SDLS104 - Coaxial hulls under annular flow

Summary

One considers a hardware configuration made up of two coaxial cylindrical hulls, in interaction with a fluid running out in annular space separating the hulls.

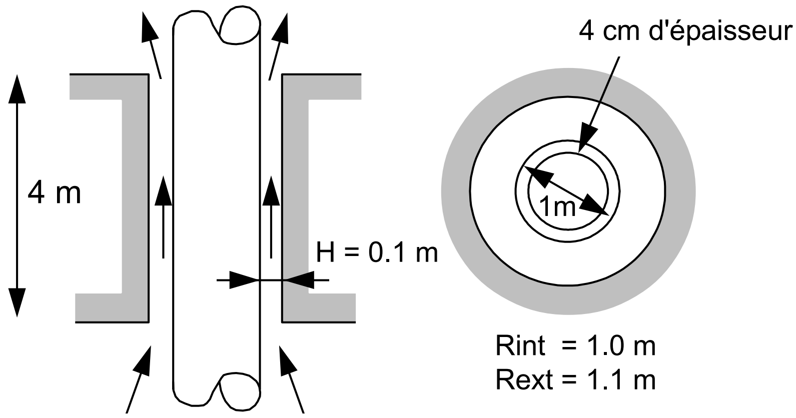
The goal of this CAS-test is to validate the model of coupling fluid-structure developed in the operator CALC_FLUI_STRU for this kind of configurations.

One is interested here more particularly in the evolution of the modal parameters (frequency and reduced damping) according to the rate of flow of the fluid. The reference solution is provided by a calculation carried out with code MOCCA (Model of Coupling in Annular Containment).

1 Problem of reference

1.1 Geometry

The studied configuration consists of two coaxial cylindrical hulls of $4\,m$ of height



The internal hull has an average radius R_1 of $0{,}98\,m$ and a thickness e_1 of $4\,cm$.

The external hull has an average radius R_2 of $1{,}105\,m$ and a thickness e_2 of $1\,cm$.

Note:

The thickness and the average radius of annular space between the two hulls are given by $H=R_{\text{ext}}-R_{\text{int}}=0{,}1\,m$ $\quad R=\frac{R_{\text{int}}+R_{\text{ext}}}{2}=1{,}05\,m$

with $R_{\text{int}}=R1+\frac{e_1}{2}=1\,m$ $\quad R_{\text{ext}}=R_2-\frac{e_2}{2}=1{,}1\,m$

1.2 Properties of material

The material constituting the two hulls is steel. Its physical characteristics are

$$\rho=7800\,kg/m^3 \qquad E=2.10^{11}\,Pa \qquad \nu=0{,}3$$

1.3 Boundary conditions and loadings

The external hull is supposed to be rigid: all the nodes are embedded.

Concerning the internal hull, the conditions of self-supporting quality are the following ones: partly lower embedded end ($z=0$) and free partly higher ($z=4\text{m}$).

2 Reference solution

2.1 Method of calculating used for the reference solution

The solution of reference is obtained by a calculation carried out by means of code MOCCA (Model of Coupling in Annular Containment) [bib1], [bib2]. This last was validated on several experimental configurations of which the models TAXI of the ECA [bib2] and GRAPPE2 from EDF [bib3].

The modal characteristics of the structure except flow being informed, code MOCCA makes it possible to calculate the evolutions of the frequencies and reduced depreciation of each mode of the structure according to the rate of the flow. This resolution is carried out numerically by a method of finished the differences type.

The evolutions of the modal parameters associated with the first mode of a nature of hull equal to 1 constitute, in this case, the reference solution.

2.2 Results of reference

One considers the fifth mode of the structure, first mode of order 1 in hull. The Eigen frequency of this mode except flow is of $90,4\,Hz$.

Mean velocity of flow (m/s)	**Eigen frequency** (Hz)	**Modal reduced damping** (%)
0.	31.8794	0.0353905
5.	31.8806	1.27602
10.	31.8842	2.50164
15.	31.8900	3.74046
20.	31.8982	4.97402
25.	31.9087	6.20616
30.	31.9217	7.43705
35.	31.9372	8.66394
40.	31.9546	9.89269

2.3 Uncertainty on the solution

The model of coupling fluid-structure MOCCA_COQUE [bib4] reabsorbed in the operator `CALC_FLUI_STRU` was developed in the optics of structures hulls. It makes it possible to take into account modes of hulls of an unspecified nature but is limited to uniform annular games.

Code MOCCA was for its part developed in the optics of movements of type beam, under the effect of annular flows variable thickness. One will thus establish comparisons for modes of a nature of hull equal to 1, in the presence of uniform annular flows.

Model MOCCA_COQUE is purely analytical, while code MOCCA is based on a method of resolution digital of the fluid problem. Differences between the reference solution and the results of *Code_Aster* are thus to wait.

2.4 Bibliographical references

1. L. PEROTIN, S. GRANGER, “with numerical model for fluid-structure coupling of has confined cylinder submitted to axial year annular flow”, proceedings fifth international symposium one flow - induced vibration and noise, Anaheim, CA, 1992, vol. 5, pp. 1-16.

2. L. PEROTIN, S. GRANGER, “with linearized unsteady model for computing the dynamics of cylindrical structures subjected to non-uniform annular flows At high international Reynolds numbers”, proceedings sixth conference one flow-induced vibration, London, April 1995 “Newspaper of Fluids and Structures” (1997) 11,183-205.

3. L. PEROTIN, S. GRANGER, “Digital simulation of the hydroelastic behavior of model GRAPPE2, using code MOCCA”, HT-32/93/017/A.

4. L. PEROTIN, “Note of principle of model MOCCA_COQUE”, HT-32/95/021/A.

3 Modeling A

3.1 Characteristics of modeling

The geometry of the structures and the characteristics of material constituting the hulls were presented before.

Concerning the absolute roughness of wall of the structures, one takes a value of $10^{-5} m$.

The surrounding fluid is water. The values taken for the density and kinematic viscosity are respectively

$$\rho_f = 1000 kg/m^3 \qquad \nu_f = 10^{-6} m^2/s$$

One considers the flow not confined upstream and downstream from the structures.

The model of resolution used is analytical model MOCCA_COQUE reabsorbed in *Code_Aster* (operator CALC_FLUI_STRU). One selects the fifth mode in air of the structure then one solves for this mode the problem of coupling. The mean velocities of flow vary 0 with $40 m/s$ by step of $5 m/s$. One obtains thus for this mode evolutions of the Eigen frequency and the damping reduced according to the rate of flow.

3.2 Characteristics of the grid

The two hulls are with a grid in an identical way. In order to make them interdependent one of the other, one adds a group of meshs connecting the nodes to the level of embedding.

One a: 17 nodes on a vertical generator
60 nodes on a crown

960 meshs QUAD4 on each hull
60 meshs QUAD4 to solidarize the two hulls (bases embedded)

3.3 Features tested

Operator DEFI_FLUI_STRU : definition of the characteristics of a hardware configuration made up by two coaxial cylindrical hulls for a calculation of coupling fluid-structure; keyword factor COQUE_COAX.

Operator CALC_FLUI_STRU : resolution of the coupling fluid-structure for a configuration of the type “coaxial hulls”; calculation of the evolutions of the modal parameters (reduced frequencies and depreciation) according to the rate of flow of the fluid.

4 Results of modeling A

4.1 Values tested

Evolutions of the Eigen frequency and the reduced damping of the fifth mode in air of the structure, according to the mean velocity of the flow.

Speed of flow (m/s)	**Frequency MOCCA (Hz)**	**Frequency *Aster* (Hz)**	**variation (%)**	**Amor. reduced MOCCA (%)**	**Amor. reduced *Aster* (%)**	**variation (%)**
0.	31.8794	32.5315	2.046	0.0353905	0.0359752	1.652
5.	31.8806	32.5327	2.045	1.27602	1.24509	– 2.114
10.	31.8842	32.5361	2.045	2.50164	2.43947	– 2.485
15.	31.8900	32.5419	2.044	3.74046	3.64669	– 2.507
20.	31.8982	32.5500	2.043	4.97402	4.84884	– 2.517
25.	31.9087	32.5603	2.042	6.20616	6.04989	– 2.518
30.	31.9217	32.5731	2.041	7.43705	7.24936	– 2.524
35.	31.9372	32.5880	2.038	8.66394	8.44513	– 2.526
40.	31.9546	32.6054	2.037	9.89269	9.64298	– 2.524

4.2 Remarks

The results are in conformity so that one could wait.

A variation of about 2% on the frequency and reduced damping appears, ascribable with the differences between the models and the methods of resolution. This variation is reasonable taking into account the initial frequency of the structure except flow ($90,4\,Hz$).