FDLL200 - Piping embedded and free by beam fluid-structure

Summary:

The objective is to calculate the low frequency behavior of a piping filled with water. Piping has a circular section; it is embedded at an end and free other side.

One uses the elements of beam élasto-acoustics available in *Code_Aster* who take into account the fluid interaction structure (`PHENOMENON = 'MECHANICAL', MODELING = 'FLUI_STRU'`).

The boundary conditions are mechanical to simulate the embedding of the structure, and acoustics to simulate the condition of tank of the fluid in this point (boundary conditions of worthless pressure and fluid potential of displacement no one).

The fluid which one considers is a heavy fluid in order to put forward the phenomenon of coupling between the column of fluid and the structure constitutive of piping. The properties of the fluid and structural material are selected so that the celerity of a wave being propagated in the fluid is the same one as the celerity of a mechanical wave being propagated in piping. Under these conditions, the first mode of the structure resounds at the same frequency as the column of fluid.

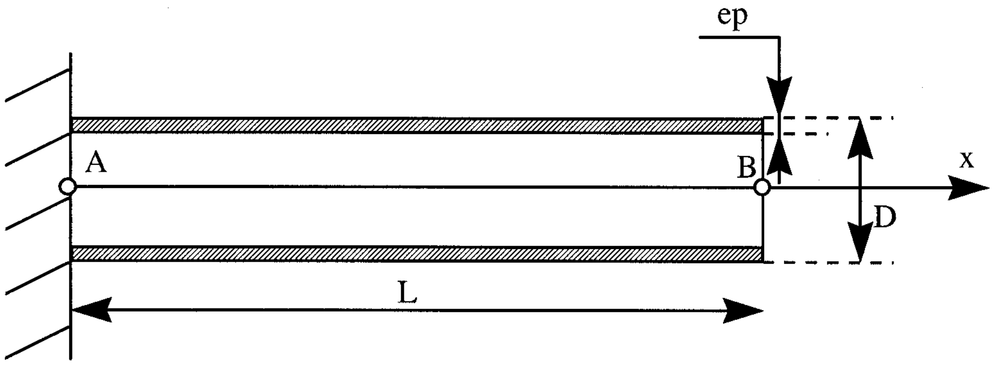
Modeling A is based on a constant section and an exact analytical solution exists then which provides the first Eigen frequency. Its comparison with the results produced by *Code_Aster* (search for eigenvalues) the taking into account of the fluid coupling structure in the longitudinal direction makes it possible to validate, the transverse effects being non-existent in this model. One tests thus partially the matrix of stiffness and that of mass.

Modelings B and C are used to validate the case of the variable circular sections. In the first, the section is declared of variable type (`VARI_SECT=' HOMOTHETIQUE'` in `AFFE_CARA_ELEM`) but the parameters define a constant section. The solution is thus the same one as for modeling A. In last modeling, the section is really variable and it is not made whereas a test of not-regression.

1 Problem of reference

1.1 Geometry

Piping is a hollow roll with circular section, filled with fluid.



Characteristics of piping:

length: $L=1,0\,m$

external diameter: $D=0,1\,m$

thickness: $ep=0,01\,m$

For modeling C, one modifies the section which becomes variable: the diameter varies from 0.1 to 0.11 m whereas the thickness varies from 0.011 to 0.01 Mr.

1.2 Properties of materials

The physical characteristics of material constituting the tube are the following ones:

Young modulus: $E=1,0\cdot 10^{10}\,Pa$
Poisson's ratio: $\nu=0,3$
density: $\rho_s=1,0\cdot 10^4\,kg/m^3$
celerity longitudinal wave: $c_s=\sqrt{\dfrac{E}{\rho_s}}=1,0\cdot 10^3\,m/s$

The physical characteristics of fluid material in the tube are the following ones:

density: $\rho_f=1,0\cdot 10^3\,kg/m^3$
speed of sound: $c_f=1,0\cdot 10^3\,m/s$

1.3 Boundary conditions and loading

- Displacement only according to the axis of x .
- Embedding of piping in the end A .
- Free piping in the end B .
- For the fluid condition of tank in the end A .

2 Reference solution

2.1 Method of calculating used for the reference solution

One studies the vibratory behavior of a piping filled with fluid. Piping is embedded with one of its ends and free at the other end. The section of piping is constant and circular. One is interested in the low frequencies of the longitudinal behavior of piping.

One defines:

length of the tube:	L
Young modulus of the pipe:	E
diameter external of the pipe:	D
thickness of the walls:	ep
surface of the solid section:	S_s
surface of the fluid section:	S_f
celerity in the pipe (structure):	c_s
celerity in the fluid:	c_f

One chose the characteristics of the fluid and the pipe in order to have the following relation:

$$c_f=c_s=\sqrt{\frac{E}{\rho_s}}=c=1000\,m/s$$

In this typical case of equality of celerities, one shows [bib2] that the first Eigen frequency of the coupled problem is such as:

$$tg\left(\frac{\omega L}{c_s}\right)=\sqrt{\frac{S_s}{S_f}\cdot\frac{E}{\rho_f c^2}}$$

It is worth in this case: $f=157{,}94\,Hz$

2.2 Results of reference

Only one modeling is used. The calculation of the modes is in formulation u,p,φ . There is no reference solution if the section is variable (modeling C).

2.3 Uncertainty of the solution

Analytical solution.

2.4 Bibliographical references

1. WAECKEL F., DUVAL C.: Note of principle and use of the pipes implemented in *Code_Aster*. Note interns R & D HP-61/92.138

2. DUVAL C.: Dynamic response under random excitation in *Code_Aster*. Note interns R & D HP-61/92.148

3 Modeling A

3.1 Characteristics of modeling

The modeling of the beams élasto-acoustics is in formulation u, θ, p, ϕ.
It is carried out by the assignment on meshs of the type SEG2 (segments with 2 nodes) of elements `PHENOMENON = 'MECHANICAL', MODELING = 'FLUI_STRU'`.

One assigns to the elements the characteristics of circular section:

external ray	$R_{ext}=0{,}100\,m$	
thickness	$ep=0{,}010\,m$	cf [§1.1]

One also assigns to these elements a mixed material of behavior at the same time `ELAS` :

Young modulus	$E=1{,}0.1010\,Pa$	
Poisson's ratio	$\nu=0{,}3$	
density	$\rho_s=1000\,kg/m^3$	

and `FLUID` :

celerity	$c=1000\,m/s$	
density	$\rho_f=1000\,kg/m^3$	cf [§1.2]

Degrees of freedom (DDL) of translation in y and z (`DY` and `DZ`) and all degrees of freedom of rotation (`DRX`, `DRY MARTINI` and `DRZ`) of all the nodes are blocked.
In order to embed the end A piping, one also blocks the degree of freedom of translation in x (`DX`) node $NO1$.
For the fluid the condition of tank at the end A is imposed by `CLOSE = 0.` and `PHI = 0.` with the node $NO1$.

3.2 Characteristics of the grid

The full number of nodes used for this grid is of 26.
The meshs are 25 and of type `SEG2`.
The file of grid is with the format `ASTER`.

3.3 Calculation

One wishes to validate the elements of beam élasto-acoustics.
One calculates the frequency of the first axial mode coupled with the operator `CALC_MODES`.

3.4 Values tested

The test relates to the frequency of the first coupled axial mode of piping containing a fluid.
The tolerance of relative variation compared to the analytical value is worth 0,1%.

Number of the mode	Analytical value
1	$157{,}93981\,Hz$ Value not regression

3.5 Notice

The values of reference are at the same time the analytical values and also those obtained by *Code_Aster* during the restitution of the CAS-test, which will thus make it possible to check to it not later regression of the code during its evolution.

4 Modeling B

4.1 Characteristics of modeling

One takes again modeling A by modifying only the declaration of the section of piping. Under the keyword AFFE_CARA_ELEM, one declares a case of section variable with VARI_SECT=' HOMOTHETIQUE', mboard with parameters of ray and diameter remaining constant. One thus seeks to validate the option of variable section, within the meaning of the keyword, but by finding the same solution as for modeling A.

4.2 Values tested

The test relates to the frequency of the first coupled axial mode of piping containing a fluid which must be identical to that of modeling A.
The tolerance of relative variation compared to the analytical value is worth 0,1%.

Number of the mode	Analytical value
1	$157{,}93981\,Hz$ Value not regression

4.3 Notice

The values of reference are at the same time the analytical values and also those obtained by *Code_Aster* during the restitution of the CAS-test, which will thus make it possible to check to it not later regression of the code during its evolution.

5 Modeling C

5.1 Characteristics of modeling

One takes again modeling A by modifying only the circular section which becomes variable. The diameter varies from 0.1 to 0.11 m whereas the thickness varies from 0.011 to 0.01 Mr.

5.2 Values tested

The test relates to the frequency of the first coupled axial mode of piping containing a fluid. As the section is variable, one cannot compare oneself any more with the reference solution and only it not - regression is checked for this modeling.

6 Summary of the results

It is noted that the computed value of the frequency of the first coupled axial mode reproduced very exactly the analytical value with a relative precision of 0,004%, in the case of a constant section.