FDLL200 - Clamped and free pipework by beam fluid-structure

Summarized:

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

One uses the beam elements élasto-acoustics available in *Code_Aster* which take into account the fluid interaction structure (`PHENOMENE = "MECHANICAL", MODELISATION = "FLUI_STRU"`).

The boundary conditions are mechanical to simulate the fixed support of structure, and acoustics to simulate the condition of tank of the fluid in this point (boundary conditions of pressure null 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 fluid column and structure constitutive of the pipework. The properties of the fluid and the structural material are selected so that the celerity of one wave being propagated in the fluid is the same one as the mechanical celerity of one wave being propagated in the pipework. Under these conditions, the first mode of structure resounds with the same frequency as the fluid column.

An exact analytical solution exists which provides the first eigenfrequency. Its comparison with the results produced by *Code_Aster* (search for eigenvalues) makes it possible to validate the taking into account of the fluid coupling structure in the longitudinal meaning, the transverse effects being non-existent in this model. One tests thus partially the stiffness matrix and that of mass.

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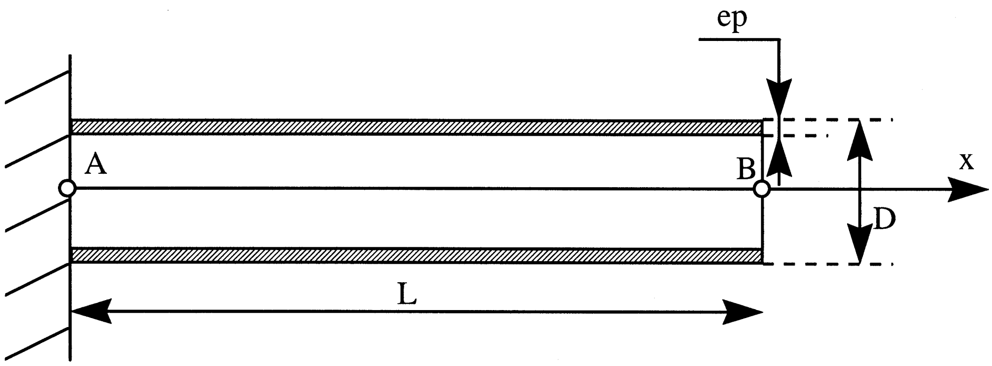
1 Problem of reference

1.1 Geometry

the pipework is a hollow roll with circular section, filled with fluid.



Characteristics of the pipework:

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

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

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

1.2 Properties of the materials

the physical characteristics of the 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: $c_s=\sqrt{\frac{E}{\rho_s}}=1{,}0\cdot 10^3\,m/s$

The physical characteristics of the 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 Des. x
- Fixed support of the pipework in the end A .
- Free pipework in the end B .
- For the fluid condition of tank in the end A .

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2 Reference solution

2.1 Method of calculating used for the reference solution

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

One defines:

length of the tube:	L
Young's modulus of the pipe:	E
diameter external of the pipe:	D
thickness of the walls:	ep
area of the solid section:	S_s
area 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 eigenfrequency 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 modelization is used. The computation modes is in formulation u, p, φ .

2.3 Uncertainty of the analytical

solution Solution.

2.4 Bibliographical references

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

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

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3 Modelization A

3.1 Characteristic of the modelization

The modelization of the beams élasto-acoustics are in formulation u, θ, p, φ.
It is carried out by the assignment on meshes of type SEG2 (segments with 2 nodes) of elements `PHENOMENE = "MECHANICAL"`, `MODELISATION = "FLUI_STRU"`.

One assigns to the elements the characteristics of circular section:

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

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

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

and `FLUIDE` :

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

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

3.2 Characteristics of the mesh

the nombre total of nodes used for this mesh is of 26.
Meshes are 25 and of type `SEG2`.
Mesh file is with the Aster format .

3.3 Computation

One wishes to validate the beam elements élasto-acoustics.
One carries out the computation of the frequency of the first axial mode coupled with operator `MODE_ITER_SIMULT`.

3.4 Values tested

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

Number of the analytical	mode Value
1	$157,93981\,Hz$
	non regression Value

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3.5 Notices

the values of reference are at the same time the analytical values and also those obtained by *Code_Aster* during the restitution of the benchmark, which will thus make it possible to check non regression later code during its evolution.

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4 Summary of the results

One notes that the computed value of the frequency of the first coupled axial mode reproduced very exactly the analytical value with a relative accuracy of 0.004%.

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