

## FDLV108 - Calculation of damping added in annular flow (variable density)

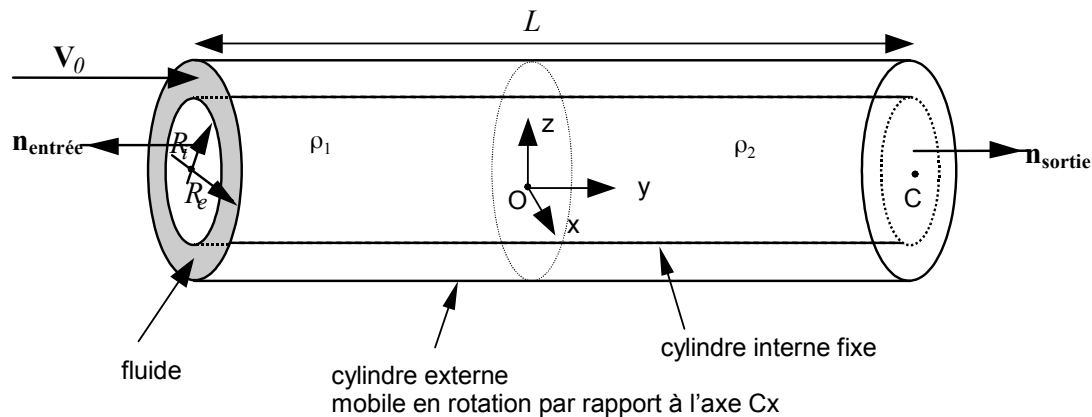
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### Summary:

This test of the fluid-structure field implements the calculation of mass and damping added on a cylindrical structure subjected to an annular flow which one supposes potential. One calculates mass and damping added by the flow on the structure for a speed upstream of  $4 \text{ m.s}^{-1}$ , on a model 3D for the fluid and hull for the structure. The structure has a displacement of rotation around a pivot located at the downstream end of the cylinder compared to the flow. The interest of the test lies in the taking into account of a fluid field of density **nonhomogeneous**.

## 1 Problem of reference

### 1.1 Geometry



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

$$R_i = 1 \text{ m}$$

$$R_e = 1.1 \text{ m}$$

$C$  : not pivot of the external structure (swivelling around  $Cx$ )

### 1.2 Properties of materials

**fluid:** density  $\rho_1 = 1000 \text{ kg.m}^{-3}$  ;  $\rho_2 = 750 \text{ kg.m}^{-3}$  ;

**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:**

- 1) 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  $-4$ );
- 2) to model the variation of density, one forces a condition of continuity of the flow on the interface;
- 3) 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.

**Structure:**

- 1) one imposes on the external cylinder a displacement of the type

$$\mathbf{X}_i = \left[ \frac{L}{2} - y \right] \mathbf{z}$$

with the nodes of the grid of this cylinder.

## 2 Reference solution

### 2.1 Method of calculating used for the reference solution

For the calculation of the added coefficients:

one shows [bib1] that the coefficients of mass and added depreciation depend, in each area where  $\rho$  is constant, 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 rotation movement of the external cylinder around the pivot C [bib1]:

$$\begin{aligned} \bar{\phi} &= V_0 y \\ \text{For the area relative to } \rho_1 : \phi_1 &= \frac{R_e^2}{R_e^2 - R_i^2} r + \frac{R_i^2}{r} y + \frac{L}{2} \sin \theta \text{ avec } \mathbf{X}_i = \left[ \frac{L}{2} - y \right] \mathbf{z} \\ \phi_2 &= \frac{R_e^2 V_0}{R_e^2 - R_i^2} r + \frac{R_i^2}{r} \sin \theta \end{aligned}$$

$$\begin{aligned} \bar{\phi} &= \frac{\rho_1 V_0}{\rho_2} y \\ \text{For the area relative to } \rho_2 : \phi_1 &= \frac{R_e^2}{R_e^2 - R_i^2} r + \frac{R_i^2}{r} y + \frac{L}{2} \sin \theta \text{ avec } \mathbf{X}_i = \left[ \frac{L}{2} - y \right] \mathbf{z} \\ \phi_2 &= \frac{\rho_1}{\rho_2} \frac{R_e^2 V_0}{R_e^2 - R_i^2} r + \frac{R_i^2}{r} \sin \theta \end{aligned}$$

However the added modal coefficients projected on this mode of rotation are written:

$$\begin{aligned} M_a &= \rho \int_{\text{cylindre externe}} \phi_1 \mathbf{X}_i \cdot \mathbf{n} dS \\ C_a &= \rho \int_{\text{cylindre externe}} (\phi_2 + \nabla \bar{\phi} \cdot \nabla \phi_1) (\mathbf{X}_i \cdot \mathbf{n}) dS \end{aligned}$$

maybe by separating the integral on two half-cylinders:

$$\begin{aligned} C_a &= -\rho_1 \frac{V_0 R_e^2 \pi}{R_e^2 - R_i^2} (R_e^2 + R_i^2) L^2 \\ M_a &= (7\rho_1 + \rho_2) \frac{R_e^2}{R_e^2 - R_i^2} (R_e^2 + R_i^2) \frac{L^3 \pi}{3} \end{aligned}$$

## 1) 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:

$$e = 2.10^{-2} \text{ m} \quad L = 50 \text{ m} \quad R_i = 1 \text{ m} \quad R_2 = 1,1 \text{ m} \quad A = 4.24 \cdot 10^8 \text{ N.m rad}^{-1} \text{ s}$$

The added mass brought by the flow is worth:

$$M_a = 1.614 \cdot 10^9 \text{ kg m}^2 \text{ (independent of the value rate of flow)}$$

Added damping is worth with  $V_0 = 4 \text{ m.s}^{-1}$  (it is independent of the change of density):

$$C_a = -0.399 \cdot 10^9 \text{ N.m rad}^{-1} \text{ s}$$

Knowing that the damping of the mechanical system is worth  $A = 4.24 \cdot 10^8 \text{ N.m rad}^{-1} \text{ s}$ , the total damping of the fluid system/structure is written:

$$1) \text{ with } V_0 = 4 \text{ m/s} : \alpha = -1.5 \cdot 10^8 \text{ N.m rad}^{-1} \text{ s}$$

The flow does not amplify the vibrations. Structural damping interns is sufficiently important to dissipate the energy brought by the flow to the structure. **The system is still deadened.**

## 2.2 Results of reference

Analytical result.

## 2.3 References bibliographical

- 1) 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

## 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:	240 meshes QUAD4 elements of hulls MEDKQU4
For the fluid:	240 meshes QUAD4 thermal elements THER_FACE4 on cylindrical surfaces
	540 meshes QUAD4 thermal elements THER_FACE4 on the faces of entry, of exit and interface fluid volume
	720 meshes HEXA8 thermal elements THER_HEX8 in fluid annular volume

### 3.2 Values tested

Identification	Reference
Added coefficients	
mass:	1,614 10 <sup>9</sup>
damping	- 0,399 10 <sup>9</sup>

## 4 Summary of the results

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The computational tool of damping under flow (potential assumption) was validated on the mode of rotation of a cylindrical structure subjected to an annular flow with variable density. 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 cylinder is sufficiently long, the semi-analytical model being makes of it only one approximate solution of the posed problem.