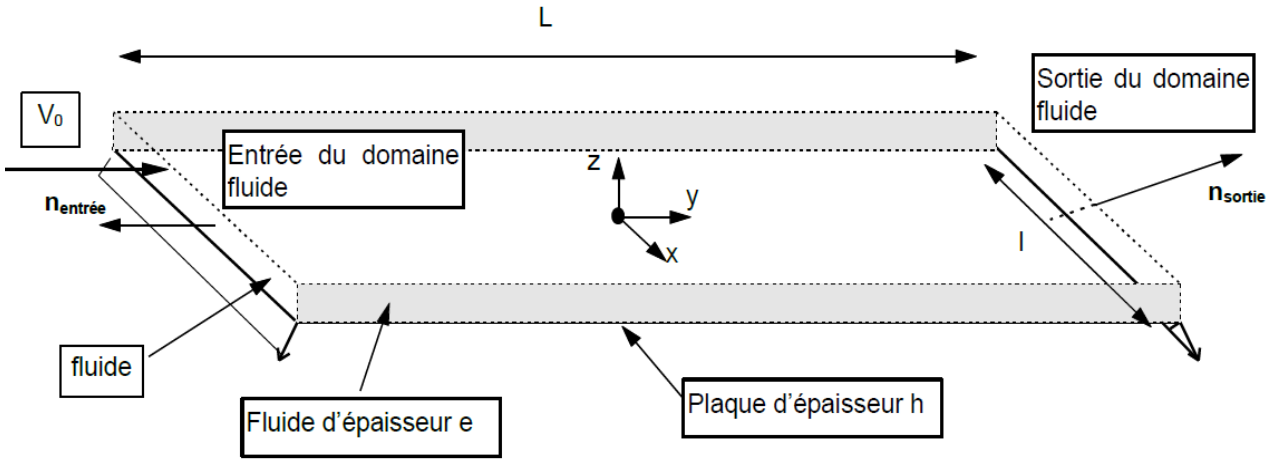
SDLS105 - Plane plate subjected to a turbulence homogeneous

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 plates with elements of fluid coupling/structure to test the method of Corcos whose function of correlation is appropriate to flows drawn up turbulent plans.

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 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 (by analogy with the thermal analysis, one imposes a normal heat flow equivalent of -4),
- to calculate the fluid disturbance brought by the movement of the plate 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 imposed correspondent on a first mode of inflection [bib2]:

$$X_1=\sin\frac{\pi\,y}{L}$$

2 Reference solution

2.1 Method of calculating used for the reference solution

For the calculation 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 the flow is worth:

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

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

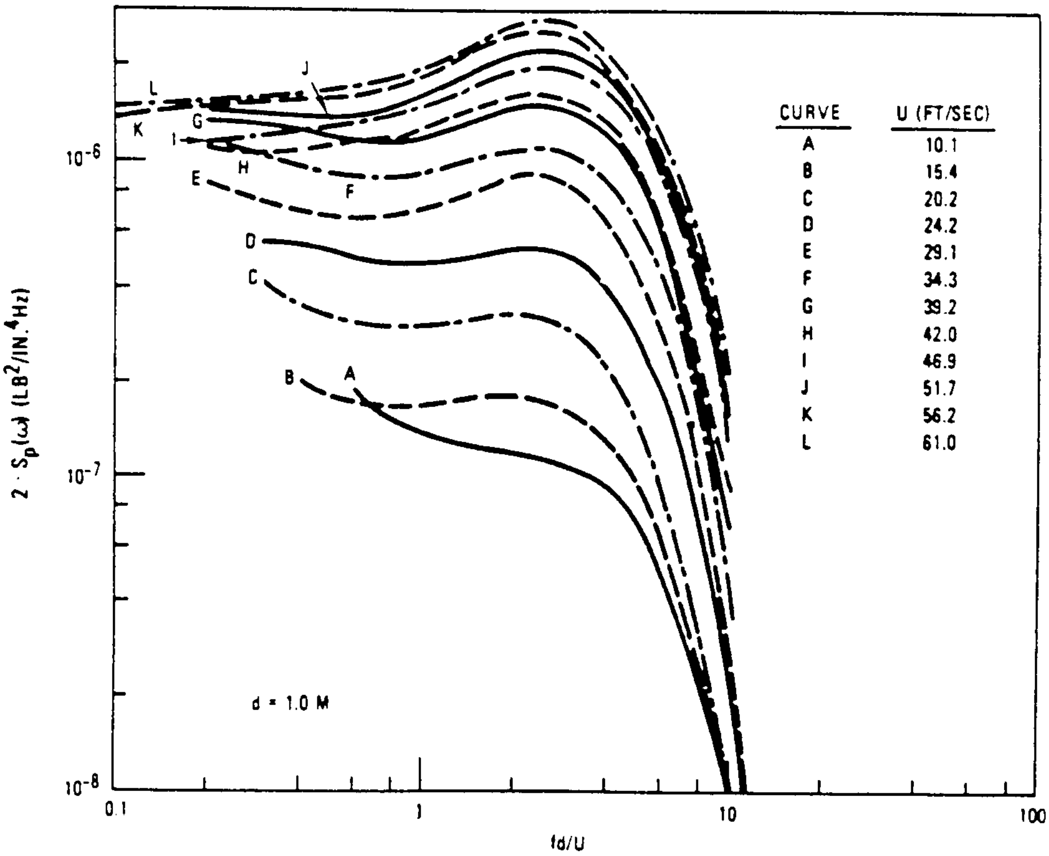
$$C_{11}^a = 0,$$
$$C_{22}^a = 0,$$
$$C_{12}^a = 0.266\, 10^5\, N.m^{-1}.$$

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 autospectre of modal effort obtained starting from a spectrum of pressure characteristic of established turbulent flows.

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



One has for DSP of pressure:

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

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

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

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

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

The function acceptance, defined in any general information 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:

$$J^2_{A_{nm}}(\omega)=\int_A\int_A e^{-k_T|y-y'|}e^{-k_L|x-x'|}\cos(\frac{\omega(x-x')}{U_c})\sin(\frac{k_n x}{L})\sin(\frac{k_m x'}{L})\,\mathrm{dxdy}\,dx'\,dy'$$
$$=\int_{-l/2}^{l/2}\int_{-l/2}^{l/2} e^{-k_T|y-y'|}dydy''\int_0^L\int_0^L e^{-k_L|x-x'|}\cos(\frac{\omega(x-x')}{U_c})\sin(\frac{k_n x}{L})\sin(\frac{k_m x'}{L})dxdx'.$$

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

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

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 modal DSP of effort is worth respectively:

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

In the case of modeling A, one also tests the definition of a spectrum of turbulence using one function of the unspecified frequency, via the keyword SPEC_CORR_CONV_2. The selected function is:

$$S_p(\omega)=10^{10}e^{-(\omega/0.1)^2}$$

Thus, for the pulsation $0.01\,rad/s$ and $0{,}1\,rad/s$, the modal DSP of effort is worth respectively:

$\omega(rad/s)$	$DSP(\omega)$
0.01	24,82703E13
0.1	7,24164E13

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

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

For the solid:	160 meshs QUAD4 elements of hulls MEDKQU4
For the fluid:	160 meshs QUAD4 elements thermics THER_FACE4 on the plane surface
	184 meshs QUAD4 thermal elements THER_FACE4 on the faces of entry and exit of fluid volume
	480 meshs HEXA8 thermal elements THER_HEXA8 in fluid volume

3.2 Sizes tested and results

For the case SPEC_CORR_CONV_1

Identification	frequency (Hz)	Type of reference	Reference	% tolerance
$SF1F1(\omega)\,\omega=0.01$	1.59155e-03	'NON_REGRESSION'	-	-
$SF1F1(\omega)\omega=1$	1.59155e-01	'ANALYTICAL'	7.532370E6	0.8

With the elements of plate DKT:

Identification	frequency (Hz)	Type of reference	Reference	% tolerance
$SF1F1(\omega)\,\omega=0.01$	1.59155e-03	'ANALYTICAL'	7.288480E8	0.11
$SF1F1(\omega)\,\omega=1$	1.59155e-01	'ANALYTICAL'	7.532370E6	0.8

For the case SPEC_CORR_CONV_2 where an exponential function of spectrum is defined:

Identification	frequency (Hz)	Type of reference	Reference	% tolerance
$SF1F1(\omega)\omega=0.01$	1.59155e-03	'NON_REGRESSION'	-	-
$SF1F1(\omega)\omega=0.1$	1.59155e-02	'NON_REGRESSION'	-	-

4 Modeling B

4.1 Characteristics of modeling

Compared to modeling A, one modifies 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 Sizes tested and results

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

The theoretical answer was evaluated with software MAPLE version 5.

Identification	frequency (Hz)	Type of reference	Reference	% tolerance
$SF1F1(\omega)\,\omega=0.01$	1.59155e-03	'ANALYTICAL'	7.288480E8	0,2
$SF1F1(\omega)\,\omega=1$	1.59155e-01	'ANALYTICAL'	7.532370E6	0.8
$SF1F1(\omega)\,\omega=1$	0.082750	'NON_REGRESSION'	-	-
$SF1F1(\omega)\,\omega=1$	0.4532570	'NON_REGRESSION'	-	-

Identification	frequency (Hz)	Type of reference	Reference	% tolerance
$S_U(\omega)\,f=0.08275$	8.27500e-02	'NON_REGRESSION'	-	-
$S_U(\omega)\,f=0.05$	5.00000e-02	'NON_REGRESSION'	-	-
$S_U(\omega)\,f=0.025$	2.50000e-02	'NON_REGRESSION'	-	-

5 Summary of the results

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