

## SDLS109 - Eigen frequencies of a ring cylindrical thick

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### 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:

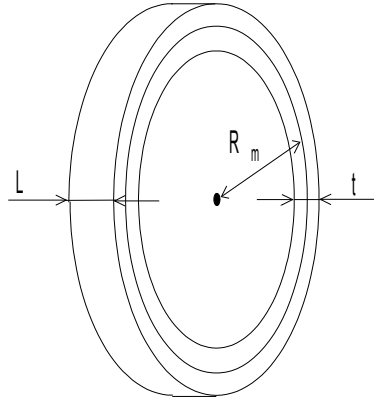
- 1) plates of the type `DKQ` (finite element `MEDKQU4`) and `DSQ` (finite element `MEDSQU4`),
- 2) plates of the type `DKT` (finite element `MEDKTR3`) and `DST` (finite element `MEDSTR3`) with a grid out of ears and star grid,
- 3) three-dimensional hulls of type `COQUE_3D` (finite elements `MEC3QU9H` and `MEC3TR7H`),
- 4) 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_HEX8`) 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`, `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  $R_m=0.369\text{ m}$ , thickness  $t=0.048\text{ m}$  and length  $L=0.05\text{ m}$ .

### 1.2 Properties of material

The material is homogeneous, isotropic, elastic linear. The elastic coefficients are:

$$E=185000\text{ MPa} \text{ and } \nu=0.3.$$

The density is constant and is worth:  $\rho=7800\text{ kg.m}^{-3}$ .

### 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  $211.65\text{ Hz}$  and  $598.64\text{ Hz}$ . The search for clean modes is carried out on the tape  $200-800\text{ Hz}$  in order to collect these two modes of Fourier.

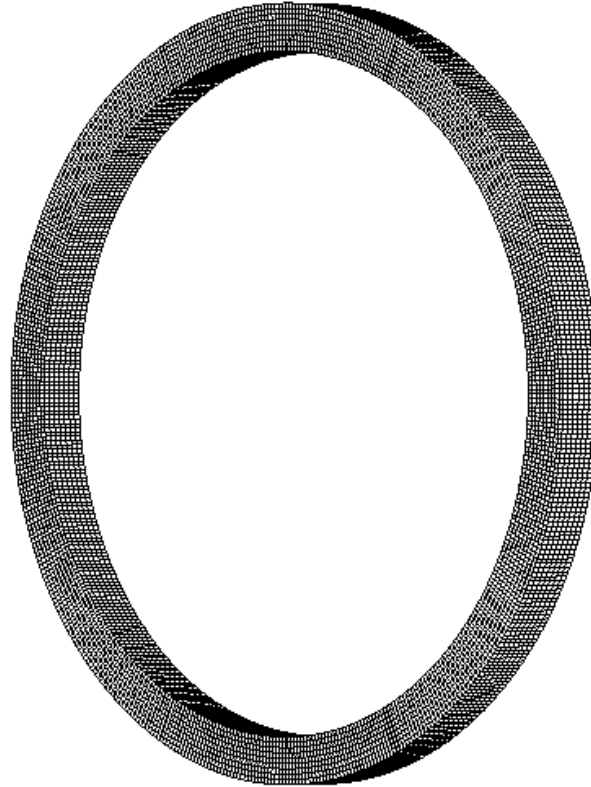
### 1.5 Bibliographical reference

- 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 meshes and type: 38400 HEXA8

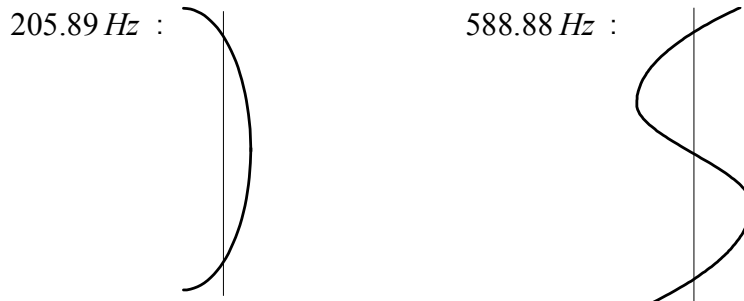
### 2.3 Values of reference tested

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

Mode	Eigen frequencies (Hz)
ovalization	210.55
n	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:



## 2.5 Uncertainties

Uncertainty is resulting from the analysis of convergence of the grid where Eigen frequencies with the grid of reference  $600 \times 8 \times 8$  are compared with those of the grids  $500 \times 7 \times 9$ .

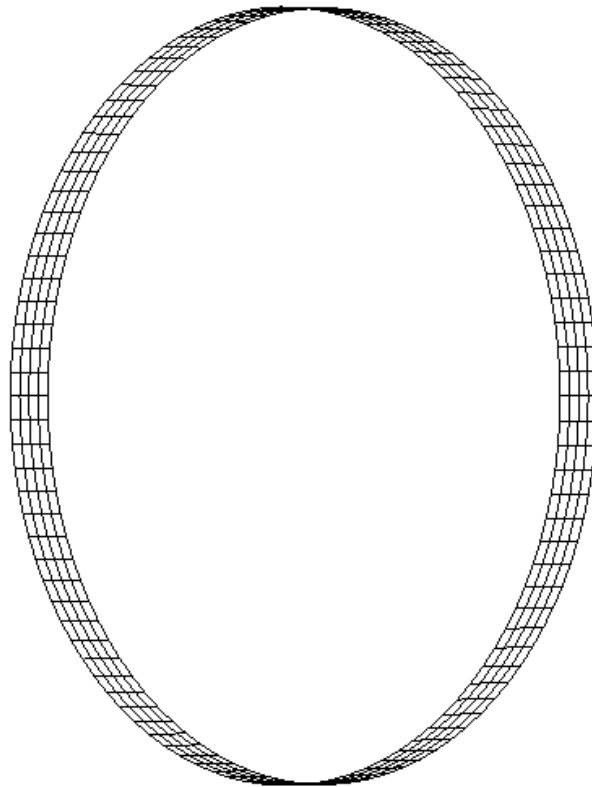
Many elements			Eigen frequencies ( Hz )	
Circumference	Thickness	Length	Ovalization	Trifoliolate
100	3	3	232.03	648.62
200	3	3	225.20	628.74
400	5	8	221.02	616.34
500	7	9	210.64	588.18
600	8	8	210.55	587.92

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 meshes and type: 400 QUAD4

### 3.3 Values tested

(Frequencies in Hertz). Modeling with test negative COEF\_RIGI\_DRZ. In this case ddl DRZ has a physical direction of "drilling rotation" or rotation around the normal on the average surface.

Mode	Reference	% difference	% difference
ovalization	210.55	0.44	- 0.46
	210.55	0.44	- 0.46
trifoliate	587.92	1.75	- 0.27
	587.92	1.75	- 0.27
except plan	205.89	13.99	
	205.89	13.99	
	588.88	9.75	- 9.49
	588.88	9.75	- 9.49

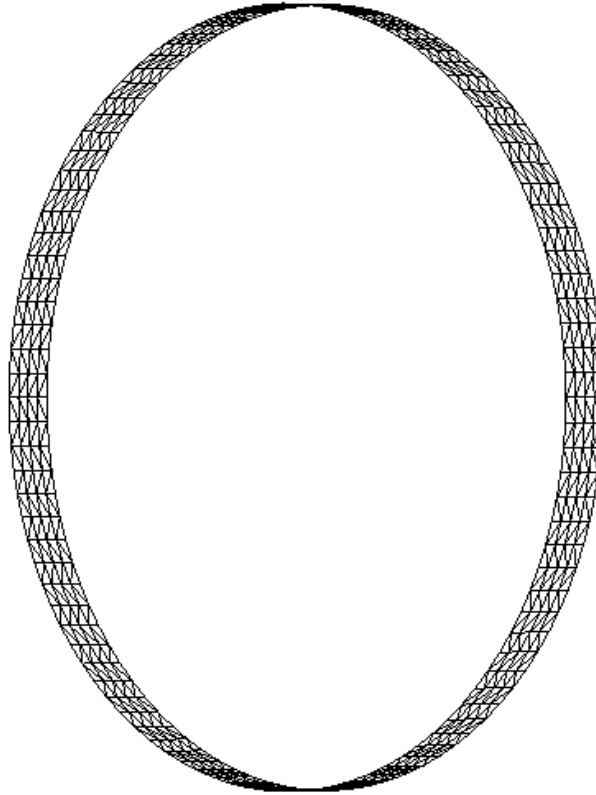
One also tests, the differences as a result between models DSQ and DKQ.

## 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 meshes 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  $200 \text{ Hz}$ .

## 4 Modeling B

Plates DKT and DST - ear grid



Geometry discretized on the average radius  $R_m = 0.369 \text{ m}$  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 meshes 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

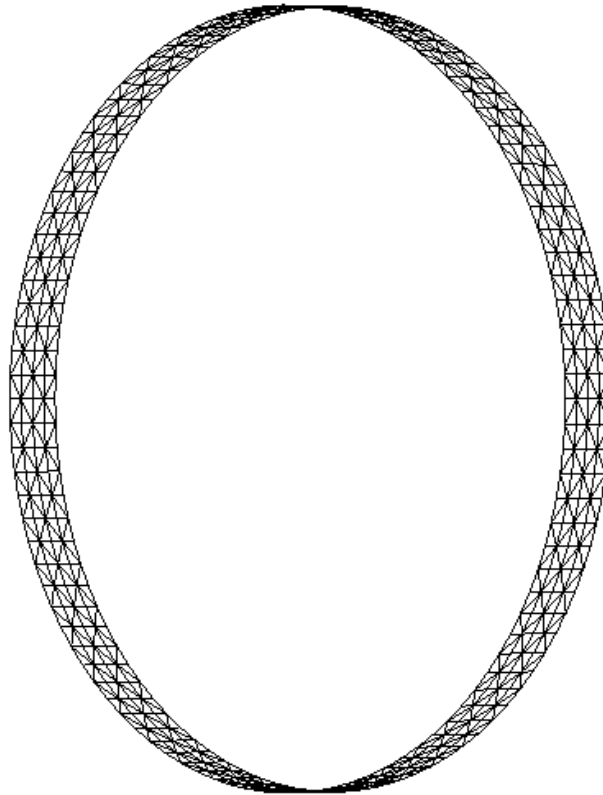
## 4.3 Remarks

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 meshes 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

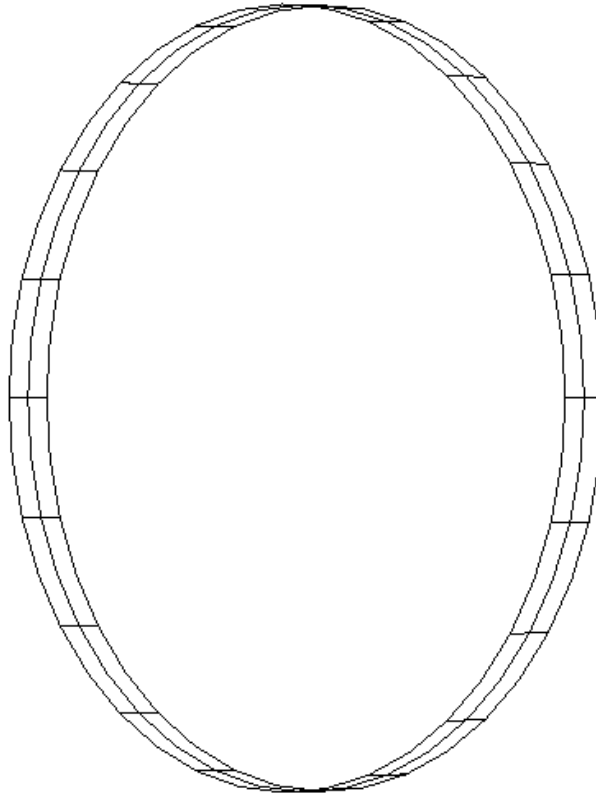
## 5.3 Remarks

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  $R_m=0.369\text{ m}$  is represented above. Elements COQUE\_3D are meshes 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 meshes 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

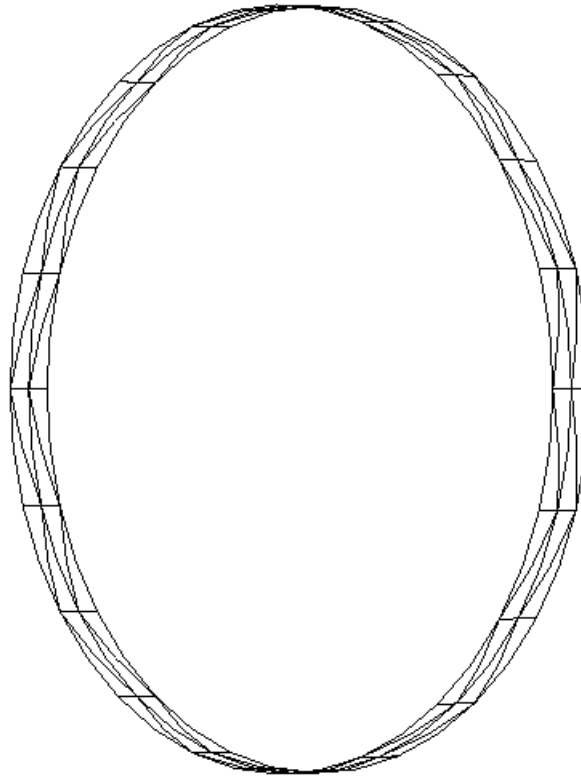
## 6.4 Remarks

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  $R_m=0.369\text{ m}$  is represented above. Elements COQUE\_3D are meshes 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 meshes 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

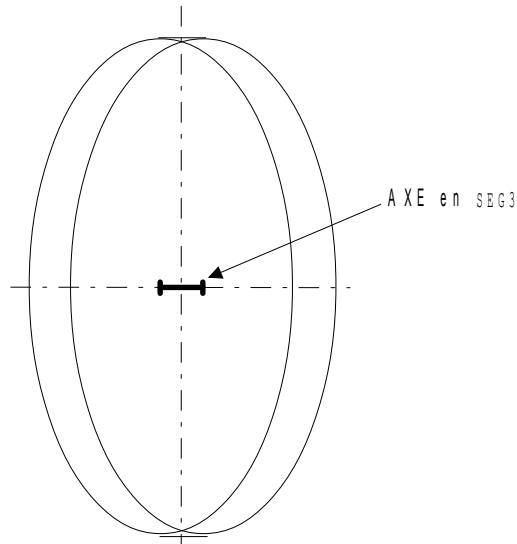
## 7.4 Remarks

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

## 8 Modeling F

### 8.1 Characteristics of modeling

PIPE and TUYAU\_6M.



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

### 8.2 Characteristics of the grid

Many nodes: 5  
Number of meshes and type: 2 `SEG3`

### 8.3 Values tested

(Frequencies in Hertz)

Mode	Reference	Aster <code>PIPE</code>	% difference	Aster <code>TUYAU_6M</code>	% 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

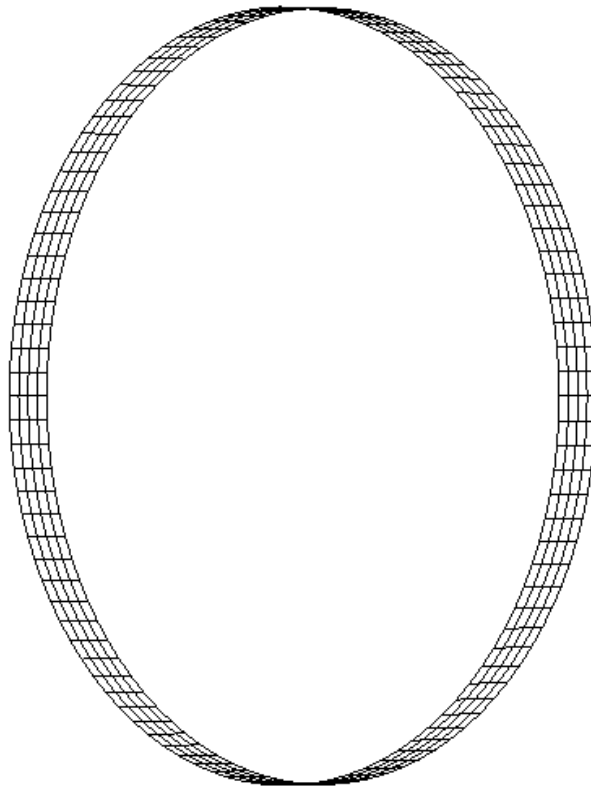
### 8.4 Remarks

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.

## 9 Modeling G

### 9.1 Characteristics of modeling

Modeling SHB



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

### 9.2 Characteristics of the grid

Many nodes: 1000

Number of meshes and type: 400 HEXA8, 400 QUAD4

### 9.3 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



## 10 Summary of the results

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- Even if the got results are honourable, models DKQ, DSQ, DKT, DST, 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, 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%.