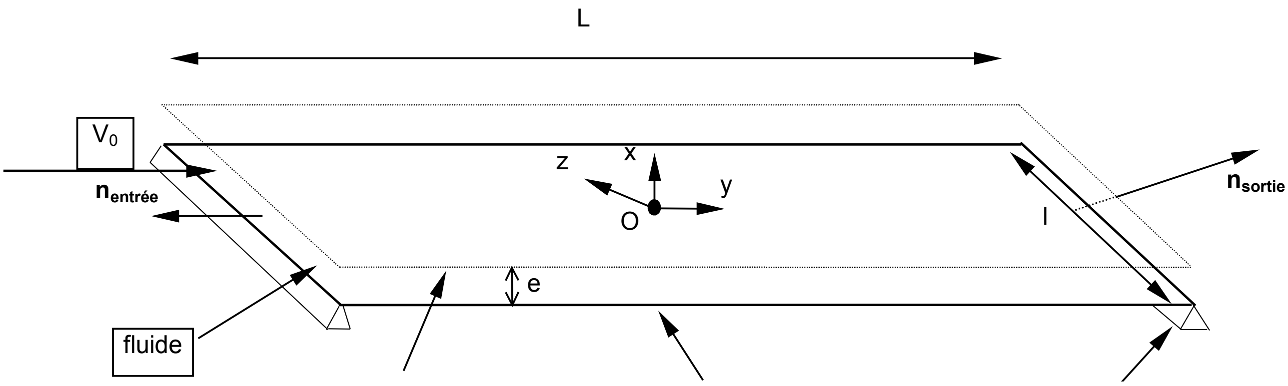
FDLV109 - Computation of coefficients added out of Summarized plane

flow:

This test of the fluid field/structure implements the computation of mass, stiffness and damping added on a plane structure subjected to a confined flow which one supposes potential. These added coefficients are calculated for a velocity upstream of $4\,m.s^{-1}$, on a model 3D for the fluid and shell for structure. The structure is subjected to an imposed displacement of bending.

1 Problem of reference

1.1 Geometry



$L=50\,m$

$I=5\,m$

thickness of fluid $e=0.5\,m$

thickness of the plate $h=0.5\,m$

the reference $Oxyz$ is at a distance from $\frac{e}{2}$ plate

1.2 Properties of the materials

Fluid: density $\rho=1000\,kg.m^{-3}$ (water).

Structure: $\rho_s=7800\,kg/m^3$; $E=2.1\,10^{11}\,Pa$; $\nu=0.3$ (steel).

1.3 Boundary conditions and loadings

Fluid:

- to simulate steady flow, one forces on the face of entry of the fluid a normal velocity of $-4\,m/s$ (by thermal analysis, one imposes a normal heat flux are equivalent of – 4),
- to compute: the fluid disturbance brought by the motion of the external cylinder one imposes a boundary condition of Dirichlet in a node of the fluid.
- one imposes in $x=\frac{e}{2}$ the condition $\varphi_1=\varphi_2=0$ which corresponds to a null flow through the higher fluid wall.

Structure:

- the plate is subjected to a displacement corresponding to its first two modes of bending [bib2]:

$$X_1=\sin\frac{\pi y}{L} \quad ; X_2=\sin\frac{2\pi y}{L}$$

2 Reference solution

2.1 Method of calculating used for the reference solution

For computation of the added coefficients:

one shows [bib1] that the coefficients of mass and added depreciation depend on the permanent potential fluid velocities $\bar{\phi}$ as well as two fluctuating potentials ϕ_1 and ϕ_2 : these potentials are in the case of written the motion of bending of the plate [bib1]:

For the first mode: $$\begin{cases} \bar{\varphi}^{(1)} = V_0 y \\ \varphi_1^{(1)} = \left(x - \frac{e}{2}\right)\sin\frac{\pi y}{L} \\ \varphi_2^{(1)} = \frac{V_0 \pi}{L}\left(x - \frac{e}{2}\right)\cos\frac{\pi y}{L} \end{cases}$$

For the second mode: $$\begin{cases} \bar{\varphi}^{(2)} = V_0 y \\ \varphi_1^{(2)} = \left(x - \frac{e}{2}\right)\sin\frac{2\pi y}{L} \\ \varphi_2^{(2)} = \frac{2V_0 \pi}{L}\left(x - \frac{e}{2}\right)\cos\frac{2\pi y}{L} \end{cases}$$

However the added modal coefficients projected on these modes of bending are written:

$$M_{ij}^a = \rho \int_{\text{cylindre externe}} \varphi_1^{(i)} \mathbf{X}_j \ . \ \mathbf{n} \ dS$$
$$C_{ij}^a = \rho \int_{\text{cylindre externe}} \left(\varphi_2^{(i)} + \nabla\bar{\varphi}^{(i)} . \nabla\varphi_1^{(i)}\right)\left(\mathbf{X}_j \ . \ \mathbf{n}\right) \ dS$$
$$K_{ij}^a = \rho \int_{\text{cylindre externe}} \left(\nabla\bar{\varphi}^{(i)} . \nabla\varphi_2^{(i)}\right)\left(\mathbf{X}_j \ . \ \mathbf{n}\right) \ dS$$

that is to say:

$$M_{11}^a = M_{22}^a = \rho e l \frac{L}{2} \ ; \ M_{12}^a = 0$$
$$C_{11}^a = C_{22}^a = 0 \ ; \ C_{12}^a = C_{21}^a = -\frac{8}{3}\rho e l V_0$$
$$K_{11}^a = -\rho e V_0^2 \frac{\pi^2 l}{2L} \ ; \ K_{22}^a = -\rho e V_0^2 \frac{2\pi^2 l}{L} \ ; \ K_{12}^a = 0$$

•Numerical applications:

One did a calculation of added damping which corresponds for the velocity given to a deadened vibratory behavior of structure:

velocity V_0 with $4\,m.s^{-1}$

the values of the mechanical system are:

$$e=h=5.10^{-1}m \qquad L=50m \qquad l=5\ m$$

The added mass brought by flow is worth:

$$M_{11}^a = 0.625\ 10^5 kg$$
$$M_{22}^a = 0.625\ 10^5 kg$$
$$M_{12}^a = 0$$

The damping added is worth with $V_0 = 4\,m.s^{-1}$:

$$C_{11}^a = 0$$
$$C_{22}^a = 0$$
$$C_{12}^a = 0.266\ 10^5\ \ N.m^{-1}$$

The added stiffness is worth with $V_0 = 4\,m.s^{-1}$:

$$K_{11}^a = -0.3943\ 10^4\ \ N.m^{-1}\ rad^2$$
$$K_{22}^a = -0.1577\ 10^5\ \ N.m^{-1}\ rad^2$$
$$K_{12}^a = 0$$

2.2 Results of reference

Result analytical.

2.3 References bibliographical

•ROUSSEAU G., LUU H.T. : Mass, damping and stiffness added for a vibrating structure placed in a potential flow - Bibliography and establishment in *the Code_Aster* - HP-61/95/064
•BLEVINS R.D: Formulated for natural frequency and shape mode. ED. Krieger 1984

3 Modelization A

3.1 Characteristic of the modelization

For the system 3D on which one calculates the added coefficients:

For solid:
160 meshes `QUAD4`
shell elements `MEDKQU4`

For the fluid:
160 meshes `QUAD4`
elements thermal `THER_FACE4`
on the plane surface

184 meshes `thermal`
QUAD4 elements `THER_FACE4`
on the sides of entry and output of fluid volume

480 meshes `thermal`
HEXA8 elements `THER_HEXA8`
in fluid volume

3.2 Values tested

Identification	Reference
M_{11}^a	0.625 105
M_{22}^a	0.625 105
M_{12}^a	0
C_{11}^a	0
C_{22}^a	0
C_{12}^a	0.266 105
K_{11}^a	– 0.394 104
K_{22}^a	– 0.157 105
K_{12}^a	0

4 Summary of the results

the computational tool of coefficients added under flow (potential assumption) were validated on the first two modes of bending of a plane structure. It is necessary however to note [bib1] that the very good agreement between the model semi-analytical proposed for comparison and numerical computation are obtained only if the plate is sufficiently long, the model semi-analytical being makes of it only one approximate solution of the posed problem.