

## FDLV109 - Calculation of coefficients added in flow plan

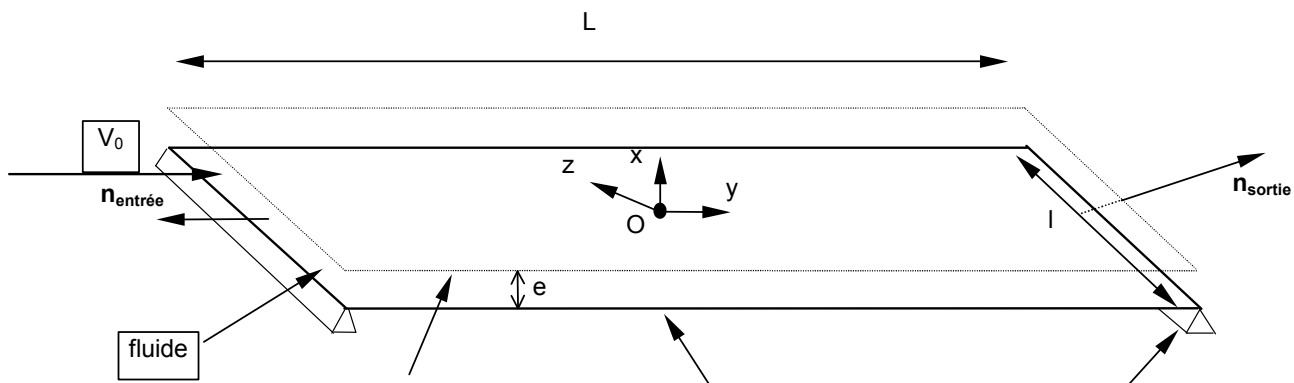
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### Summary:

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  $4 \text{ m.s}^{-1}$ , 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



$$L = 50 \text{ m}$$

$$I = 5 \text{ m}$$

thickness of fluid  $e = 0.5 \text{ m}$

thickness of the plate  $h = 0.5 \text{ m}$

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

### 1.2 Properties of materials

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

Structure:  $\rho_s = 7800 \text{ kg/m}^3$  ;  $E = 2.1 \cdot 10^{11} \text{ Pa}$  ;  $\nu = 0.3$  (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  $-4 \text{ m/s}$  (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  $\phi_1$  and  $\phi_2$  : these potentials are in the case of written the movement of inflection of the plate [bib1]:

$$\bar{\phi}^{(1)} = V_0 y$$

For the first mode:

$$\phi_1^{(1)} = x - \frac{e}{2} \sin \frac{\pi y}{L}$$

$$\phi_2^{(1)} = \frac{V_0 \pi}{L} x - \frac{e}{2} \cos \frac{\pi y}{L}$$

$$\bar{\phi}^{(2)} = V_0 y$$

For the second mode:

$$\phi_1^{(2)} = x - \frac{e}{2} \sin \frac{2\pi y}{L}$$

$$\phi_2^{(2)} = \frac{2V_0 \pi}{L} x - \frac{e}{2} \cos \frac{2\pi y}{L}$$

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

$$M_{ij}^a = \rho \int_{\text{cylindre externe}} \phi_2^{(i)} \mathbf{X}_j \cdot \mathbf{n} dS$$

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

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

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  $4 \text{ m.s}^{-1}$

The values of the mechanical system are:

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

The added mass brought by the flow is worth:

$$M_{11}^a = 0.625 \cdot 10^5 \text{ kg}$$

$$M_{22}^a = 0.625 \cdot 10^5 \text{ kg}$$

$$M_{12}^a = 0$$

Added damping is worth with  $V_0 = 4 \text{ m.s}^{-1}$  :

$$C_{11}^a = 0$$

$$C_{22}^a = 0$$

$$C_{12}^a = 0.266 \cdot 10^5 \text{ N.m}^{-1}$$

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

$$K_{11}^a = -0.3943 \cdot 10^4 \text{ N.m}^{-1} \text{ rad}^2$$

$$K_{22}^a = -0.1577 \cdot 10^5 \text{ N.m}^{-1} \text{ rad}^2$$

$$K_{12}^a = 0$$

## 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

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### 3.1 Characteristics of modeling

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

For the solid: 160 meshes QUAD4  
elements of hulls MEDKQU4

For the fluid: 160 meshes QUAD4  
elements thermics THER\_FACE4  
on the plane surface

184 meshes QUAD4  
thermal elements THER\_FACE4  
on the faces of entry and exit of fluid volume

480 meshes HEXA8  
thermal elements THER\_HEXAS  
in fluid volume

### 3.2 Values tested

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

## 4 Summary of the results

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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.