SDLL118 - Beam subjected to a fluid excitation - elastic axial

Summary:

One considers a PVC tube placed at the center of a cylindrical enclosure of section circular and subjected to the action of an axial water flow. This hardware configuration corresponds to the experimental device of Tanaka and al. [bib1] which is used to measure the evolutions of frequency and reduced damping of the first mode of the tube according to the mean velocity of the flow.

The goal of this CAS-test is to validate the resorption of the model MEFISTEAU [R4.07.04] allowing to calculate the modal characteristics of a telegraphic structure under confined axial flow, by taking account of an excitation of the fluid-rubber band type.

The features particular to test are the following ones:

- operator DEFI_FLUI_STRU [U4.25.01]: definition of the parameters for the taking into account of the coupling fluid-rubber band, in the case of a configuration of standard “the tube bundle under axial flow” (keyword factor FAISCEAU_AXIAL),
- operator CALC_FLUI_STRU [U47.66.02]: calculation of the evolutions of the frequencies and modal reduced depreciation according to the mean velocity of the flow, by the implementation of the model MEFISTEAU.

The digital results of the simulation of the device of Tanaka and al. are validated by comparison with the experimental results. Taking into account relatively important uncertainties on the experimental values, the results of reference for nonthe regression of the code are those obtained numerically during the restitution of the CAS-test.

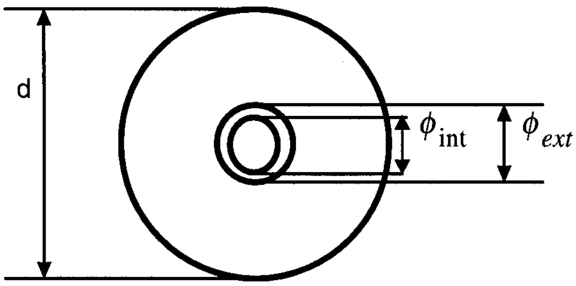
1 Problem of reference

1.1 Geometry

The tube considered is a hollow roll whose characteristic dimensions are the following ones:

length	$L=1\,m$
external diameter	$\phi_{\mathrm{ext}}=13\,mm$
internal diameter	$\phi_{\mathrm{int}}=8{,}8\,mm$

The tube is placed in the center of a cylindrical enclosure of circular section. The internal diameter of the enclosure is worth $d=5\,cm$.



The surface roughness of the tube is worth $\varepsilon=10^{-5}\,m$.

1.2 Properties of materials

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

Young modulus	$E=2{,}80.10^{9}\,Pa$
Poisson's ratio	$\nu=0{,}3$
density	$\rho=1500\,kg/m^{3}$

Water surrounding the tube has the following properties:

density	$\rho_{eau}=1000\,kg/m^{3}$
kinematic viscosity	$\nu_{eau}=1{,}1.10-6\,m^{2}/s$

1.3 Boundary conditions and loadings

The two ends of the tube are connected to fixed supports by two metal stems. The relative flexibility of inflection of these stems releases the degrees of freedom of rotation of the ends of the tube. One can thus estimate that the conditions of self-supporting quality of the tube are of the standard kneecap-kneecap, the metal stems introducing of each end an additional stiffness of rotation.

Moreover, these stems make it possible to apply an axial load to the tube, which can thus be prestressed in traction or compression. In practice, two configurations are studied:

- nonprestressed tube: no effort is applied. This configuration corresponds to modeling A of the CAS-test,
- tube prestressed in compression by application of an axial load of $40\,N$ at an end.

This configuration corresponds to modeling B of the CAS-test.

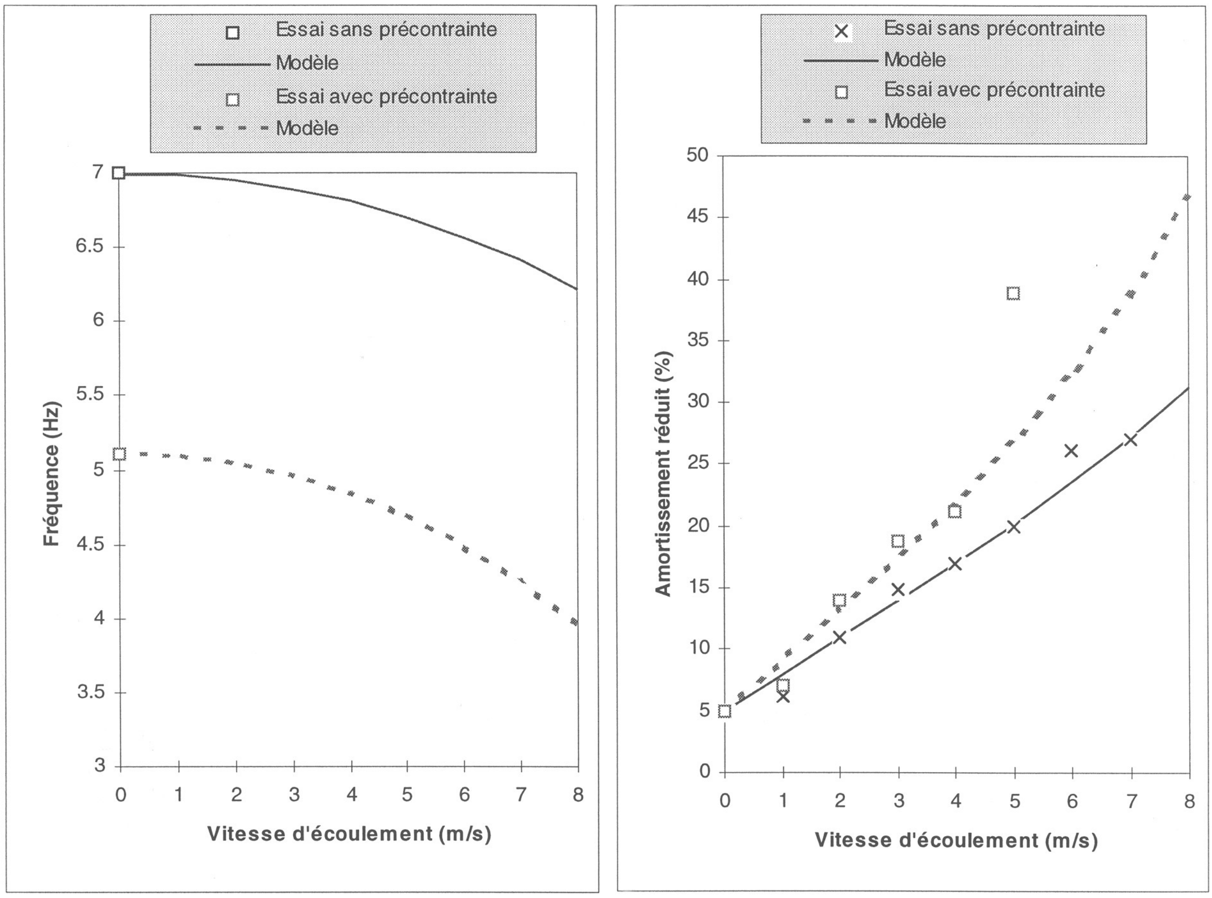
1.4 Bibliographical reference

1.Mr. TANAKA, K. FUJITA, A. HOTTA and NR. KONO: “Parallel flow-induced damping of PWR fuel assembly”, ASME Conference, Pittsburgh, Pa, PVP vol. 133 (1988)

2 Reference solution

The experimental mesures taken on the device of Tanaka and al. provide the values of reference for the validation of the model.

The two graphs below, representing the evolutions of the frequencies and the reduced damping of the first double mode of inflection according to the mean velocity of the flow, make it possible to compare the results of the model with the experimental results.



Taking into account uncertainties to the measures, the tolerance of relative variation for the validation of the model is rather broad. This is why experimental measurements cannot be used as values of reference for the CAS-test, a more narrow tolerance being necessary to guarantee to it not regression of the code. The values of reference used are thus those obtained numerically during the restitution of the CAS-test.

3 Modeling A

3.1 Characteristics of modeling

The tube is represented by 100 elements of right beams of Timoshenko (MECA_POU_D_T), supported per as many meshs segments to 2 nodes (SEG2). Two elements MECA_DIS_TR are added to the nodes ends of the tube, allowing to model the metal stems by discrete stiffnesses of rotation.

One carries out with the elements of beam the characteristics of circular section:

external ray	$R_{ext}=6{,}5.10^{-3}m$	
thickness	$E=2{,}1.10^{-3}m$	(cf paragraph [§1.1])

One also assigns to these elements a material of behavior ELAS :

Young modulus	$E=2{,}80.10^{9}Pa$	
Poisson's ratio	$\nu=0{,}3$	
density	$\rho=1500\,kg/m^{3}$	(cf paragraph [§1.2])

One assigns to the discrete elements the same stiffness of rotation around the two orthogonal axes with neutral fibre of the tube:

$$K_r=6{,}29\,Nm/rad$$

This stiffness of rotation was adjusted in order to find the Eigen frequency of the first double mode in air.

Degrees of freedom in translation DX and DZ nodes ends $N1$ and $N101$ are blocked in order to prohibit a rigid movement of body of the tube (axial translatory movement). It is also blocked DY node $N1$. Moreover, in each node, one blocks the degree of freedom of rotation DRY , in order to prohibit any movement of torsion.

The tube is immersed in a cylindrical enclosure of $2{,}5\,cm$ of interior ray (cf paragraph [§1.1]). The profiles of density and kinematic viscosity of surrounding water are supposed to be constant along the tube:

density	$\rho_{eau}=1000\,kg/m^{3}$	
kinematic viscosity	$\nu_{eau}=1{,}1.10^{-6}m^{2}/s$	(cf paragraph [§1.2])

No axial load is applied to the tube which is thus not prestressed.

The evolutions of the frequency and the reduced damping of the first double mode of inflection are calculated for a beach mean velocities of flow of 0 with $8\,m/s$, by step of $1\,m/s$.
One takes account of an initial reduced damping of the tube of the 4,8%.

3.2 Characteristics of the grid

The full number of nodes used for the grid is of 101.
Meshs (of type SEG2) are 100.
The file of grid is with the format ASTER.

3.3 Stages of calculation

The validation of the operators of coupling fluid-structure, for configurations of standard "the tube bundle under axial flow" is made in two principal stages.

The first consists in defining the parameters of taking into account of the coupling fluid-structure with the operator DEFI_FLUI_STRU follow-up of the keyword FAISCEAU_AXIAL.
The second is the calculation of the evolutions of modal frequency and reduced damping according to the mean velocity of the flow, with the operator CALC_FLUI_STRU and by the implementation of the model MEFISTEAU.

3.4 Values tested

The tests relate to the frequency and the reduced damping of the first double mode of inflection of the tube, at the mean velocity of flow of $0 m/s$ and $4 m/s$. 2 types of test are carried out:

1) a test of comparison with experimental measurements,
2) a test to guarantee to it not regression of the code.

3.4.1 Frequency of the first mode doubles inflection

1) Test of comparison with the experiment, at the rate of flow of $0 m/s$:

The tolerance of relative variation compared to the experimental value is worth 0,1%.

Number of the mode	Experimental value	Computed value	Relative variation
1	7 Hz	7.000871 Hz	1.2E-02%
2	7 Hz	7.000871 Hz	1.2E-02%

3.4.2 Reduced damping of the first mode doubles inflection

1) Test of comparison with the experiment, at the rate of flow of 4 m/s:

The tolerance of relative variation compared to the reference is worth 1%.

Number of the mode	Experimental value	Computed value	Relative variation
1	17%	17%	0,2%
2	17%	17%	0,2%

3.5 Remarks

The values of reference are those obtained by *Code_Aster* during the restitution of the CAS-test, which thus makes it possible to check to it not regression of the code during its evolution.

4 Modeling B

4.1 Characteristics of modeling

Modeling B is identical to modeling A (cf paragraph [§3.1]), but this time the tube is prestressed in compression.

An axial load of compression of $23,7 N$ is applied to the node end $N101$. The intensity of the effort was thus readjusted compared to the experimental value provided of $40 N$, in order to correctly find the value of frequency of the first mode doubles in air (cf paragraphs [§1.2], [§1.3]). This readjustment can apply by modeling summary of the metal stems ensuring the self-supporting quality and the setting in compression.

One deduces from the nodal effort the vector of elementary efforts, then an assembled vector which is built according to the classification of the degrees of freedom of the tube. The static deformation due to the setting in compression is then obtained by multiplying the vector assembled by the reverse of the matrix of structural rigidity. Using this static deformation, one calculates then a stress field to the elements, whose is deduced a geometrical matrix of rigidity. This one is then added to the matrix of structural rigidity in order to obtain the matrix of rigidity of the tube in compression, which is finally used for the calculation of the modes in air.

The evolutions of the frequency and the reduced damping of the first double mode of inflection are calculated for a beach mean velocities of flow of 0 with $8 m/s$, by step of $1 m/s$. One takes account of an initial reduced damping of the tube of 4.3%.

4.2 Characteristics of the grid

The characteristics of the grid of this second modeling are the same ones as those of modeling A, is: 101 nodes used and 100 meshs of the type `SEG2`.

The file of grid is with the format `ASTER`.

4.3 Stages of calculation

Just as for modeling A, the features to be validated are those of the operators of coupling fluid-structure for configurations of standard “the tube bundle under axial flow” (cf paragraph [§3.3]).

Moreover, modeling B makes it possible to test other features.
The first makes it possible to carry out the calculation of a field of displacements to the nodes by inversion of the matrix of rigidity structural and produced reverse by a vector of assembled effort, with the operators `TO FACTORIZE` and `TO SOLVE`.
The second allows the calculation of a geometrical matrix of rigidity using a stress field the elements, with the operator `CALC_MATR_ELEM`, option `RIGI_GEOM`.

4.4 Values tested

The tests relate to the frequency and the reduced damping of the first double mode of inflection of the tube, at the mean velocity of flow of $0 m/s$ and $4 m/s$. 2 types of test are carried out:

1) a test of comparison with experimental measurements,
2) a test to guarantee to it not regression of the code.

4.4.1 Frequency of the first mode doubles inflection

1) Test of comparison with the experiment, at the rate of flow of $0 m/s$:

The tolerance of relative variation compared to the reference is worth 0,1%.

Number of the	Experimental value	Computed value	Relative variation

mode			
1	5.1 Hz	5.10426 Hz	8.4E-02%
2	5.1 Hz	5.10426 Hz	8.4E-02%

4.4.2 Reduced damping of the first mode doubles inflection

1) Test of comparison with the experiment, at the rate of flow of $4\,m/s$:

The tolerance of relative variation compared to the reference is worth 10%.

Number of the mode	Experimental value	Computed value	Relative variation
1	21,10%	21,94%	4,00%
2	21,10%	21,94%	4,00%

4.5 Remarks

The values of reference are those obtained by *Code_Aster* during the restitution of the CAS-test, which makes it possible to check to it not regression of the code during its evolution.