ADLV100 - Piston coupled to a column of fluid

Summary:

Calculation in fluid coupling acoustics-structure of the first mode of a system fluide1 - piston fluid 2.

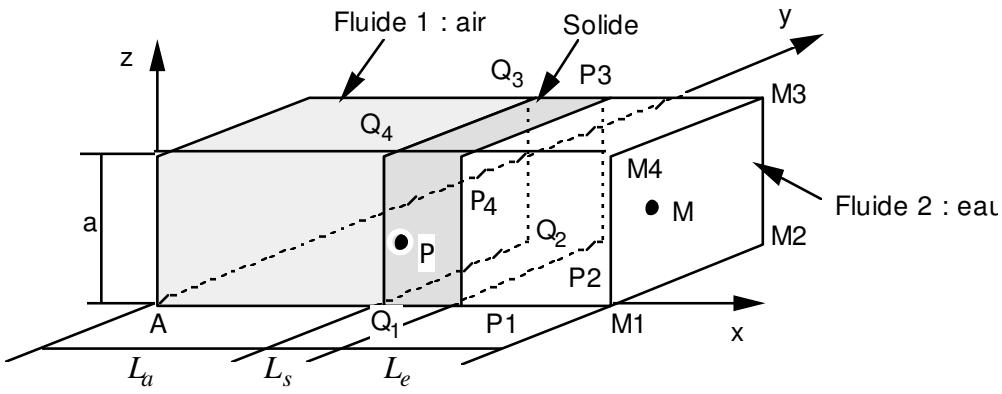
One tests the matrices of rigidity and mass of the elements of the fluid type and standard coupling fluid-structure.

One tests also the boundary condition of type free surface.

Seize modelings is tested.

1 Problem of reference

1.1 Geometry



$L_a=0.075$, $L_s=0.025$, $L_e=0.05\,m$

constant square section, $a=0.05\,m$

or circular section (in the axisymmetric case) constant of ray $R=a=0.05\,m$.

1.2 Properties of materials

solid: $E=2.10^{11}\,Pa$	$\rho_s=7800\,kg/m^3$	$\nu=0.3$
air: $c_a=340\,m/s$	$\rho_a=1.2\,kg/m^3$	
water: $c_e=1400\,m/s$	$\rho_e=1000\,kg/m^3$	$c=célérité\,du\,son$

$c=$ speed of sound in the fluid

1.3 Boundary conditions and loading

- For all the points M face $(M1\,M2\,M3\,M4)$ the pressure and the potential of displacement are worthless (condition of type free surface),
- for the points P solid, one blocks all the degrees of freedom except the translation in x so that this solid behaves like a piston according to the axis x .

2 Reference solution

2.1 Method of calculating used for the reference solution

With the low frequencies, the wavelengths acoustic of the movements considered are large compared to dimension characteristic of fluid volume $(\omega L/c \ll 1)$. The problem is thus monodimensional according to the axis x.

It is shown [bib1] that a light fluid as the air acts primarily as an added stiffness while a heavy fluid behaves only like one added mass. One can thus calculate the first Eigen frequency of the system:

$$\omega = \sqrt{\frac{k}{m}} \qquad \text{avec} \qquad \begin{aligned} k &= k_{air} = \rho_a c_a^2 \frac{S}{L_a} \\ m &= m_s + m_e = \rho_s L_s S + \rho_e L_e S \end{aligned}$$

Soit,

$$\omega = \sqrt{\frac{\rho_a c_a^2}{L_a(\rho_s L_s + \rho_e L_e)}}$$

Note:

The first own pulsation ω system checks well $(\omega L/c \ll 1)$.

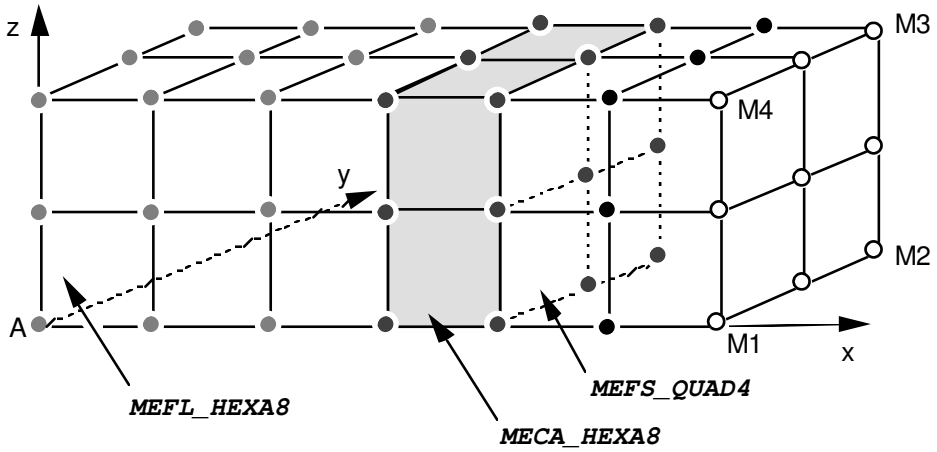
2.2 Bibliographical references

1) GIBERT - Vibrations of the Structures. Interactions with the fluids. Random sources of excitation - Collection of the Management of the Studies and Searchs for EDF.

3 Modeling A

3.1 Characteristics of modeling

Elements MECA_HEXA8, MEFL_HEXA8, MEFS_QUAD4



Boundary conditions:

in all itS nodes of the face M

```
DDL_IMPO: (GROUP_NO: noeusurf NEAR: 0. PHI: 0.)
```

in all the nodes of the piston

```
(GROUP_NO: noeupist DY: 0. DZ: 0.)
```

3.2 Characteristics of the grid

Many nodes:	63
Many meshs and types:	24 HEXA8, 8 QUAD4

3.3 Values tested

Frequency (Hz)

Reference	*Aster*	Error (%)
13.8285	13.8277	< 0.01

3.4 Remarks

Calculations of modes carried out by:

```
CALC_MODES
              OPTION=' AJUSTE',
              CALC_FREQ=_F (FREQ= (10. , 20.))
```

One does not know the analytical solution of the first clean vector.

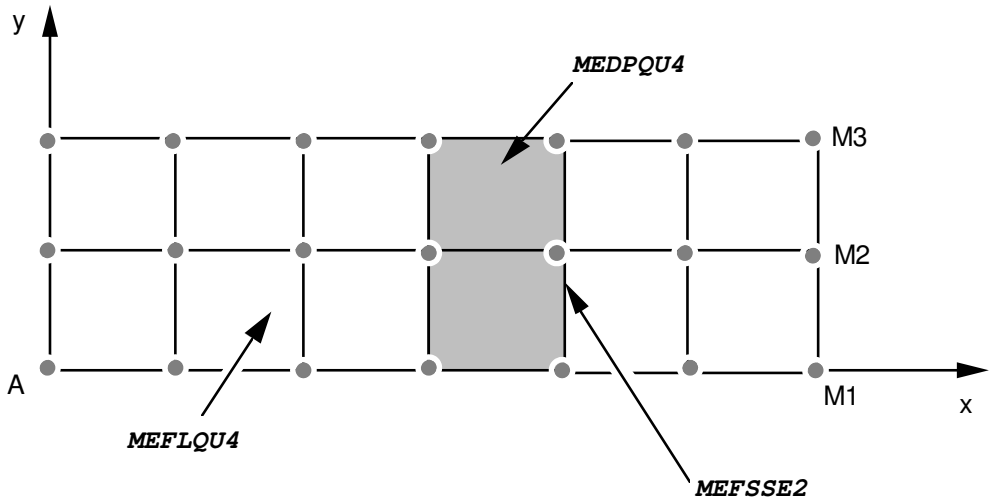
Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

4 Modeling B

4.1 Characteristics of modeling

Elements MEDPQU4, MEFLQU4, MEFSSE2



Boundary conditions:

in all itS nodes of the face M

```
DDL_IMPO: (GROUP_NO: noeusurf NEAR: 0. PHI: 0.)
```

in all the nodes of the piston

```
(GROUP_NO: noeupist DY: 0.)
```

4.2 Characteristics of the grid

Many nodes: 21
Many meshs and types: 12 QUAD4, 4 SEG2

4.3 Values tested

Frequency (Hz)

Reference	*Aster*	Error (%)
13.8285	13.8277	< 0.01

4.4 Remarks

Calculations carried out by:

```
CALC_MODES
              OPTION=' AJUSTE',
              CALC_FREQ=_F (FREQ= (10. , 20.))
```

One does not know the analytical solution of the first clean vector.

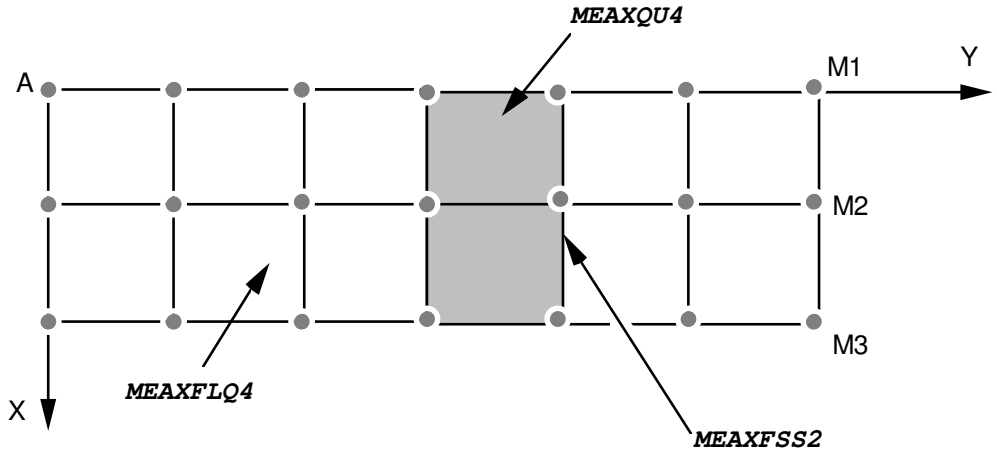
Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

5 Modeling C

5.1 Characteristics of modeling

Elements MEAXQU4, MEAXFLQ4, MEAXFSS2



Boundary conditions:

in all itS nodes of the face M

```
DDL_IMPO: (GROUP_NO: noeusurf NEAR: 0. PHI: 0.)
```

in all the nodes of the piston

```
(GROUP_NO: noeupist DY: 0.)
```

Not $M1:N019$, $M2:N020$, $M3:N021$, $A:N01$

5.2 Characteristics of the grid

Many nodes: 21
Many meshs and types: 12 QUAD4, 4 SEG2

5.3 Values tested

Frequency (Hz)

Reference	*Aster*	Error (%)
13.8285	13.8277	< 0.01

5.4 Remarks

Calculations carried out by:

```
CALC_MODES
              OPTION=' BANDE',
              CALC_FREQ=_F (FREQ= (5. , 100.))
```

One does not know the analytical solution of the first clean vector.

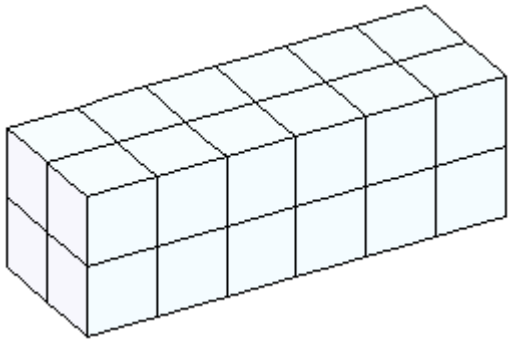
Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

6 Modeling D

6.1 Characteristics of modeling

Elements MECA_HEXA20, MEFL_HEXA20, MESF_QUAD8



Boundary conditions:
in all itS nodes of the face M

```
DDL_IMPO: (GROUP_NO: noeusurf NEAR: 0. PHI: 0.)
```

in all the nodes of the piston

```
(GROUP_NO: noeupist DY: 0. DZ: 0.)
```

6.2 Characteristics of the grid

Many nodes:	201
Many meshs and types:	24 HEXA20, 8 QUAD8

6.3 Values tested

Frequency (Hz)

Reference	*Aster*	Error (%)
13.8285	13.8277	-0,006

6.4 Remarks

Calculations of modes carried out by:

```
CALC_MODES
              OPTION=' AJUSTE',
              CALC_FREQ=_F (FREQ= (10. , 20.))
```

One does not know the analytical solution of the first clean vector.

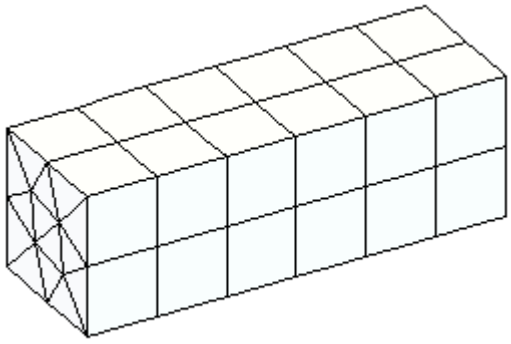
Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

7 Modeling E

7.1 Characteristics of modeling

Elements MECA_PENTA15, MEFL_PENTA15, MESF_TRIA6



Boundary conditions:
in all the nodes of the face M

```
DDL_IMPO: (GROUP_NO: noeusurf NEAR: 0. PHI: 0.)
```

in all the nodes of the piston

```
(GROUP_NO: noeupist DY: 0. DZ: 0.)
```

7.2 Characteristics of the grid

Many nodes:	331
Many meshs and types:	84 PENTA15, 28 TRIA6

7.3 Values tested

Frequency (Hz)

Reference	*Aster*	Error (%)
13.8285	13.8277	-0,006

7.4 Remarks

Calculations of modes carried out by:

```
CALC_MODES
              OPTION=' AJUSTE',
              CALC_FREQ=_F (FREQ= (10. , 20.))
```

One does not know the analytical solution of the first clean vector.

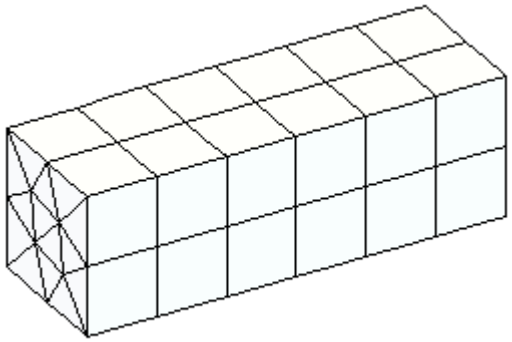
Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

8 Modeling F

8.1 Characteristics of modeling

Elements MECA_PENTA6, MEFL_PENTA6, MESF_TRIA3



Boundary conditions:
in all itS nodes of the face M

```
DDL_IMPO: (GROUP_NO: noeusurf NEAR: 0. PHI: 0.)
```

in all the nodes of the piston

```
(GROUP_NO: noeupist DY: 0. DZ: 0.)
```

8.2 Characteristics of the grid

Many nodes: 84
Many meshs and types: 84 PENTA6, 28 TRIA3

8.3 Values tested

Frequency (Hz)

Reference	*Aster*	Error (%)
13.8285	13.8277	-0,006

8.4 Remarks

Calculations of modes carried out by:

```
CALC_MODES
              OPTION=' AJUSTE',
              CALC_FREQ=_F (FREQ= (10. , 20.))
```

One does not know the analytical solution of the first clean vector.

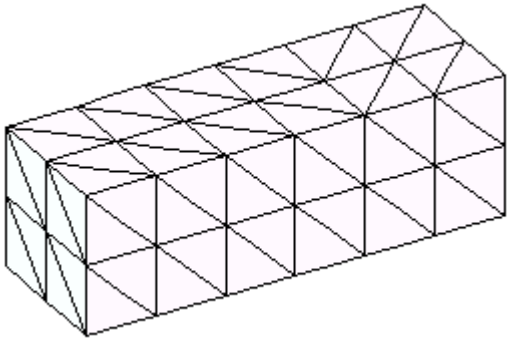
Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

9 Modeling G

9.1 Characteristics of modeling

Elements MECA_TETRA10, MEFL_TETRA10, MESF_TRIA6



Boundary conditions:
in all itS nodes of the face M

```
DDL_IMPO: (GROUP_NO: noeusurf NEAR: 0. PHI: 0.)
```

in all the nodes of the piston

```
(GROUP_NO: noeupist DY: 0. DZ: 0.)
```

9.2 Characteristics of the grid

Many nodes:	366
Many meshs and types:	173 TETRA10, 16 TRIA6

9.3 Values tested

Frequency (Hz)

Reference	*Aster*	Error (%)
13.8285	13.8277	-0,006

9.4 Remarks

Calculations of modes carried out by:

```
CALC_MODES
              OPTION=' AJUSTE',
              CALC_FREQ=_F (FREQ= (10. , 20.))
```

One does not know the analytical solution of the first clean vector.

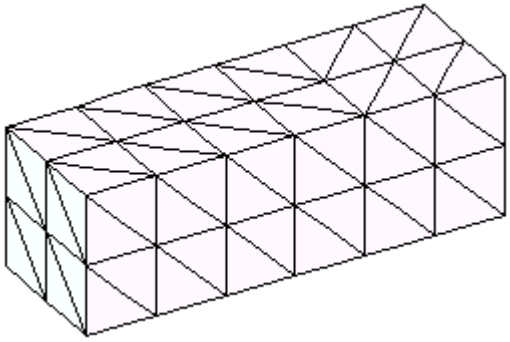
Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

10 Modeling H

10.1 Characteristics of modeling

Elements MECA_TETRA4, MEFL_TETRA4, MESF_TRIA3



Boundary conditions:
in all the nodes of the face M

```
DDL_IMPO: (GROUP_NO: noeusurf NEAR: 0. PHI: 0.)
```

in all the nodes of the piston

```
(GROUP_NO: noeupist DY: 0. DZ: 0.)
```

10.2 Characteristics of the grid

Many nodes: 69
Many meshs and types: 173 TETRA4, 16 TRIA3

10.3 Values tested

Frequency (Hz)

Reference	*Aster*	Error (%)
13.8285	13.8277	-0,006

10.4 Remarks

Calculations of modes carried out by:

```
CALC_MODES
                OPTION=' AJUSTE',
                CALC_FREQ=_F (FREQ= (10. , 20.))
```

One does not know the analytical solution of the first clean vector.

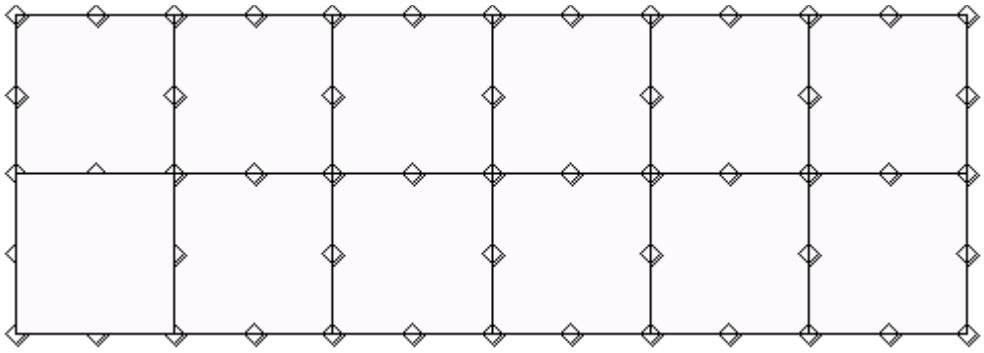
Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

11 Modeling I

11.1 Characteristics of modeling

Elements MEDPQU8, MEFLQU8, MEFSSE3



Boundary conditions:
in all the nodes of the face M

```
DDL_IMPO: (GROUP_NO: noeusurf NEAR: 0. PHI: 0.)
```

in all the nodes of the piston

```
(GROUP_NO: noeupist DY: 0.)
```

11.2 Characteristics of the grid

Many nodes:	53
Many meshs and types:	12 QUAD8, 4 SEG3

11.3 Values tested

Frequency (Hz)

Reference	*Aster*	Error (%)
13.8285	13.8277	-0,006

11.4 Remarks

Calculations carried out by:

```
CALC_MODES
              OPTION=' AJUSTE',
              CALC_FREQ=_F (FREQ= (10. , 20.))
```

One does not know the analytical solution of the first clean vector.

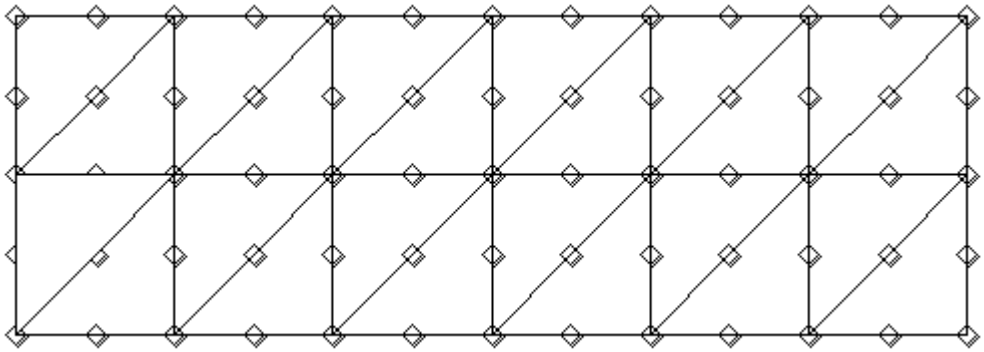
Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

12 Modeling J

12.1 Characteristics of modeling

Elements MEDPTR6, MEFLTR6, MEFSSE3



Boundary conditions:
in all the nodes of the face M

```
DDL_IMPO: (GROUP_NO: noeusurf NEAR: 0. PHI: 0.)
```

in all the nodes of the piston

```
(GROUP_NO: noeupist DY: 0.)
```

12.2 Characteristics of the grid

Many nodes:	65
Many meshs and types:	24 TRIA6, 4 SEG3

12.3 Values tested

Frequency (Hz)

Reference	*Aster*	Error (%)
13.8285	13.8277	-0,006

12.4 Remarks

Calculations carried out by:

```
CALC_MODES
              OPTION=' AJUSTE',
              CALC_FREQ=_F (FREQ= (10. , 20.))
```

One does not know the analytical solution of the first clean vector.

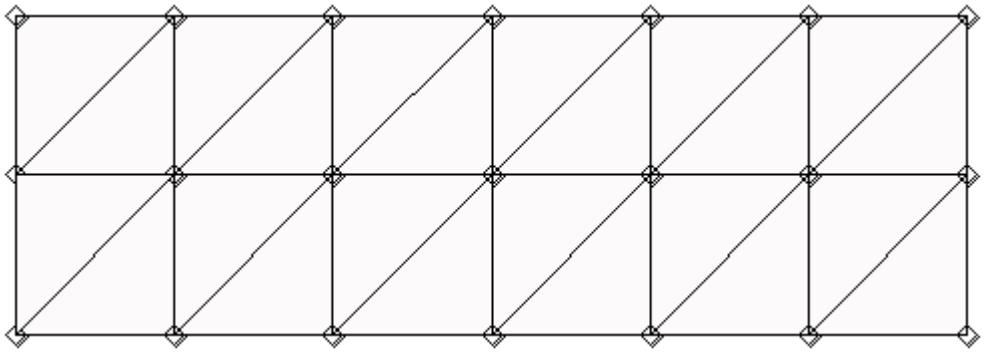
Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

13 Modeling K

13.1 Characteristics of modeling

Elements MEDPTR3, MEFLT3, MEFSSE2



Boundary conditions:
in all the nodes of the face M

```
DDL_IMPO: (GROUP_NO: noeusurf NEAR: 0. PHI: 0.)
```

in all the nodes of the piston

```
(GROUP_NO: noeupist DY: 0.)
```

13.2 Characteristics of the grid

Many nodes: 65
Many meshs and types: 24 TRIA3, 4 SEG2

13.3 Values tested

Frequency (Hz)

Reference	*Aster*	Error (%)
13.8285	13.8277	-0,006

13.4 Remarks

Calculations carried out by:

```
CALC_MODES
              OPTION=' AJUSTE',
              CALC_FREQ=_F (FREQ= (10. , 20.))
```

One does not know the analytical solution of the first clean vector.

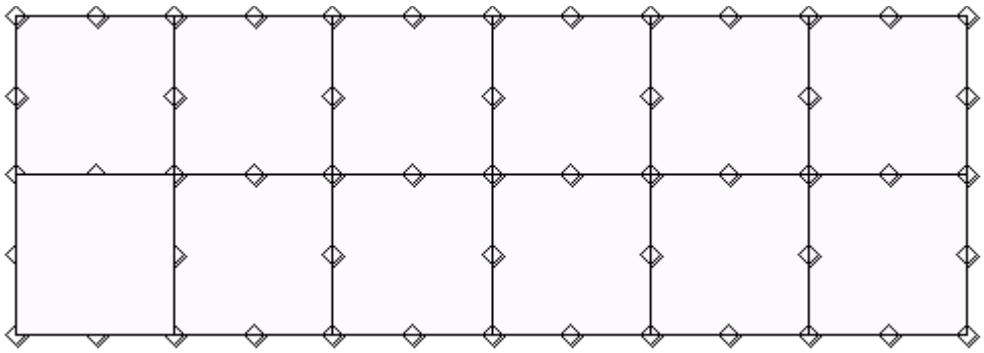
Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

14 Modeling L

14.1 Characteristics of modeling

Elements MEAXQU8, MEAXFLQU8, MEAXFSSE3



Boundary conditions:
in all itS nodes of the face M

```
DDL_IMPO: (GROUP_NO: noeusurf NEAR: 0. PHI: 0.)
```

in all the nodes of the piston

```
(GROUP_NO: noeupist DY: 0.)
```

14.2 Characteristics of the grid

Many nodes:	53
Many meshs and types:	12 QUAD8, 4 SEG3

14.3 Values tested

Frequency (Hz)

Reference	*Aster*	Error (%)
13.8285	13.8277	-0,006

14.4 Remarks

Calculations carried out by:

```
CALC_MODES
              OPTION=' AJUSTE',
              CALC_FREQ=_F (FREQ= (10. , 20.))
```

One does not know the analytical solution of the first clean vector.

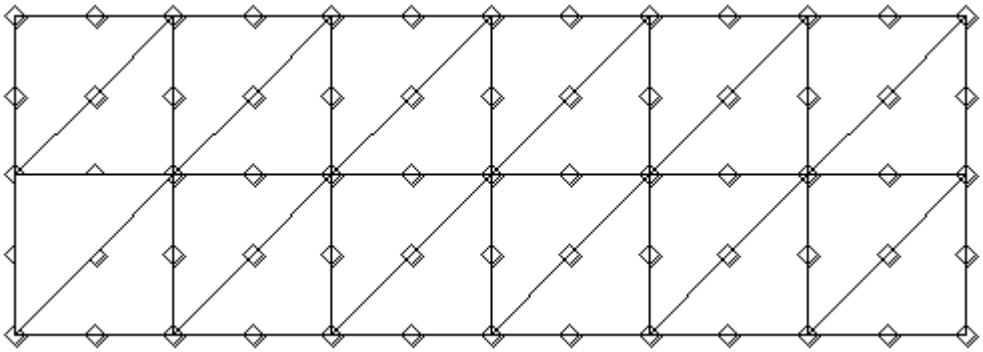
Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

15 Modeling M

15.1 Characteristics of modeling

Elements MEAXTR6, MEAXFLTR6, MEAXFSSE3



Boundary conditions:
in all itS nodes of the face M

```
DDL_IMPO: (GROUP_NO: noeusurf NEAR: 0. PHI: 0.)
```

in all the nodes of the piston

```
(GROUP_NO: noeupist DY: 0.)
```

15.2 Characteristics of the grid

Many nodes: 65
Many meshs and types: 24 TRIA6, 4 SEG3

15.3 Values tested

Frequency (Hz)

Reference	*Aster*	Error (%)
13.8285	13.8277	-0,006

15.4 Remarks

Calculations carried out by:

```
CALC_MODES
              OPTION=' AJUSTE',
              CALC_FREQ=_F (FREQ= (10. , 20.))
```

One does not know the analytical solution of the first clean vector.

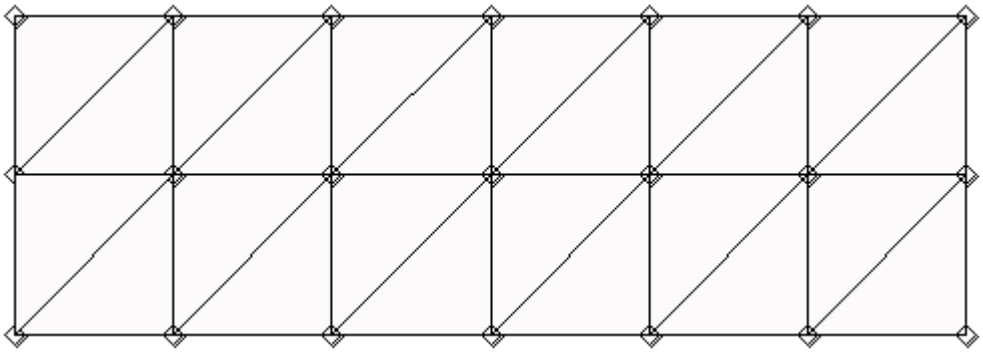
Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

16 Modeling NR

16.1 Characteristics of modeling

Elements MEAXTR3, MEAXFLTR3, MEAXFSSE2



Boundary conditions:
in all itS nodes of the face M

```
DDL_IMPO: (GROUP_NO: noeusurf NEAR: 0. PHI: 0.)
```

in all the nodes of the piston

```
(GROUP_NO: noeupist DY: 0.)
```

16.2 Characteristics of the grid

Many nodes: 21
Many meshs and types: 24 TRIA6, 4 SEG3

16.3 Values tested

Frequency (Hz)

Reference	*Aster*	Error (%)
13.8285	13.8277	-0,006

16.4 Remarks

Calculations carried out by:

```
CALC_MODES
              OPTION=' AJUSTE',
              CALC_FREQ=_F (FREQ= (10. , 20.))
```

One does not know the analytical solution of the first clean vector.

Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

17 Modeling O

17.1 Characteristics of modeling

Elements MECA_HEXA8, MEFL_HEXA8, MEFL_PYRAM5, MEFS_QUAD4

One takes again the grid of modeling A by replacing a layer elements of fluid HEXA8 by a layer of elements of fluid PYRAM5.

Boundary conditions:

in all itS nodes of the face M

```
DDL_IMPO: (GROUP_NO: noeusurf NEAR: 0. PHI: 0.)
```

in all the nodes of the piston

```
(GROUP_NO: noeupist DY: 0. DZ: 0.)
```

17.2 Characteristics of the grid

Many nodes:	71
Many meshs and types:	16 HEXA8, 48 PYRAM5, 8 QUAD4

17.3 Values tested

Frequency (Hz)

Reference	*Aster*	Error (%)
13.8285	13.8277	< 0.01

17.4 Remarks

Calculations of modes carried out by:

```
CALC_MODES
              OPTION=' AJUSTE',
              CALC_FREQ=_F (FREQ= (10. , 20.))
```

One does not know the analytical solution of the first clean vector.

Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

18 Modeling P

18.1 Characteristics of modeling

Elements MECA_HEXA20, MEFL_HEXA20, MEFL_PYRAM13, MESF_QUAD8

The grid of modeling is taken again O in passing from linear to the quadratic one and while creating a layer of elements of fluid PYRAM 13 .

Boundary conditions:
in all itS nodes of the face M

```
DDL_IMPO: (GROUP_NO: noeusurf NEAR: 0. PHI: 0.)
```

in all the nodes of the piston

```
(GROUP_NO: noeupist DY: 0. DZ: 0.)
```

18.2 Characteristics of the grid

Many nodes:	273
Many meshs and types:	16 HEXA20, 48 PYRAM13, 8 QUAD8

18.3 Values tested

Frequency (Hz)

Reference	*Aster*	Error (%)
13.8285	13.8277	-0,006

18.4 Remarks

Calculations of modes carried out by:

```
CALC_MODES
              OPTION=' AJUSTE',
              CALC_FREQ=_F (FREQ= (10. , 20.))
```

One does not know the analytical solution of the first clean vector.

Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

19 Summary of the results

The value of the modal frequency obtained with *Code_Aster* is satisfactory since, with a moderated discretization, it is equal to 0.01% close with the theoretical solution, whatever the type of modeling.