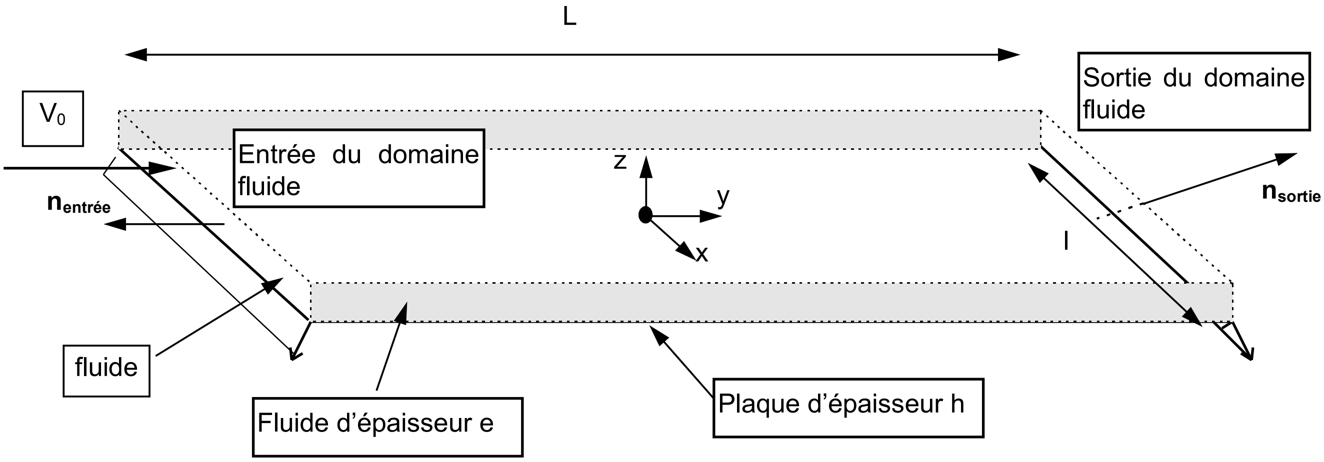
SDLS105 - Plane plate subjected to a homogeneous turbulence

Abstract

This test of the field of the linear dynamics of the shells and plates implements the computation of acceptance, a function intended to calculate the DSP of force modal from a DSP of pressure. This precise test of plate type implements a modelization with elements of fluid coupling/structure to test the method of Corcos whose function of correlation is appropriate to established turbulent plane flows.

1 Problem of reference

1.1 Geometry



$L=50\,m$

$l=5\,m$

thickness of fluid $e=0.5\,m$

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

1.2 Properties of the 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 velocity of $-4\,m/s$, the velocity of entry $\vec{V}_0$ of the fluid being of opposite direction to the norm of entry (by analogy with the thermal analysis, one imposes a normal heat flux are equivalent of -4),
- to compute: the fluid disturbance brought by the motion of the plate one imposes a boundary condition of Dirichlet in a node of the fluid.
- one imposes in $x=\frac{e}{2}$ the condition $\phi_1=\phi_2=0$ which corresponds to a null flow through the higher fluid wall.

Structure:

- the plate is subjected to a displacement imposed corresponding on a first mode of bending [bib2]:

$$X_1 = \sin \frac{py}{L}$$

2 Reference solution

2.1 Method of calculating used for the reference solution

For computation of the added coefficients, one returns to the case test FDLV109.

One did a calculation of damping added to the rate of flow ($V_0 = 4\ m.s^{-1}$).

The added mass brought by flow is worth:

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

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

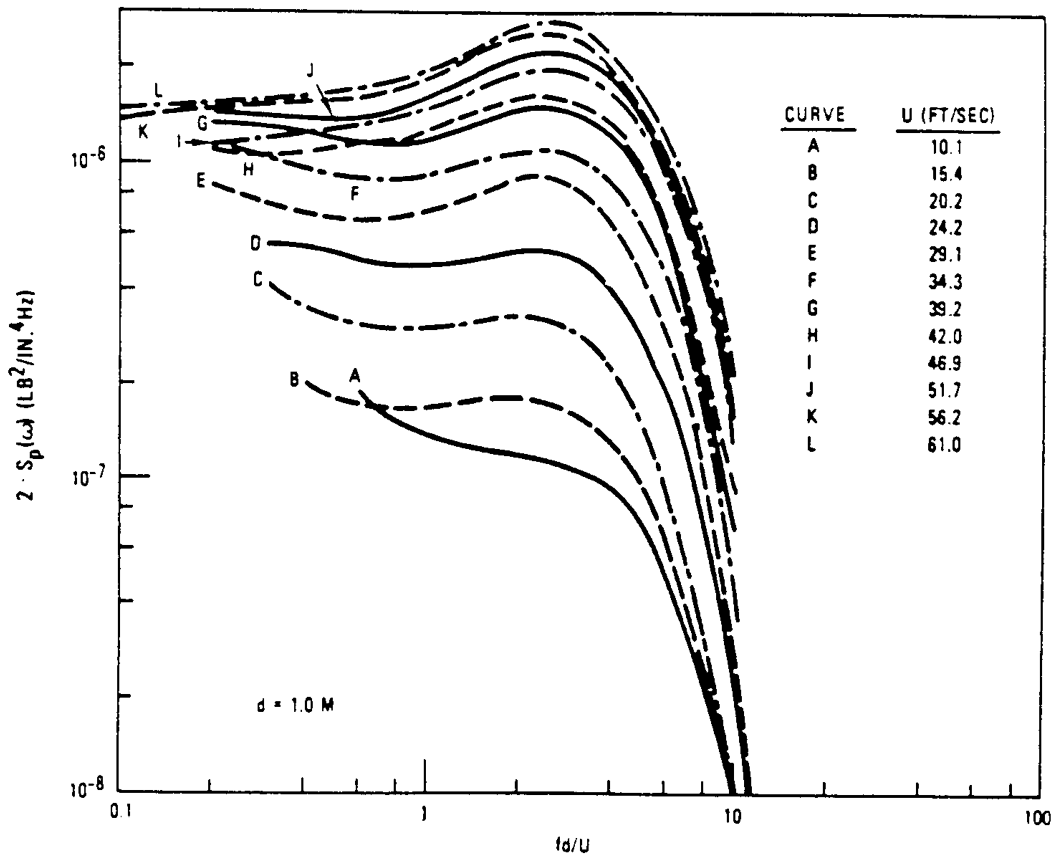
$$C_{11}^a = 0,$$
$$C_{22}^a = 0,$$
$$C_{12}^a = 0.266\ 10^5\ N.m^{-1}.$$

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

$$K_{11}^a = -0.3943\ 10^4\ N.m^{-1}.\text{rad}^2,$$
$$K_{22}^a = -0.1577\ 10^5\ N.m^{-1}.\text{rad}^2,$$
$$K_{12}^a = 0.$$

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

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



One has for DSP of pressure:

$$F_{R_p}^{(s)}(w)=K^2(\rho U^2)^2 d^3 \text{ for } 0,1<\frac{wd}{2\text{pU}}<10$$

the function of coherence chosen in the case of this plate subjected to parallel flow, is resulting from a model of Corcos:

$$r^{(s)}(x-x',w)=e^{-k_L(x-x')}e^{-k_T(y-y')}\cos(w(x-x')/U_c).$$

The parameters k_T and k_L are called parameters of Bakewell and are worth according to the pulsation:

$$k_L=0.1\frac{w}{U_c} \text{ and } k_T=0.55\frac{w}{U_c}$$

the function acceptance, defined in any generality by

$$J_{A_{ij}}^2(w)=\underbrace{\int_A\int_A r(x-x',w)f_{i_\alpha}(x)f_{j_{\alpha'}}(x')n_\alpha(x)n_{\alpha'}(x')\mathrm{dA}\,dA'}_{\text{acceptance}}$$

is worth in our case:

$$J^2_{A_{nm}}(w)=\underbrace{\int_A\int_A e^{-k_T|y-y'|}e^{-k_L|x-x'|}\cos\left(\frac{w(x-x')}{U_c}\right)\sin\left(\frac{k_n x}{L}\right)\sin\left(\frac{k_m x'}{L}\right)\mathrm{dxdy}\,dx'\,dy'}_{\text{acceptance}}$$

$$=\int_{-l/2}^{l/2}\int_{-l/2}^{l/2} e^{-k_T|y-y'|}dydy''\int_0^L\int_0^L e^{-k_L|x-x'|}\cos\left(\frac{w(x-x')}{U_c}\right)\sin\left(\frac{k_n x}{L}\right)\sin\left(\frac{k_m x'}{L}\right)dxdx'.$$

The first integral in factor has an analytical statement and is worth:

$$\int_{-l/2}^{l/2}\int_{-l/2}^{l/2} e^{-k_T|y-y'|}dydy'=\frac{2l}{k_T}-2\left(\frac{1-e^{-k_T l}}{k_T^2}\right).$$

One gives in table Ci after values of this integral:

$\omega(rad/s)$	$I_T(\omega)$
0.01	24.9121
0.1	24.1414
1.	18.0988
2.	13.8102
10.	4.2803

the other factor is more complex to evaluate. One thus numerically calculated this integral using the software Maple V.5:

$\omega(rad/s)$	$I(\omega)$
0.01	1006.601
0.1	815.3964
1.	14.319
2.	6.5836
10.	1.288

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

$\omega(rad/s)$	$DSP(\omega)$
0.01	7.28848E8
1.	7.53237E6

2.2 Results of reference

Result analytical.

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 *the 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 computation of acceptance in *the Code_Aster*. Spectral response of structures with a turbulent excitation random HP51/97/027/A

3 Modelization A

3.1 Characteristic of the modelization

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

For solid:	160 meshes QUAD4 shell elements MEDKQU4
For the fluid:	160 meshes QUAD4 elements thermal THER_FACE4 on the plane surface
	184 meshes thermal QUAD4 elements THER_FACE4 on the sides of entry and output of fluid volume
	480 meshes thermal HEXA8 elements THER_HEXA8 in fluid volume

3.2 Functionalities tested

Commands			
DEFI_SPECT_TURB	SPEC_CORR_CONV_1	METHODE	"CORCOS"
PROJ_SPEC_BASE	MODE_MECA	MODELE_INTERFACE	

3.3 Quantities tested and results

Identification	frequency	Reference	*Aster*	% difference
$SF1F1(\omega)\omega=1$	1.59155e-01	7.53237e+06	7.59109e+06	0.780
$SF1F1(\omega)\omega=0.01$	1.59155e-03	7.28848e+08	7.28121e+08	0.100

4 Modelization B

4.1 Characteristic of the modelization

Compared to the modelization A, one modify only the values of the densities, which are multiplied by 30:

- Fluid: $\rho=30000\,kg.m^{-3}$ (water),
- Structure: $\rho_s=23400\,kg/m^3$ (steel).

One thus proceeds so as to decrease the cut-off frequency of the problem.

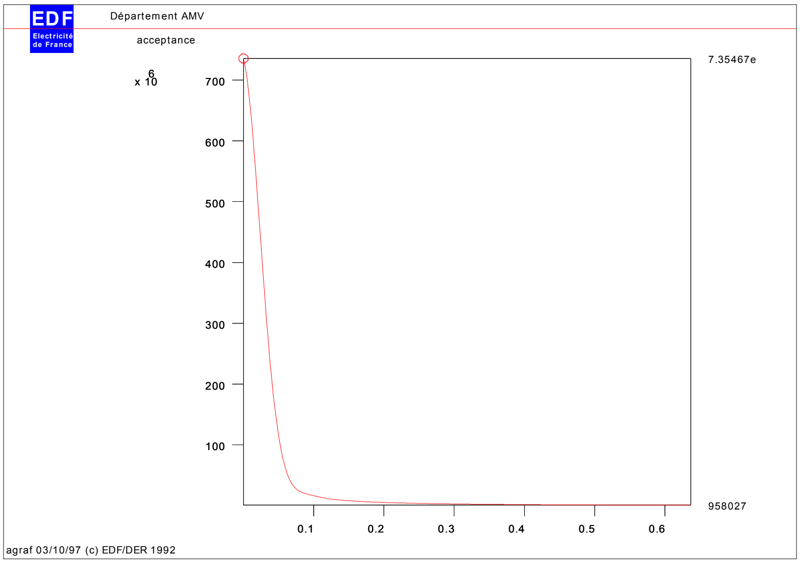
4.2 Quantities tested and results

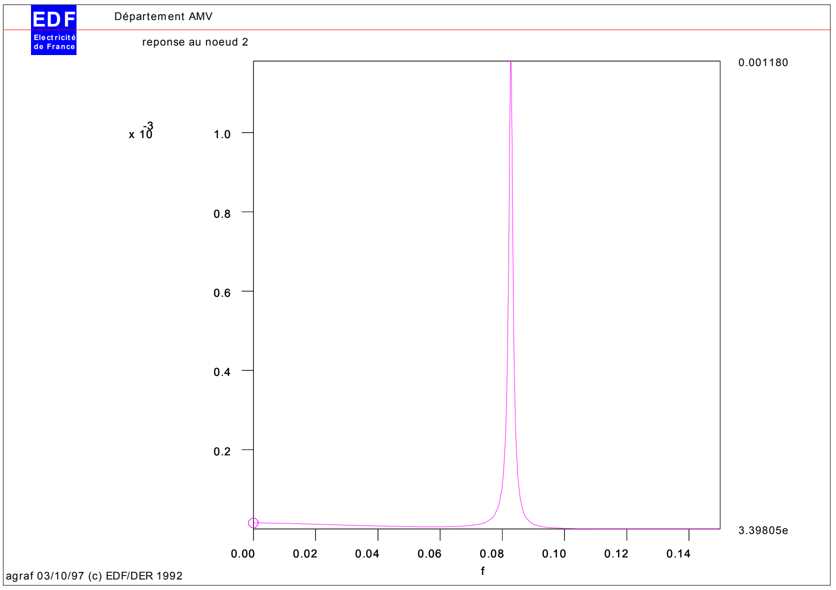
It is a question of testing the spectral response of structure with the turbulent excitation previously defined in the modelization A but calculated for 128 points of frequency. One tests for various frequencies the value of the spectral response to node 2 of the board which is in $13.75\,m$ center of the board.

The theoretical response was evaluated with software MAPLE version 5.

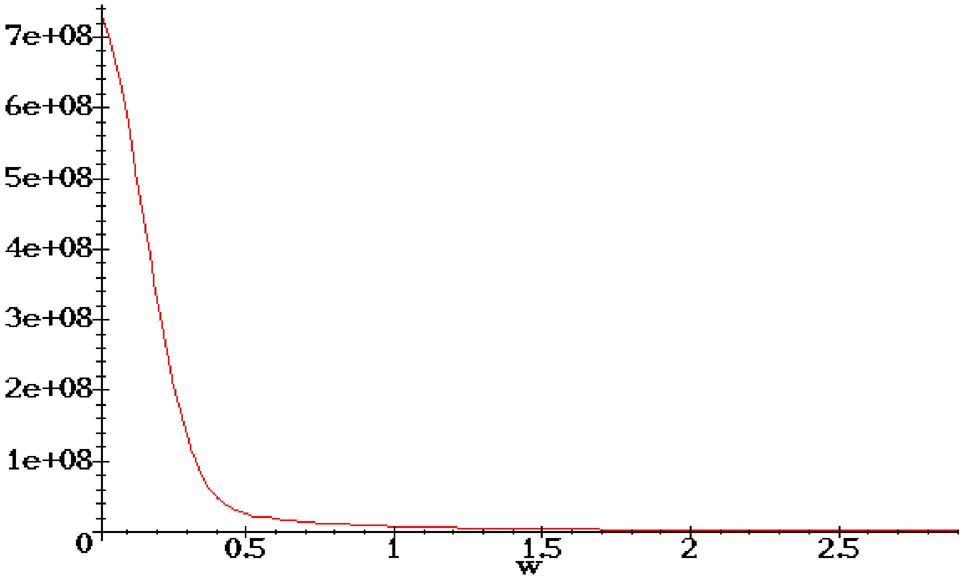
Identification	frequency (Hz)	Reference	*Aster*	% difference
$S_U(\omega)\,f=0.025$	2.50000e-02	1.09850e-05	1.09799e-05	0.046
$S_U(\omega)\,f=0.05$	5.00000e-02	6.09100e-06	6.09255e-06	0.025
$S_U(\omega)\,f=0.08275$	8.27500e-02	1.17770e-03	1.18010e-03	the 0.204

curves of acceptance and response given by *Code_Aster* are given below:





The curve of acceptance given by the Maple software V is represented below:



5 Summary of the results

the computational tool of acceptance in the case of a homogeneous turbulence on a plane plate was validated.