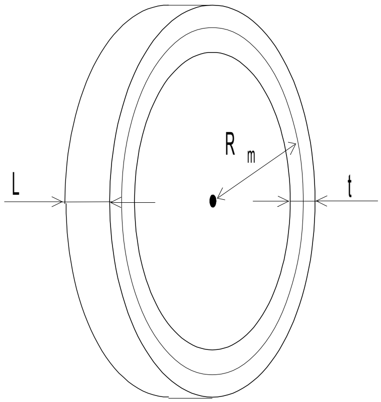
1) plates of the type DKQ (finite element MEDKQU4) and DSQ (finite element MEDSQU4),
2) plates of the type DKT (finite element MEDKTR3) and DST (finite element MEDSTR3) with a grid out of ears and star grid,
3) three-dimensional hulls of type COQUE_3D (finite elements MEC3QU9H and MEC3TR7H),
4) slices of hull in plane constraints of type COQUE_C_PLAN (finite element METCSE3),
5) telegraphic elements with kinematics of beam and modes of Fourier PIPE (finite element METUSEG3) and TUYAU_6M (finite element MET6SEG3).

The got results are compared with the solution resulting from a voluminal modeling of the ring (finite element MECA_HEXA8) revealing the modes of Fourier of order 2 (ovalization) and 3 (trifoliate) like 2 modes except plan. The variations on the frequencies of the modes of ovalization and trifoliate are close to:

- 0.4% in DSQ and COQUE_3D in QUAD9,
- 0.7% in COQUE_3D in TRIA7, COQUE_C_PLAN, PIPE and TUYAU_6M,
- 1% for DKQ, DKT and DST.

1 Problem of reference

1.1 Geometry



It is about a cylindrical ring, of average radius $R_m = 0.369\,m$, thickness $t = 0.048\,m$ and length $L = 0.05\,m$.

1.2 Properties of material

The material is homogeneous, isotropic, elastic linear. The elastic coefficients are:
$E = 185000\,MPa$ and $\nu = 0.3$.
The density is constant and is worth: $\rho = 7800\,kg.m^{-3}$.

1.3 Boundary conditions and loadings

The structure is free in space.

1.4 Order of magnitude of the Eigen frequencies

The required clean modes correspond to the modes of Fourier of order 2 and 3 of the ring. The frequencies of a ring can be estimated starting from an analytical model of curved beam of Euler [bib1]. For a mode of Fourier of order n , the frequency is worth:

$$f_n = \frac{n(n^2-1)}{2\pi R_m^2}\sqrt{\frac{E\,I_y}{m(n^2+1)}}$$

where: $I_y = \frac{L t^3}{12}$ and $m = \rho L t$

For the modes of ovalization ($n=2$) and trifoliate ($n=3$), the corresponding frequencies are worth respectively $211.65\,Hz$ and $598.64\,Hz$. The search for clean modes is carried out on the tape $200-800\,Hz$ in order to collect these two modes of Fourier.

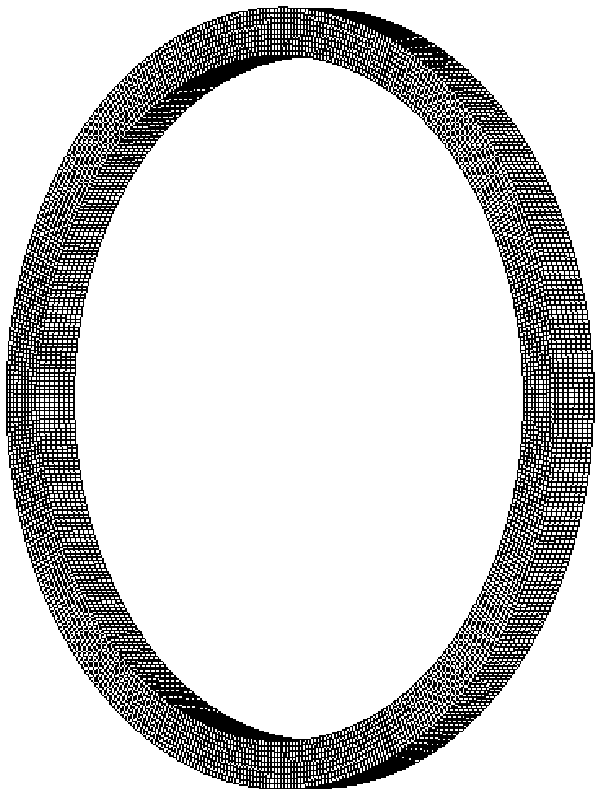
1.5 Bibliographical reference

1) Blevins R.D., Formulated for natural frequency and shape mode, N.Y.: Van Nostrand Reynhold Company, 1979.492 p.

2 Modeling of reference

2.1 Characteristics of the modeling of reference

Voluminal elements 3D



The discretized geometry is represented above. Elements 3D are voluminal with 8 nodes of the type HEXA8. The number of nodes on the circumference is 600, on thickness 9 and length 9.

2.2 Characteristics of the grid

Many nodes: 48600
Number of meshs and type: 38400 HEXA8

2.3 Values of reference tested

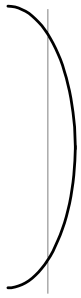
Frequencies of the clean modes of ovalization, trifoliate and except plan.

Mode	Eigen frequencies (Hz)
ovalizatio n	210.55 210.55
trifoliate	587.92 587.92
except plan	205.89 205.89 588.88 588.88

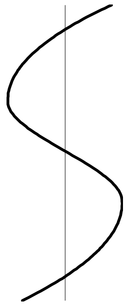
2.4 Remarks

The axisymmetric problem has double modes in the plan and except plan.
The modes except plan have the following deformations:

$205.89\ Hz$:



$588.88\ Hz$:



2.5 Uncertainties

Uncertainty is resulting from the analysis of convergence of the grid where Eigen frequencies with the grid of reference $600\times8\times8$ are compared with those of the grids $500\times7\times9$.

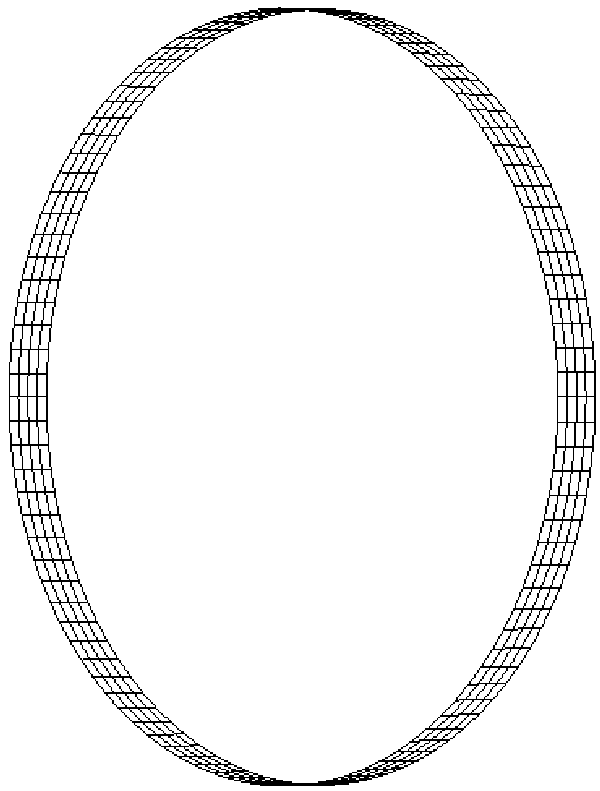
Many elements			Eigen frequencies (Hz)	
Circumference	**Thickness**	**Length**	**Ovalization**	**Trifoliate**
100	3	3	232.03	648.62
200	3	3	225.20	628.74
400	5	8	221.02	616.34
500	7	9	210.64	588.18
600	8	8	210.55	587.92

Uncertainty is of 0.05% on the frequency.

3 Modeling A

3.1 Characteristics of modeling

Plates DKQ and DSQ.



The discretized geometry is represented above. Elements DKQ and DSQ are plane facets with four nodes of the type QUAD4. The number of nodes on the circumference is 100 and over length 5.

3.2 Characteristics of the grid

Many nodes: 500
Number of meshs and type: 400 QUAD4

3.3 Values tested

(Frequencies in Hertz)

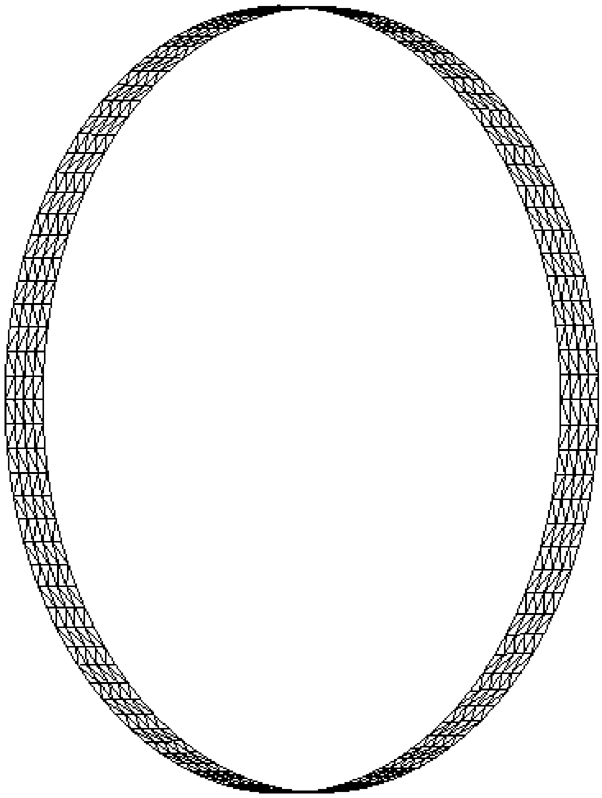
Mode	Reference	Aster DKQ	% difference	Aster DSQ	% difference
ovalization	210.55	211.48	0.44	209.57	– 0.46
	210.55	211.48	0.44	209.57	– 0.46
trifoliate	587.92	598.23	1.75	586.30	– 0.27
	587.92	598.23	1.75	586.30	– 0.27
except plan	205.89	234.70	13.99		
	205.89	234.70	13.99		
	588.88	646.34	9.75	533.02	– 9.49
	588.88	646.34	9.75	533.02	– 9.49

3.4 Remarks

Modelings in plates `DKQ` and `DSQ` do not allow to represent the modes except plan correctly. One can think that is due to the number of meshs over the too low length (4 instead of 8 in the modeling of reference). The first frequency except plan in plates `DSQ` must be lower than $200\,Hz$.

4 Modeling B

Plates DKT and DST - ear grid



Geometry discretized on the average radius $R_m = 0.369\ m$ is represented above. Elements DKT and DST are plane facets with three nodes of the type TRIA3 laid out out of ears. The number of nodes on the circumference is 100 and over length 5.

4.1 Characteristics of the grid

Many nodes: 500
Number of meshs and type: 800 TRIA3

4.2 Values tested

(Frequencies in Hertz)

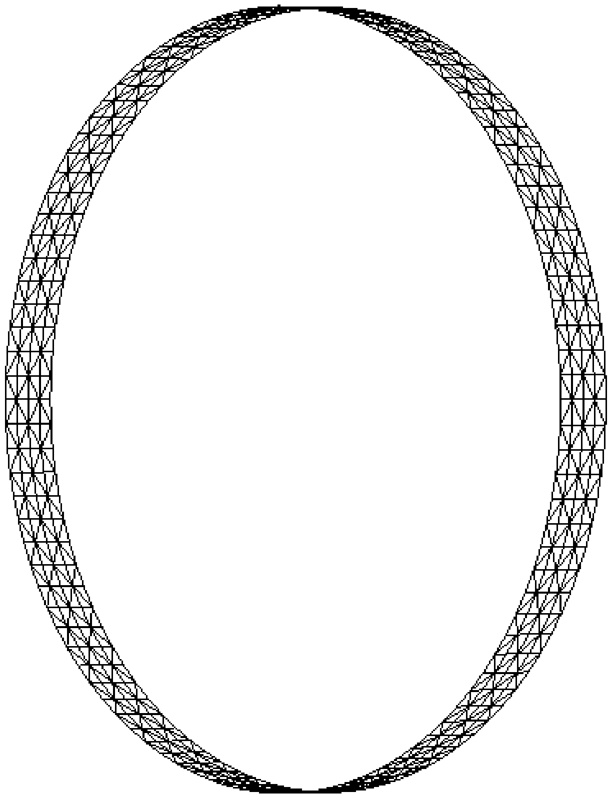
Mode	Reference	Aster DKT	% difference	Aster DST	% difference
ovalization	210.55	211.54	0.47	203.69	– 3.25
	210.55	211.54	0.47	203.69	– 3.25
trifoliate	587.92	598.64	1.82	568.70	– 3.27
	587.92	598.64	1.82	568.70	– 3.27
except plan	205.89	254.89	23.80	202.38	– 1.70
	205.89	254.89	23.80	202.38	– 1.70
	588.88	707.53	20.14	617.18	4.81
	588.88	707.53	20.14	617.18	4.81

4.3 Remarks

Modeling in plates DKT does not allow to represent the modes except plan correctly. Errors on the frequencies in plates DST are relatively important.

5 Modeling C

Plates DKT and DST - star grid



Geometry discretized on the average radius $R_m = 0.369\,m$ is represented above. Elements DKT and DST are plane facets with three nodes of the type TRIA3 laid out out of stars. The number of nodes on the circumference is 100 and over length 5.

5.1 Characteristics of the grid

Many nodes: 500
Number of meshs and type: 800 TRIA3

5.2 Values tested

(Frequencies in Hertz)

Mode	Reference	Aster DKT	% difference	Aster DST	% difference
ovalization	210.55	211.54	0.47	208.20	– 1.11
	210.55	211.54	0.47	208.20	– 1.11
trifoliate	587.92	598.58	1.81	581.00	– 1.18
	587.92	598.58	1.81	581.00	– 1.18
except plan	205.89	284.38	38.12	225.23	9.39
	205.89	284.38	38.12	225.23	9.39
	588.88	797.24	35.38	690.73	17.29
	588.88	797.24	35.38	690.73	17.29

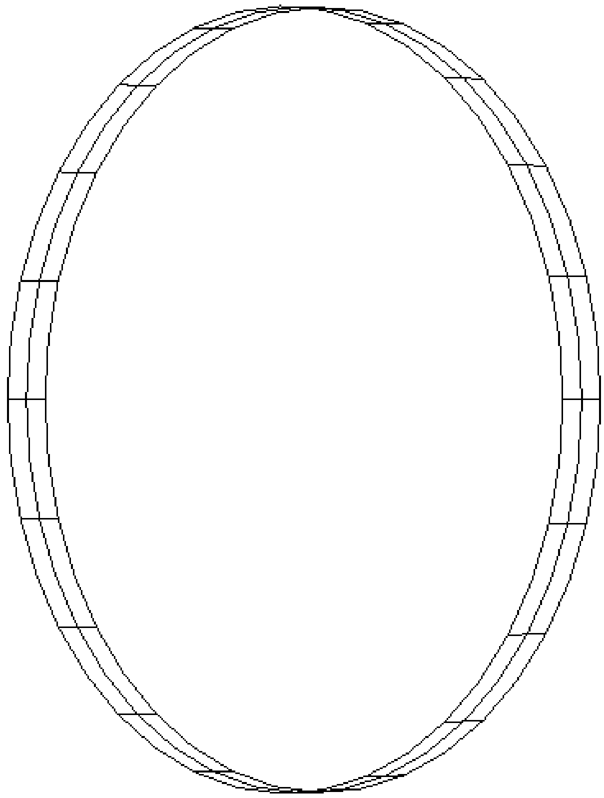
5.3 Remarks

Modelings in plates DKT and DST do not allow to represent the modes except plan correctly.

6 Modeling D

6.1 Characteristics of modeling

COQUE_3D grid in QUAD9.



Geometry discretized on the average radius $R_m=0.369\,m$ is represented above. Elements COQUE_3D are meshs with 9 nodes of the type QUAD9 allowing to take into account the radius of curvature of the ring. The nodes mediums are of course the average circumference. The number of nodes on the circumference is 40 and over length 5.

6.2 Characteristics of the grid

Many nodes: 200
Number of meshs and type: 40 QUAD9

6.3 Values tested

(Frequencies in Hertz)

Mode	Reference	*Code_Aster*	% difference
ovalization	210.55	209.91	– 0.30
	210.55	209.91	– 0.30
trifoliate	587.92	586.51	– 0.24
	587.92	586.51	– 0.24
except plan	205.89	205.14	– 0.36
	205.89	205.14	– 0.36
	588.88	587.55	– 0.23
	588.88	587.55	– 0.23

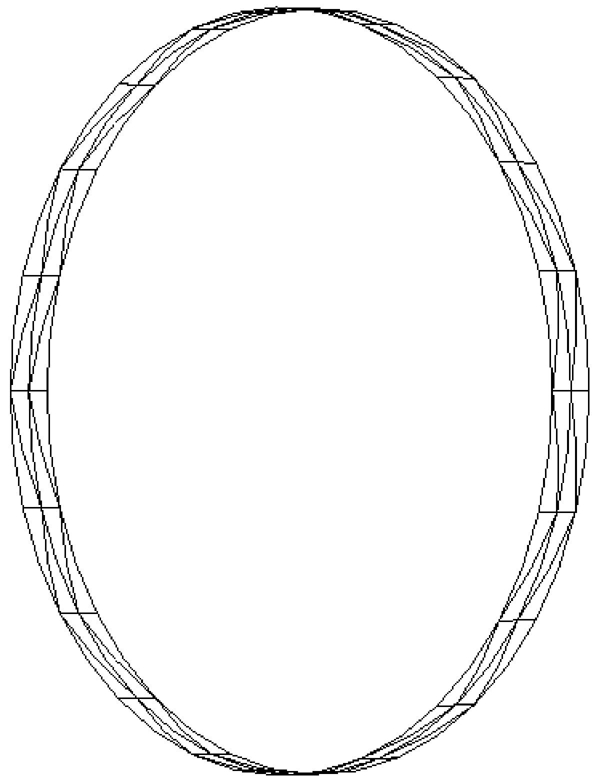
6.4 Remarks

All the frequencies are correctly estimated.

7 Modeling E

7.1 Characteristics of modeling

COQUE_3D grid in TRIA7.



Geometry discretized on the average radius $R_m = 0.369\,m$ is represented above. Elements COQUE_3D are meshs with 7 nodes of the type TRIA7 allowing to take into account the radius of curvature of the ring. The nodes mediums are of course the average circumference. The number of nodes on the circumference is 40 and over length 5.

7.2 Characteristics of the grid

Many nodes: 280
Number of meshs and type: 160 TRIA7

7.3 Values tested

(Frequencies in Hertz)

Mode	Reference	*Code_Aster*	% difference
ovalization	210.55	211.19	0.30
	210.55	211.19	0.30
trifoliate	587.92	590.98	0.52
	587.92	590.98	0.52
except plan	205.89	205.81	– 0.04
	205.89	205.81	– 0.04
	588.88	595.38	1.10
	588.88	595.38	1.10

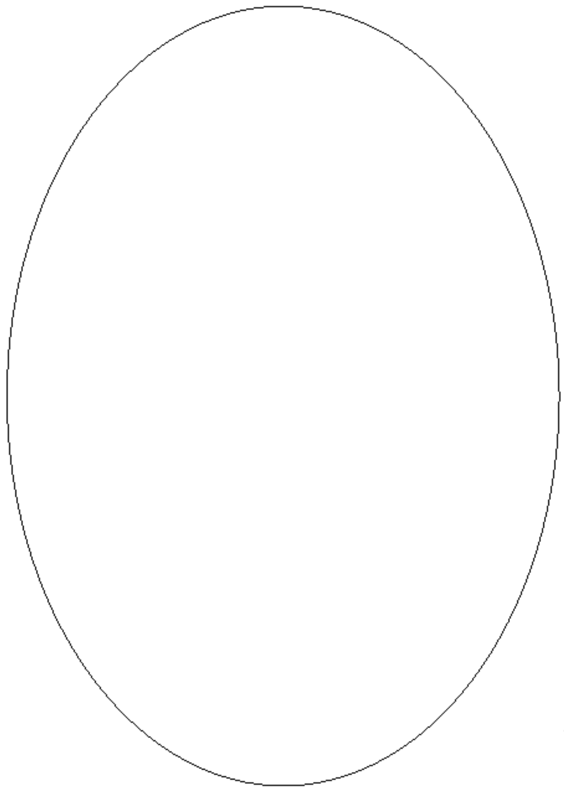
7.4 Remarks

The frequencies are less better estimated that with the elements QUAD9.

8 Modeling F

8.1 Characteristics of modeling

COQUE_C_PLAN.



Geometry discretized on the average radius $R_m=0.369\,m$ is represented above. Elements COQUE_C_PLAN are meshs with 3 nodes of the type SEG3 allowing to take into account the radius of curvature of the ring. The nodes mediums are of course the average circumference. The number of nodes on the circumference is 100.

8.2 Characteristics of the grid

Many nodes: 100
Number of meshs and type: 50 SEG3

8.3 Values tested

(Frequencies in Hertz)

Mode	Reference	*Code_Aster*	% difference
ovalization	210.55	209.14	– 0.67
	210.55	209.14	– 0.67
trifoliate	587.92	583.28	– 0.79
	587.92	583.28	– 0.79
except plan	205.89		
	205.89		
	588.88		
	588.88		

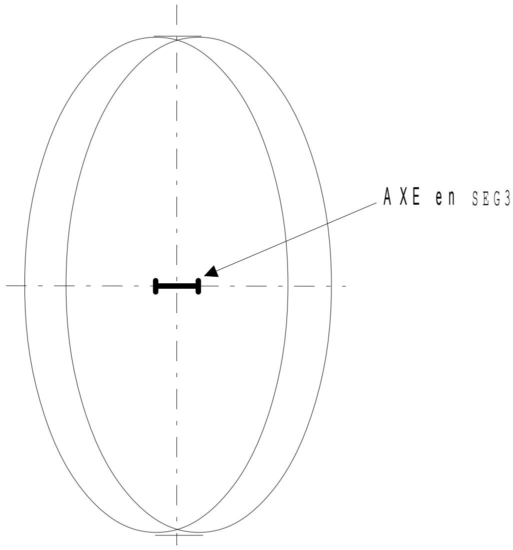
8.4 Remarks

Modeling in plane constraints does not make it possible to reveal the modes except plan of the ring.

9 Modeling G

9.1 Characteristics of modeling

PIPE and TUYAU_6M.



The geometry discretized on the axis of the ring is represented above. Elements PIPE and TUYAU_6M are meshs with 3 nodes of the type SEG3 representing the axis of the ring. The number of nodes on the axis is 5.

9.2 Characteristics of the grid

Many nodes: 5
Number of meshs and type: 2 SEG3

9.3 Values tested

(Frequencies in Hertz)

Mode	Reference	Aster **PIPE**	% difference	Aster **TUYAU_6M**	% difference
ovalization	210.55	209.02	– 0.72	209.02	– 0.72
	210.55	209.02	– 0.72	209.02	– 0.72
trifoliate	587.92	591.00	0.52	591.00	0.52
	587.92	591.00	0.52	591.00	0.52
except plan	205.89	259.74	26.15	259.74	26.15
	205.89	259.74	26.15	259.74	26.15
	588.88	649.57	10.31	649.57	10.31
	588.88	649.57	10.31	649.57	10.31

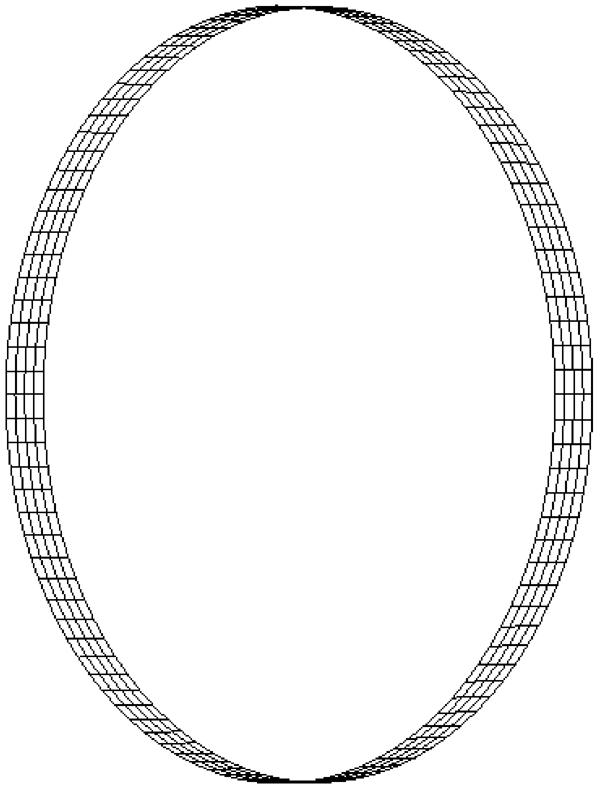
9.4 Remarks

Modelings in PIPE (limited by construction to 3 modes of Fourier) and TUYAU_6M do not allow to represent the modes except plan correctly. On the other hand, they provide the same results on the outline views, close to the reference.

10 Modeling H

10.1 Characteristics of modeling

Modeling SHB



The discretized geometry is represented above. Elements SHB8 are pressed on meshs HEXA8. The number of elements on the circumference is 100 and over length 5.

10.2 Characteristics of the grid

Many nodes: 1000
Number of meshs and type: 400 HEXA8, 400 QUAD4

10.3 Values tested

(Frequencies in Hertz)

Mode	Reference	Aster DKQ	% difference
ovalization	210.55	210.71	0.08
	210.55	210.71	0.08
trifoliate	587.92	590.84	0.5
	587.92	590.84	0.5
except plan	205.89	208.05	1.05
	205.89	208.05	1.05
	588.88	595.3	1.09
	588.88	595.3	1.09

11 Summary of the results

- Even if the got results are honourable, models DKQ, DSQ, DKT, DST, COQUE_C_PLAN, PIPE and TUYAU_6M do not allow to estimate the modes except plan of the ring. Only the model COQUE_3D with a grid in QUAD9 provides a good frequential estimate of these modes with an error lower than 0.4%.
- Models DSQ and COQUE_3D in QUAD9 give an error close to 0.3% for the modes of ovalization and trifoliate. For the models COQUE_3D in TRIA7, COQUE_C_PLAN, PIPE and TUYAU_6M, this error borders 0.7% and is higher than 1% for DKQ, DKT and DST.
- Best results of DSQ compared to DKQ confirm that the effect of transverse shearing is not negligible in the hulls notable thickness.
- On a developable geometry like that of the cylinder studied here, the quadrangular finite elements provide better results which triangular finite elements. DST, tested on an ear grid and a symmetrical star grid, are much less good than them DSQ. The same remark is also valid for COQUE_3D in TRIA7 compared to COQUE_3D in QUAD9.
- Performances of COQUE_3D are good quantitatively and in computing times. The wealth of the interpolation, the taking into account of the curve of the cylinder in the elements and the metric correction carried out in the thickness of the hull seem to explain these good performances.
- Elements SHB8 make it possible to obtain all the modes with a maximum change of about 1%.