SDLS107 – Cylinder subjected to a turbulence in axial annular flow

Summary

This test of the field of the linear dynamics of the hulls and the plates implements the calculation of acceptance, a function intended to calculate the modal DSP of effort starting from a DSP of pressure. This precise test implements a modeling of the type hulls circular with elements of fluid coupling/structure to test the method of In YanG.

1 Problem of reference

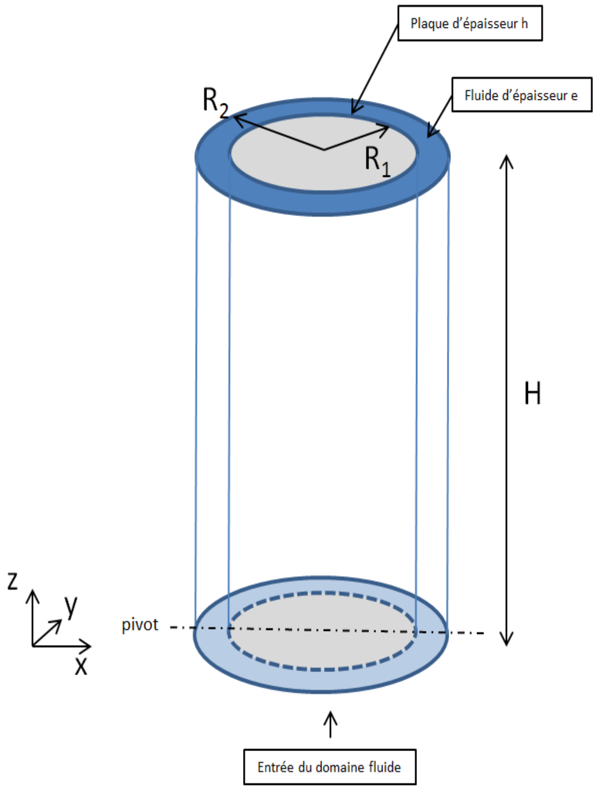
1.1 Geometry

Height rolls $H=50\,m$

Ray rolls interior $R_1=1\,m$

thickness of the fluid $e=1\,m$ (Ray rolls external $R_2=2\,m$)

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



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 $-4\,m/s$, the speed of entry $\vec{V}_0$ fluid being of opposite direction to the normal of entry,
- one imposes in $R=R_2$ the condition $\phi=0$ who corresponds to a null flow through the wall outside of the fluid.

Structure:

- the cylinder is subjected to swinging around a pivot located upstream of the axial annular flow along this cylinder:

$$X_1=z$$

Parameter for the calculation of the spectrum:

- Cut-off frequency: $F=15\text{Hz}$

- Constant for the amplitude of the spectrum of pressure $K=3,4e^{-5}s^{1/2}/m^{3/2}$
- Hydraulic diameter for the amplitude of the spectrum of pressure $d=1,5$
- Coefficient the convective speed of the swirls in the axial direction (direction of the flow) $\alpha=0,65$
- Coefficient the convective speed of the swirls in the direction orthoradiale with the cylinder, for the method of AU_YANG . $\beta=1$

2 Reference solution

2.1 Method of calculating used for the reference solution

The added mass brought by the flow is worth:

$$M_A=\rho_f \pi R_1^2 \frac{R_1^2+R_2^2}{R_2^2-R_1^2}\frac{H^3}{3}$$

Added damping is worth :

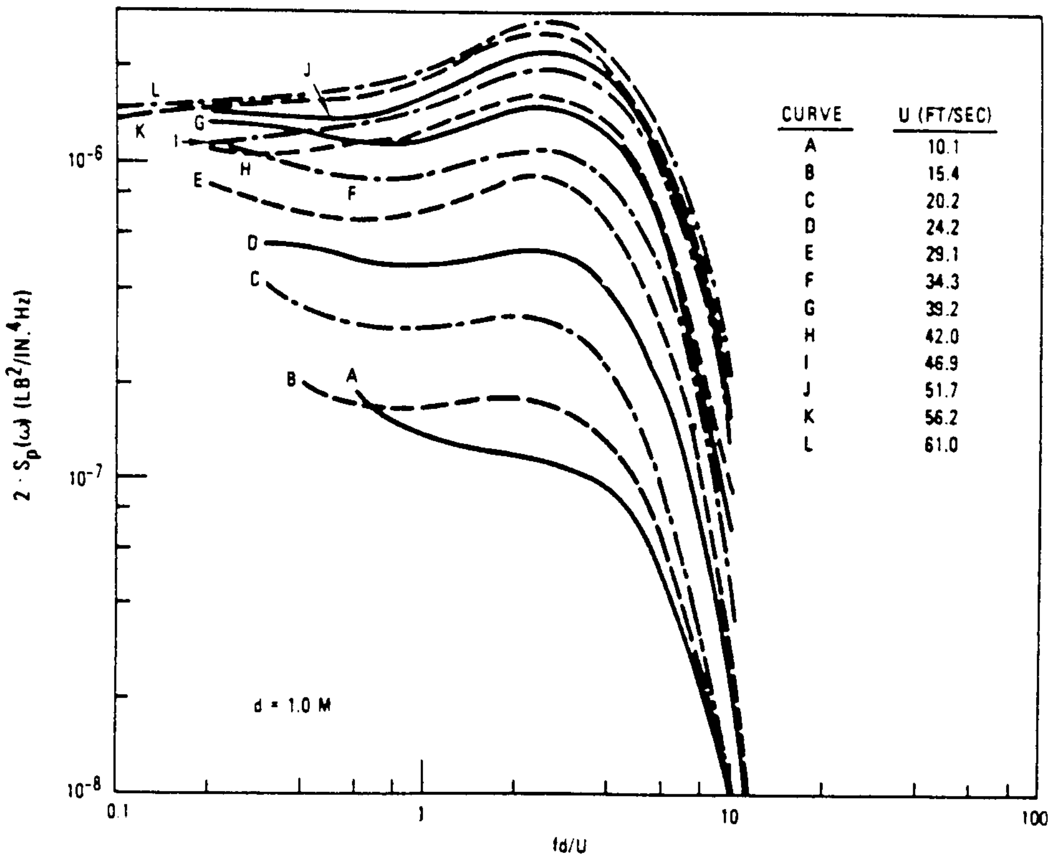
$$C_A=\rho_f \pi R_1^2 \frac{R_1^2+R_2^2}{R_2^2-R_1^2} V_0 H^2$$

The interest of the test is here to calculate and test the autospectre of modal effort obtained starting from a spectrum of pressure characteristic of established turbulent flows.

Once determined the mode of swinging out of water, taking into account these added coefficients, the autospectre of turbulent modal efforts is written:

$$DSP(\omega)=S_p(\omega) J^2_{A_{ij}}(w)$$

The spectrum chosen here is constant then null starting from a cut-off frequency:



One has as a spectrum of pressure:

$$S_p(\omega)=K^2(\rho U^2)^2 d^3 \text{ for } 0{,}1<\frac{\omega d}{2\pi U}<10$$

With the parameters chosen, $S_p(\omega)\approx 1.0$
function of coherence chosen in the case of this circular cylinder subjected to parallel flow, is resulting from a model of AU_YANG:

$$r^{(s)}(x-x',\omega)=e^{-(x-x')/\lambda}\cos(\omega(x-x')/U_c)$$
$$r^{(s)}(\theta-\theta',\omega)=e^{-R(\theta-\theta')/\lambda'}\cos(\omega(\theta-\theta')/U'_c)$$

Parameters λ and λ' are the lengths of correlation according to the axis and the direction orthoradiale respectively.
U_c is the axial convective speed of the swirls: it is equal to the product of the coefficient axial speed by the speed of the fluid, U'_c orthoradiale is convective speed swirls: it is equal to the product of the coefficient speed orthoradiale by the speed of the fluid,

The function acceptance is defined by:

$$J^2_{A_{ij}}(\omega)=\int_A\int_A r(x-x',\omega) f_{i_\alpha}(x) f_{j_{\alpha'}}(x') n_\alpha(x) n_{\alpha'}(x') \mathrm{dA}\, dA'$$

is worth in our case:

$$J^2_{A_{nm}}(\omega)=\int_A\int_A e^{-R|\theta-\theta'|/\lambda'} e^{-R|x-x'|/\lambda}\cos(\frac{\omega(x-x')}{U_c})\cos(\frac{\omega R(\theta-\theta')}{U_c'})x\cos\theta\, x'\cos\theta'\, dxRd\theta\, dx' Rd\theta'$$

$$J^2_{A_{nm}}(\omega)=\int_0^{2\pi}\int_0^{2\pi} e^{-R|\theta-\theta'|/\lambda'}\cos(\frac{\omega R(\theta-\theta')}{U_c'})\cos\theta\cos\theta' R^2 d\theta\, d\theta' \int_0^H\int_0^H e^{-R|x-x'|/\lambda}\cos(\frac{\omega(x-x')}{U_c}) x x' \mathrm{dxdx}'$$

One gives in table Ci after values of this integral using the Maple software:

$\omega(rad/s)$	$I_T(\omega)$
0.01	213612.483
0.1	214158.862
1.	222239.592
2.	105184.866
10.	453.767782

Thus, for the pulsation $0.01\, rad/s$ and $1\, rad/s$, the modal DSP of effort is worth respectively:

$\omega(rad/s)$	$DSP(\omega)$
0.01	2.13612E5
0.1	2.14159E5

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.

[2] BLEVINS R.D: Formulated for natural frequency and shape mode. ED. Krieger 1984.

[3] ROUSSEAU G. Specification of the calculation of acceptance in *Code_Aster*. Spectral response of structures with a turbulent excitation random HP51/97/027/A

3 Modeling A

3.1 Characteristics of modeling

The model contains the following elements:

For the solid:	1600 meshs QUAD4 elements of hulls MEDKQU4
For the fluid:	1600 meshs QUAD4 elements thermics THER_FACE4
	300 meshs HEXA8 and 3000 PENTA6 thermal elements THER_HEXA8/THER_PENTA6 in fluid volume

3.2 Sizes tested and results

Identification	frequency (Hz)	Type of reference	Reference	% tolerance
$DSP(\omega)\omega=0{,}01$	1.59155e-03	'SOURCE_EXTERNE'	2.13612e+05	2.0
$DSP(\omega)\omega=0.1$	1.59155e-02	'SOURCE_EXTERNE'	2.14159e+05	2.0

4 Summary of the results

The computational tool of acceptance in the case of a homogeneous turbulence on a cylinder was validated.