FDLV102 - Added mass calculated on a model generalized

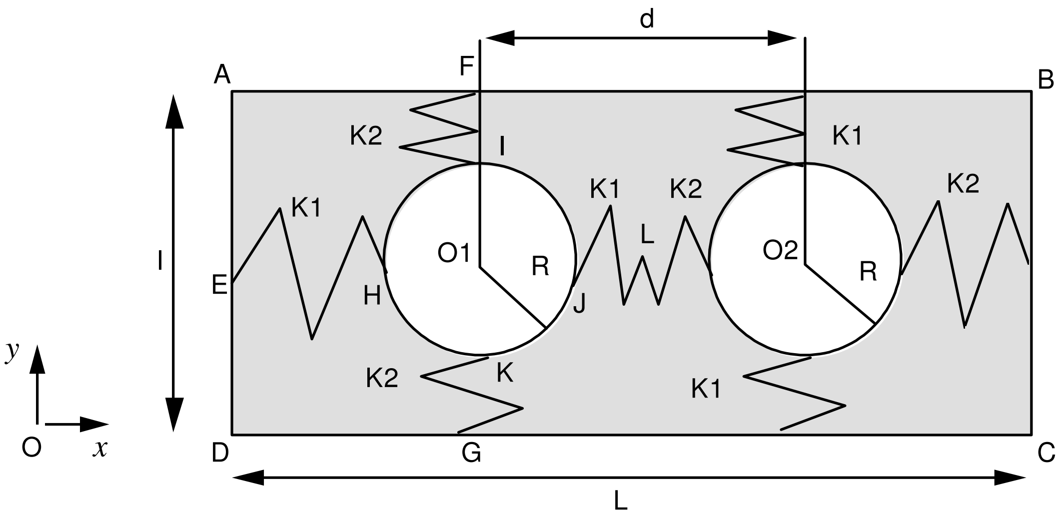
Summary:

This test belongs to the field of the fluid interaction/structure, in its aspect inertial coupling: it is a question of calculating a matrix of added mass, starting from a generalized model resulting from a calculation by dynamic under-structuring. One carries out a modal analysis on the fluid coupled system/structure starting from a calculation by under-structuring, and one compares the result with a modal calculation in direct fluid. One tests thus, for a two-dimensional fluid problem, the possibility of calculating the terms of added auto--mass and added mass of coupling between substructures deduced between them by rotation and translation (these “deduced” substructures not being with a grid).

There is currently only one modeling, which consists in assigning to the fluid grid thermal elements plans.

1 Problem of reference

1.1 Geometry



Line of cylinders with circular section connected by springs to a fixed solid mass:

length:	$L=l_x=2.0\,m$
width	$l=l_y=1.0\,m$
ray of the cylinders:	$R=0.25\,m$
distance between centers of the tubes:	$d=1.0\,m$

Coordinates of the points (in m):

	$O1$	$O2$	A	B	C	D		
x	0.	1.00	– 0.50	1.50	1.50	– 0.50		
y	0.	0.	0.50	0.50	– 0.50	– 0.50		
	E	F	G	H	I	J	K	L
x	-0.50	0.	0.	– 0.25	0.	0.25	0.	0.50
y	0.	0.50	-0.50	0.	0.25	0.	– 0.25	0.

1.2 Properties of materials

Fluid: Water

$$\rho_0=1000.0\,Kg.m^{-3}$$

Solid: Steel

$$\rho_S=7800.0\,Kg.m^{-3} \qquad E=2.E11\,Pa \qquad \nu=0.3$$

Springs connecting the cylinder (substructure n°1 with a grid) to the solid mass:

Discrete element of the type `K_T_D_L`: $K_1=(1.E7\;1.\;1.E7)\,N/m$

$$K_2=(1.\;1.E8\;1.E8)\,N/m$$

1.3 Boundary conditions and loading

Without object for the calculation of added mass.

1.4 Initial conditions

Without object for the calculation of added mass.

2 Reference solution

2.1 Method of calculating used for the reference solution

Direct modal calculation (without dynamic under-structuring)

Calculation of the clean modes in air:

One calculates with the option `'BAND'` of the operator `CALC_MODES` the first 4 Eigen frequencies of the system in air (system mass-arises):

mode 1: vibration of the two cylinders in phase according to Ox
mode 2: vibration of the cylinder n°2 according to Oy (on the right)
mode 3: vibration of the two cylinders in opposition of phase according to Ox
mode 4: vibration of the cylinder n°1 according to Oy (on the left)

These modes can be analytically given [bib1].

Code_Aster calculation provides for the Eigen frequencies in air:

mode 1: $f_1=17.3555\,Hz$ mode 2: $f_2=18.2034\,Hz$
mode 3: $f_3=42.6760\,Hz$ mode 4: $f_4=57.5418\,Hz$

Calculation of the matrix of mass added on modal basis:

On this modal basis, one calculates the matrix of added mass of order 4 with the operator `CALC_MATR_AJOU` [U4.55.10] option `'MASS_AJOU'` keyword `MODE_MECA` (terms of triangular the inferiors):

$m11=300.67\,kg/m$ $m12=0.001\,kg/m$
$m13=269.98\,kg/m$ $m14=0.009\,kg/m$
$m22=269.98\,kg/m$ $m23=0.009\,kg/m$
$m24=31.05\,kg/m$ $m33=301.71\,kg/m$
$m34=-0.011\,kg/m$ $m44=269.86\,kg/m$

Addition of this matrix to the matrix of generalized mass:

One adds the matrix thus determined to the matrix of generalized mass (operator `COMB_MATR_ASSE` [U4.53.01]) then one calculates the Eigen frequencies of the structure immersed with the operator `CALC_MODES` option `'PLUS_PETITE'` [U4.52.02].

Calculation finds the Eigen frequencies following:

mode 1: $f'_1=15.8782\,Hz$ mode 2: $f'_2=16.7811\,Hz$
mode 3: $f'_3=39.0389\,Hz$ mode 4: $f'_4=53.0488\,Hz$

2.2 Results of reference

Eigen frequencies determined by Code_Aster in a direct calculation.

2.3 Bibliographical references

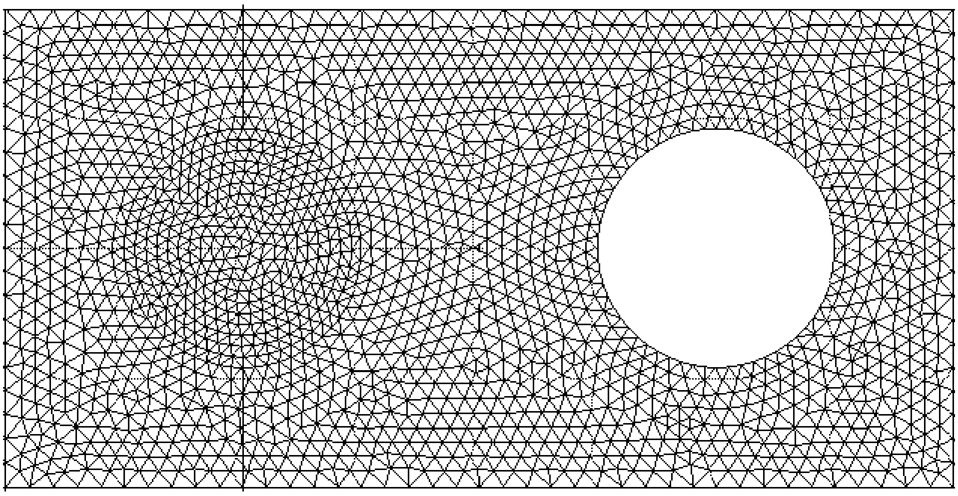
1. R.J GIBERT - Vibrations of the Structures. Interactions with fluids. Eyrolles (1988).

3 Modeling A

3.1 Characteristics of modeling

Thermal formulation planes for fluid (TRIA3 and SEG2)

Plane and discrete deformation formulation for solid (TRIA3 and SEG2)



Cutting =
40 meshs TRIA3 according to the axis of x
20 meshs TRIA3 according to the axis of y
120 meshs SEG2 on the contour of the two cylinders
4 meshs SEG2 on the contour of the two cylinders representing the meshs of the springs

Boundary conditions:

```
DDL_IMPO: (GROUP_NO: PBLOC1 DX: 0. DY: 0. DZ: 0.)
DDL_IMPO: (GROUP_NO: PBLOC2 DX: 0. DY: 0. DZ: 0.)
DDL_IMPO: (GROUP_NO: PBLOC3 DX: 0. DY: 0. DZ: 0.)
DDL_IMPO: (GROUP_NO: PBLOC4 DX: 0. DY: 0. DZ: 0.)
```

Name of the nodes: $E=PBLOC1$ $L=PBLOC2$
$F=PBLOC3$ $G=PBLOC4$

3.2 Characteristics of the grid

Many nodes: 1,881
Many meshs and types: 3,580 TRIA3, 124 SEG2

3.3 Values tested

Identification	Reference direct calculation	*Aster* calculation with under - structuring	% difference
Order of the clean mode i : 1	15.8782	15.8782	+0.0000
Order of the clean mode i : 2	16.7811	16.7815	+0.00002
Order of the clean mode i : 3	39.0389	39.0289	– 0.0002

Order of the clean mode i : 4	53.0488	53.0586	– 0.0002

3.4 Remarks

Calculations of modes carried out by:

```
CALC_MODES
            OPTION=' BANDE',
            CALC_FREQ=_F (FREQ= (2. , 70.))
```

4 Recall

Course of the calculation of mass added by modal synthesis

- Calculation of the clean modes of substructure 1 (cylinder of left with a grid) with interfaces blocked by `CALC_MODES`
- Definition of two dynamic interfaces type CRAIG-BAMPTON (imposed unit displacement):

  'EAST': corresponds to the point $PBLOC2=L$
  'SOUTHERN': corresponds to the point $PBLOC4=G$

- Definitions of 2 modal bases associated with these interfaces: operator `DEFI_INTERF_DYNA` [U4.55.03]:

  $BAMO1$: two dynamic modes and a constrained mode: unit displacement on $PBLOC2=L$
  $BAMO2$: two dynamic modes and a constrained mode: unit displacement on $PBLOC4=G$

- Definitions of 2 macronutrients associated with these modal bases: operator `MACR_ELEM_DYNA` [U4.55.05]
- Definition of the generalized model: operator `DEFI_MODELE_GENE` [U4.55.06]:

  Sous_structure_1: $CYLINDR0$: corresponds to the cylinder of left (with a grid)
  Sous_structure_2: $CYLINDR1$: corresponds to the cylinder of right-hand side (nonwith a grid)
  This second substructure is deduced from the first by rotation of -90°.
  `ANGL_NAUT: (- 90. , 0. , 0.)`
  Connection: EST and SUD
  This definition of the two substructures allows `DEFI_MODELE_GENE` to calculate the translation enters the two substructures.

- Creation of a profile line of full sky starting from the definite generalized model: operator `NUME_DDL_GENE` [U4.55.07]
- Assembly of the matrices of generalized stiffness and mass: operator `ASSE_MATR_GENE` [U4.55.08]
- Calculation of the matrix of mass added starting from the definite Generalized Model:

  The modal bases attached to each of the two substructures define fields in the nodes of displacement in the site of the 1st substructure in the grid. The operator `CALC_MATR_AJOU` [U4.55.10] transports the field to the nodes corresponding to the modal base of the second substructure via the translation and rotation defined higher to assign it to the site of the second substructure in the grid. The calculation of the added mass is thus carried out following this displacement of field to the nodes: one can thus calculate the mass added on the 1st substructure, the mass added on the second substructure as well as the term of coupling between the two substructures, taking into account the fluid environment of each substructure.

- Summation of the matrix of assembled mass generalized with the matrix of added mass: `COMB_MATR_ASSE` [U4.53.01]
- Calculation of the clean modes of the immersed total structure: `CALC_MODES` [U4.52.02].