SDLL14 - Modes of vibration of a thin elbow of pipework

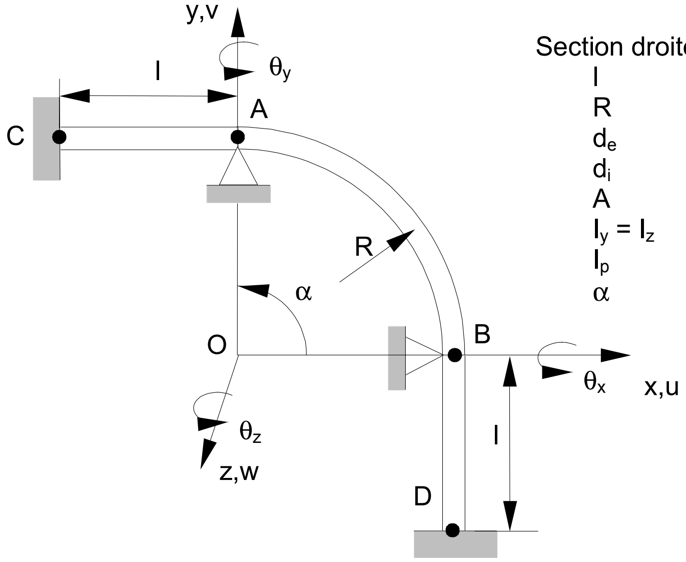
Summarized:

This test consists in searching the eigenfrequencies and the modes of vibration associated with a bent pipework. It makes it possible to validate modelizations finite elements `PIPE` (`SEG3` and `SEG4`) and `TUYAU_6M` (`SEG4`).
It also validates the computation option of the greatest eigenfrequencies 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 the material

the properties of the material constituting the plate are:

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

1.3 Boundary conditions and loadings

- Boundary conditions:
  - sections in C and D clamped
  - Point: A displacements according to y and z null
  - Point: B displacements according to x and z null

1.4 Initial conditions

Without Reference solution

2 object

2.1 Method of calculating used for the reference solution

the method of Rayleigh applied to beam elements slender right and a thin curved beam element makes it possible to determine parameters such as:

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

The values λ_i^2 and μ_i^2 are drawn from an abacus.

This formulation is usable only for the pipework very slender:

- Slenderness 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 compliance of the elbow.

2.2 Results of reference

- the first Four eigenfrequencies,
- the first Four eigen modes (2 transverse modes, 2 modes in the plane).

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

2.3 Uncertainties on the solution

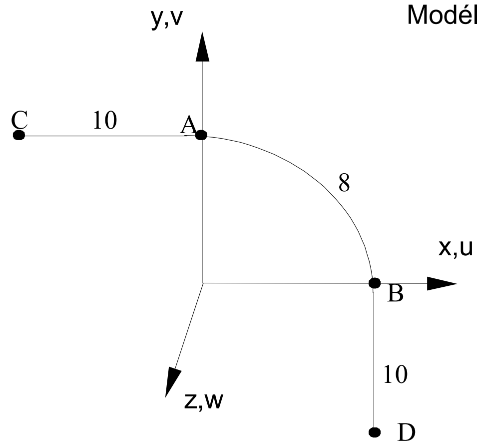
- Lower than 0.1% for the first transverse eigenfrequency,
- lower than 3% for the other eigenfrequencies.

2.4 Bibliographical references

1) VPCS: Guide 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 Modelization A

3.1 Characteristic of the modelization



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 mesh

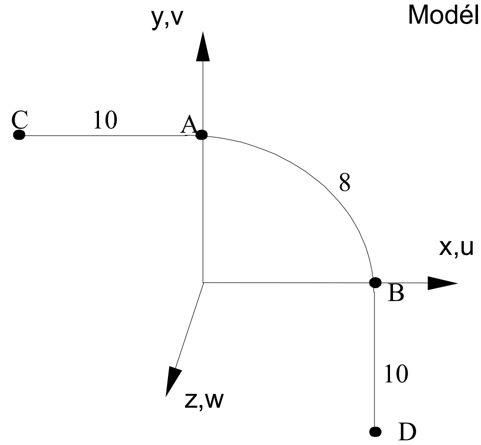
Many nodes: 57
Number of meshes and types: 28 `SEG3`

3.3 Quantities tested and results

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

4 Modelization B

4.1 Characteristic of the modelization



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 mesh

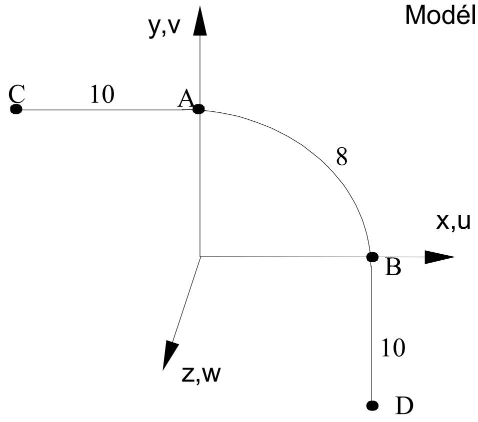
Many nodes: 57
Number of meshes and types: 28 SEG3

4.3 Quantities tested and results

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

5 Modelization C

5.1 Characteristic of the modelization



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 mesh

Many nodes: 85
Number of meshes and types: 28 SEG4

5.3 Quantities tested and results

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

5.4 Remarks

The mesh in SEG4 is obtained from a mesh SEG3 with command CREA_MAILLAGE, MODI_MAILLE with the option "SEG3_4". It is important that the medium node of the SEG3 is well in the medium, *Code_Aster* checks this condition with a tolerance.

6 Modelization D

6.1 Characteristic of the modelization

Idem that modelization A.

6.2 Caractéristiques of the mesh

Idem that modelization A.

6.3 Grandeurs tested and results

One tests the ergonomic computation of the greatest eigenfrequency of structure, thanks to option "PLUS_GRANDE" in operator CALC_MODAL. The value of reference is given by the modelization E.

7 Modelization E

7.1 Characteristic of the modelization

Idem that modelization A.

7.2 Caractéristiques of the mesh

Idem that modelization A.

7.3 Grandeurs tested and results

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

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

8 Synthèse of the results

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

The greatest calculated eigenfrequency is the same one if the ergonomic way is used or if one exchanges the roles of the matrixes to the hand.