SDLL14 - Modes of vibration of an elbow of thin piping

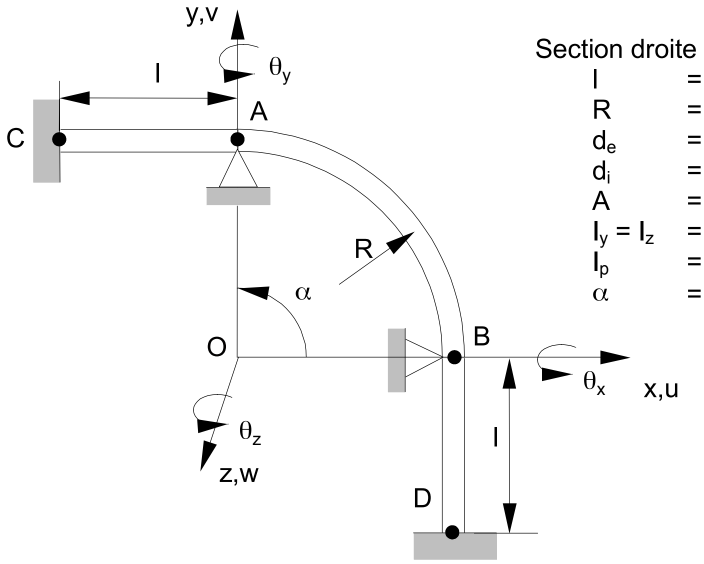
Summary:

This test consists in searching the Eigen frequencies and the modes of vibration associated with a bent piping. It makes it possible to validate modelings finite elements PIPE (SEG3 and SEG4) and TUYAU_6M (SEG4).
It also validates the option of calculation of the greatest Eigen frequencies of a structure.

The got results are compared with an analytical reference solution.

1 Problem of reference

1.1 Geometry



Section droite circulaire creuse

l	=	2.0 m
R	=	1. m
d_e	=	0.020 m
d_i	=	0.016 m
A	=	1.131×10^{-4} m²
$I_y = I_z$	=	4.637×10^{-9} m^4
I_p	=	9.274×10^{-9} m^4
α	=	90°

1.2 Properties of material

The properties of material constituting the plate are:

$E = 2.1\ 10^{11}\ Pa$	Young modulus
$\nu = 0.3$	Poisson's ratio
$\rho = 7800.\ kg/m^3$	Density

1.3 Boundary conditions and loadings

- Boundary conditions:
  - sections in C and D embedded
  - Not A : displacements according to y and z worthless
  - Not B : displacements according to x and z worthless

1.4 Initial conditions

Without object

2 Reference solution

2.1 Method of calculating used for the reference solution

The method of Rayleigh applied to elements of slim right beam and to an element of thin curved beam makes it possible to determine parameters such as:

- inflection in the plan: $f_i = \frac{\lambda_i^2}{2\pi R^2}\sqrt{\frac{E I_z}{\rho A}} \quad i=1,2$;
- transverse inflection: $f_i = \frac{\mu_i^2}{2\pi R^2}\sqrt{\frac{G I_p}{\rho A}} \quad i=1,2$;

Values λ_i^2 and μ_i^2 are drawn from an abacus.

This formulation is usable only for piping very slim:

- Twinge of the right parts higher than $\frac{l}{d_e} > 20$
- Thin elbow such as $\alpha R > 100\sqrt{\frac{I_z}{A}}$ with α, angle in the center in radian. It is not necessary to use here a coefficient of flexibility of the elbow.

2.2 Results of reference

- The first four Eigen frequencies,
- The first four clean modes (2 transverse modes, 2 modes in the plan).

  - Frequency (transverse mode 1) $17.9\,Hz$
  - Frequency (mode in plan 1) $24.8\,Hz$
  - Frequency (transverse mode 2) $25.3\,Hz$
  - Frequency (mode in plan 1) $27.0\,Hz$

2.3 Uncertainties on the solution

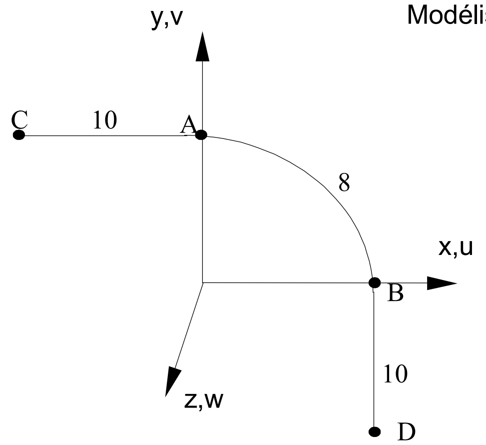
- Lower than 0.1% for the first transverse Eigen frequency,
- lower than 3% for the other Eigen frequencies.

2.4 Bibliographical references

1) VPCS: Guide of validation of the software packages of structural analysis: “test SDLL14”, SFM, technical AFNOR.
2) R.D. Blevins, formulated for natural frequency and shape mode, New York, Van Nostrand, 1979, P. 215.

3 Modeling A

3.1 Characteristics of modeling



Modélisation TUYAU (SEG3)

Conditions aux limites :

Points C et D :
- DDL de Poutre : DX = DY = DZ = DRX = DRY = DRZ = 0
- DDL de Coque : UIm = VIm = WIm = 0 (m=2,3)
  UOm = VOm = WOm = 0 (m=2,3)
  WI1 = WO1 = WO = 0

Point A :
- DDL de Poutre : DY = DZ = 0

Point B :
- DDL de Poutre : DX = DZ = 0

3.2 Characteristics of the grid

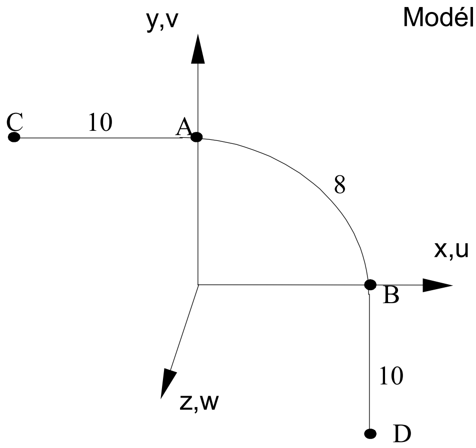
Many nodes: 57
Many meshs and types: 28 SEG3

3.3 Sizes tested and results

Identification	Reference
Frequency (Hz) Transverse 1	17.9
Frequency (Hz) in plan 1	24.8
Frequency (Hz) Transverse 2	25.3
Frequency (Hz) in plan 2	27.0

4 Modeling B

4.1 Characteristics of modeling



Modélisation TUYAU_6M (SEG3)

Conditions aux limites :

Points C et D :
- DDL de Poutre : DX = DY = DZ = DRX = DRY = DRZ = 0
- DDL de Coque : UIm = VIm = WIm = 0 (m=2,6)
  UOm = VOm = WOm = 0 (m=2,6)
  WI1 = WO1 = WO = 0

Point A :
- DDL de Poutre : DY = DZ = 0

Point B :
- DDL de Poutre : DX = DZ = 0

4.2 Characteristics of the grid

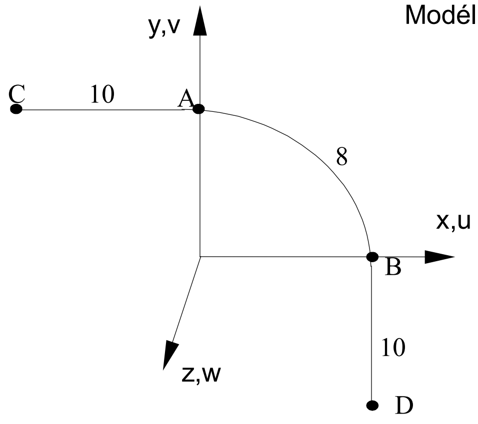
Many nodes: 57
Many meshs and types: 28 SEG3

4.3 Sizes tested and results

Identification	Reference
Frequency (Hz) Transverse 1	17.9
Frequency (Hz) in plan 1	24.8
Frequency (Hz) Transverse 2	25.3
Frequency (Hz) in plan 2	27.0

5 Modeling C

5.1 Characteristics of modeling



Modélisation TUYAU (SEG4)

Conditions aux limites :

Points C et D :
- DDL de Poutre : DX = DY = DZ = DRX = DRY = DRZ = 0
- DDL de Coque : UIm = VIm = WIm = 0 (m=2,3)
  UOm = VOm = WOm = 0 (m=2,3)
  WI1 = WO1 = WO = 0

Point A :
- DDL de Poutre : DY = DZ = 0

Point B :
- DDL de Poutre : DX = DZ = 0

5.2 Characteristics of the grid

Many nodes: 85
Many meshs and types: 28 SEG4

5.3 Sizes tested and results

Identification	Reference
Frequency (Hz) Transverse 1	17.9
Frequency (Hz) in plan 1	24.8
Frequency (Hz) Transverse 2	25.3
Frequency (Hz) in plan 2	27.0

5.4 Remarks

Grid in SEG4 is obtained starting from a grid SEG3 with the order CREA_MAILLAGE, MODI_MAILLE with the option 'SEG3_4'. It is important that the node medium of SEG3 that is to say well in the medium, *Code_Aster* check this condition with a tolerance.

6 Modeling D

6.1 Characteristics of modeling

Idem that modeling A.

6.2 Characteristics of the grid

Idem that modeling A.

6.3 Sizes tested and results

One tests the ergonomic calculation of the greatest Eigen frequency of the structure, thanks to the option 'PLUS_GRANDE' in the operator CALC_MODES. The value of reference is given by modeling E.

7 Modeling E

7.1 Characteristics of modeling

Idem that modeling A.

7.2 Characteristics of the grid

Idem that modeling A.

7.3 Sizes tested and results

One tests the calculation of the greatest Eigen frequency of the structure, by exchanging with the hand the roles of the matrices of mass and stiffness. It is in particular necessary to transfer the degrees of freedom from Lagrange of the stiffness towards the mass.

Modal calculation is carried out on the one hand with `TYPE_RESU=' GENERAL'`, which returns an eigenvalue λ ; in this case, the formula should be applied $\frac{1}{2\pi\sqrt{\lambda}}$ to convert the value into Eigen frequency. In addition with `TYPE_RESU=' DYNAMIQUE'`, which returns an Eigen frequency f ; in this case, the formula should be applied $\frac{1}{(2\pi)^2 f}$ to find the good Eigen frequency.
The value thus calculated is used as reference for modeling D.

8 Summary of the results

Results got with modeling PIPE (SEG3 and SEG4) and TUYAU_6M (SEG4) are satisfactory. The maximum change observed is lower than 2.1% .

The greatest Eigen frequency calculated is the same one if the ergonomic manner is used or if one exchanges the roles of the matrices to the hand.