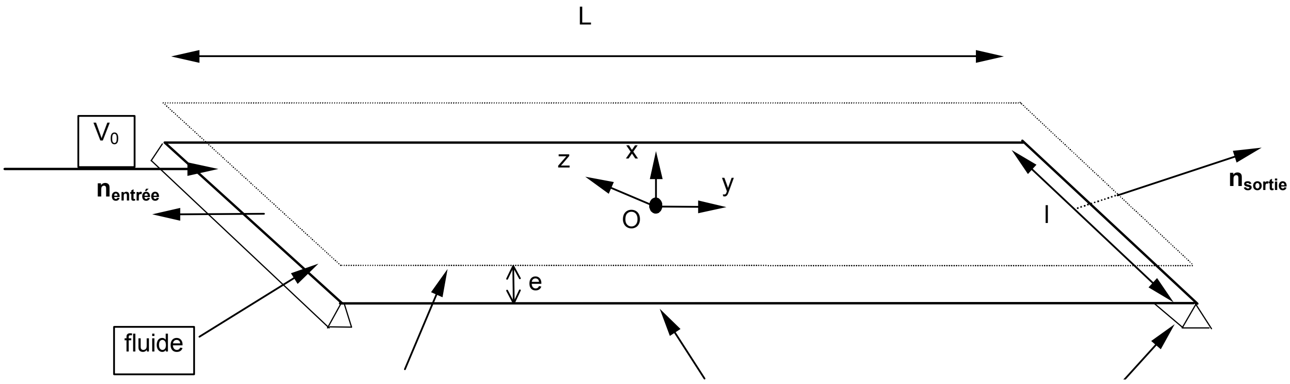
FDLV109 - Calculation of coefficients added in flow plan

Summary:

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

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 mark $Oxyz$ is located at a distance from $\frac{e}{2}$ plate

1.2 Properties of 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 speed of $-4\,m/s$ (by thermal analysis, one imposes a normal heat flow equivalent of – 4),
- to calculate the fluid disturbance brought by the movement of the external cylinder one forces a boundary condition of Dirichlet in a node of the fluid.
- one imposes in $x=\frac{e}{2}$ the condition $\phi_1=\phi_2=0$ who 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 inflection [bib2]:

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

2 Reference solution

2.1 Method of calculating used for the reference solution

For the calculation of the added coefficients:

it is shown [bib1] that the coefficients of mass and added depreciation depend on the permanent potential fluid speeds $\bar{\phi}$ as well as two fluctuating potentials ϕ_1 and ϕ_2 : these potentials are in the case of written the movement of inflection of the plate [bib1]:

For the first mode:
$$\begin{cases} \bar{\varphi}^{(1)} = V_0 y \\ \phi_1^{(1)} = \left(x - \frac{e}{2}\right) \sin\frac{\pi y}{L} \\ \phi_2^{(1)} = \frac{V_0 \pi}{L}\left(x - \frac{e}{2}\right) \cos\frac{\pi y}{L} \end{cases}$$

For the second mode:
$$\begin{cases} \bar{\varphi}^{(2)} = V_0 y \\ \phi_1^{(2)} = \left(x - \frac{e}{2}\right) \sin\frac{2\pi y}{L} \\ \phi_2^{(2)} = \frac{2 V_0 \pi}{L}\left(x - \frac{e}{2}\right) \cos\frac{2\pi y}{L} \end{cases}$$

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

$$M_{ij}^a = \rho \int_{\text{cylindre externe}} \phi_1^{(i)} \mathbf{X}_j \,.\, \mathbf{n} \; dS$$

$$C_{ij}^a = \rho \int_{\text{cylindre externe}} \left(\phi_2^{(i)} + \nabla\bar{\varphi}^{(i)} . \nabla\phi_1^{(i)}\right)\left(\mathbf{X}_j \,.\, \mathbf{n}\right) \; dS$$

$$K_{ij}^a = \rho \int_{\text{cylindre externe}} \left(\nabla\bar{\varphi}^{(i)} . \nabla\phi_2^{(i)}\right)\left(\mathbf{X}_j \,.\, \mathbf{n}\right) \; dS$$

that is to say:

$$M_{11}^a = M_{22}^a = \rho e l \frac{L}{2} \;\; ; \;\; M_{12}^a = 0$$

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

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

- Digital applications:

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

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

  The values of the mechanical system are:

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

  The added mass brought by the flow is worth:

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

  Added damping 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

Analytical result.

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 *Code_Aster* - HP-61/95/064
- BLEVINS R.D: Formulated for natural frequency and shape mode. ED. Krieger 1984

3 Modeling A

3.1 Characteristics of modeling

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

For the solid:	160 meshs QUAD4 elements of hulls MEDKQU4
For the fluid:	160 meshs QUAD4 elements thermics THER_FACE4 on the plane surface
	184 meshs QUAD4 thermal elements THER_FACE4 on the faces of entry and exit of fluid volume
	480 meshs HEXA8 thermal elements THER_HEXA8 in fluid volume

3.2 Values tested

Identification	Reference
M_{11}^a	0,625 10^5
M_{22}^a	0,625 10^5
M_{12}^a	0
C_{11}^a	0
C_{22}^a	0
C_{12}^a	0,266 10^5
K_{11}^a	– 0,394 10^4
K_{22}^a	– 0,157 10^5
K_{12}^a	0

4 Summary of the results

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