

## ADLV100 - Piston coupled to a column of fluid

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### Summary:

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

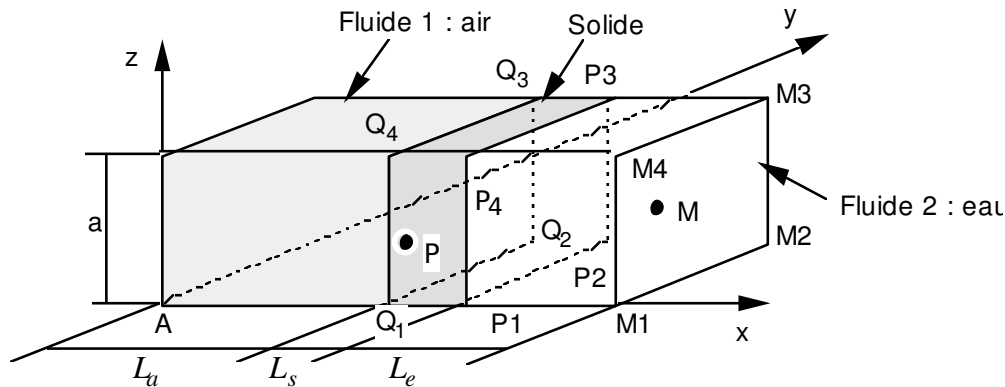
One tests the matrices of rigidity and mass of the elements of the fluid type and standard coupling fluid-structure.

One tests also the boundary condition of type free surface.

Seize modelings is tested.

## 1 Problem of reference

### 1.1 Geometry



$$L_a = 0.075, L_s = 0.025, L_e = 0.05 \text{ m}$$

constant square section,  $a = 0.05 \text{ m}$

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

### 1.2 Properties of materials

solid:  $E = 2.10^{11} \text{ Pa}$

$\rho_s = 7800 \text{ kg/m}^3$

$\nu = 0.3$

air:  $c_a = 340 \text{ m/s}$

$\rho_a = 1.2 \text{ kg/m}^3$

water:  $c_e = 1400 \text{ m/s}$

$\rho_e = 1000 \text{ kg/m}^3$

$c = \text{célérité du son}$

$c =$  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:

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

Soit,

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

**Note:**

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

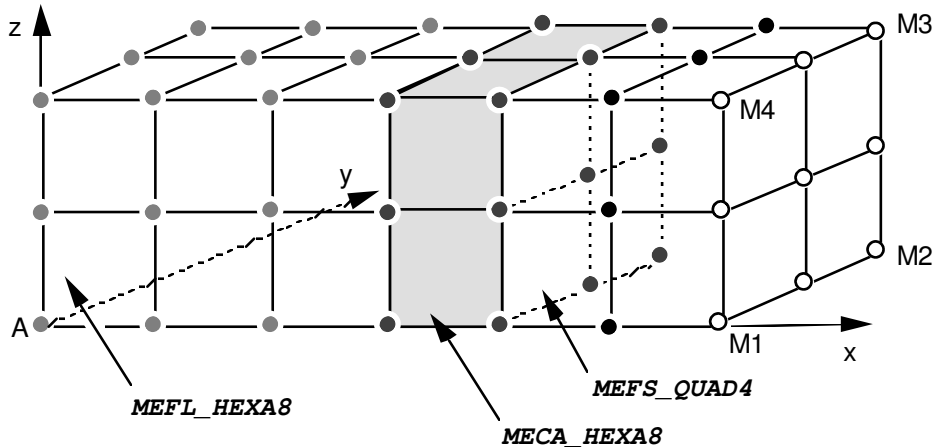
### 2.2 Bibliographical references

- 1) GIBERT - Vibrations of the Structures. Interactions with the fluids. Random sources of excitation - Collection of the Management of the Studies and Searches 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 meshes and types: 24 HEXA8, 8 QUAD4

### 3.3 Values tested

In modal calculation (CALC\_MODES)

Frequency ( Hz )		
Reference	ANALYTICAL	Error (%)
13.8285	13.8277	< 0.01

By MODE\_VIBR in DYNA\_NON\_LINE

Frequency ( Hz )		
Reference	ANALYTICAL	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.

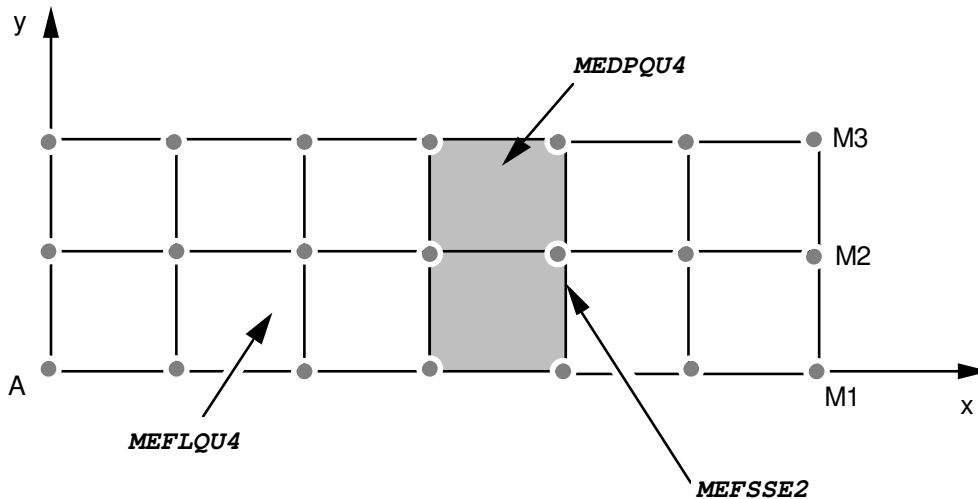
### Contents of the file results:

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

## 4 Modeling B

### 4.1 Characteristics of modeling

Elements MEDPQU4, MEFLQU4, MEFSS2



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 meshes 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.

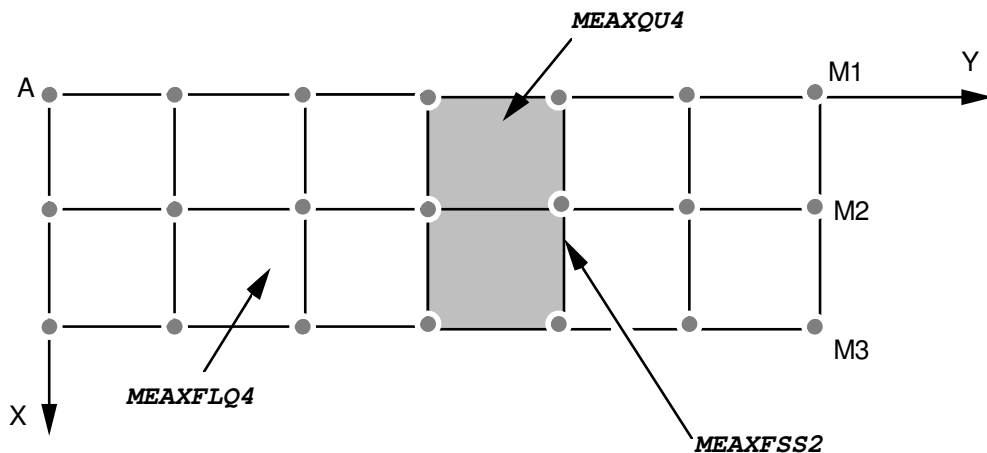
Contents of the file results:

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 meshes 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.

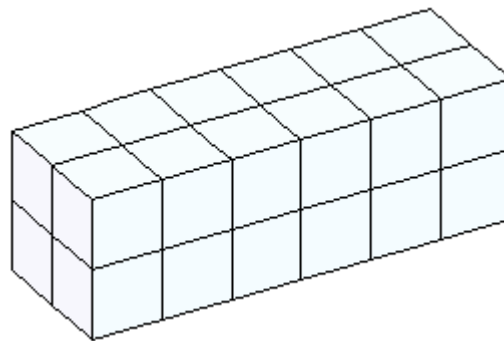
**Contents of the file results:**

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

## 6 Modeling D

### 6.1 Characteristics of modeling

Elements MECA\_HEX20, MEFL\_HEX20, 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 meshes 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:**

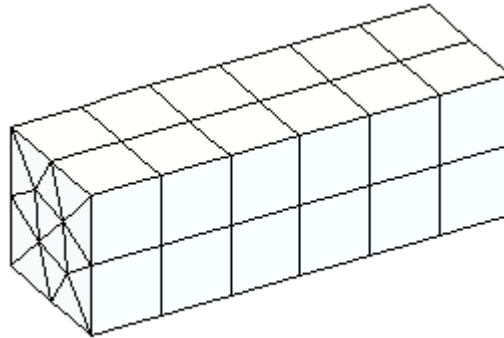
Value of the first Eigen frequency of vibration of the coupled system.



## 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 meshes 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.

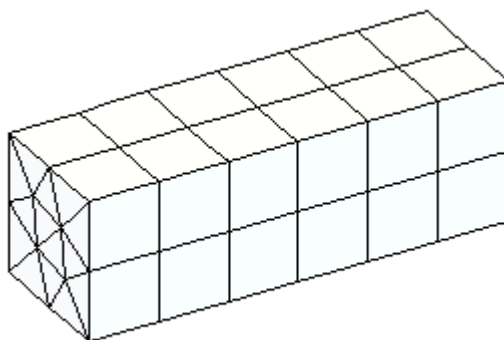
**Contents of the file results:**

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 meshes 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.

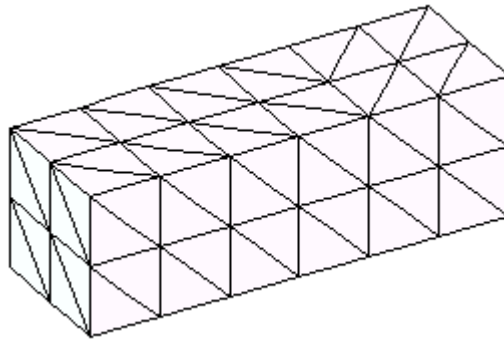
**Contents of the file results:**

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 meshes 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.

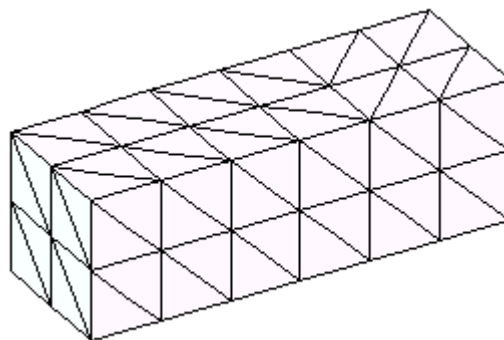
**Contents of the file results:**

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 meshes 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.

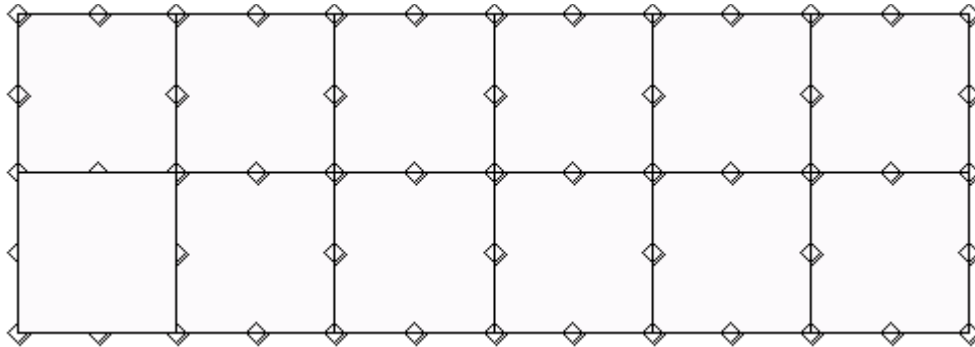
Contents of the file results:

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 meshes 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.

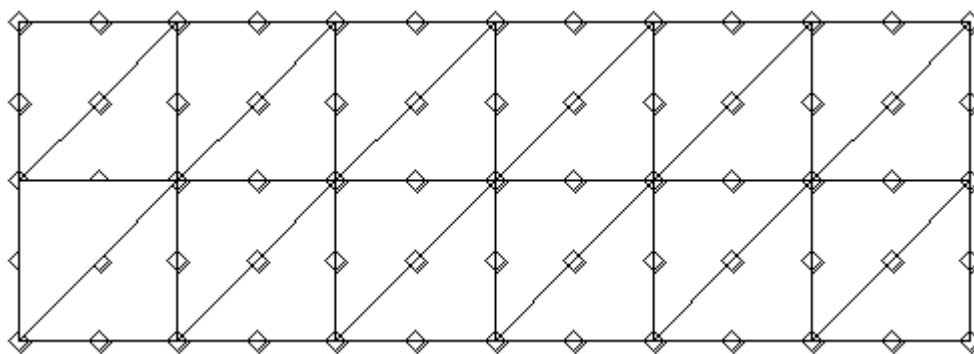
**Contents of the file results:**

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

## 12 Modeling J

### 12.1 Characteristics of modeling

Elements MEDPTR6, MEFLTR6, MEFSS3



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 meshes 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.

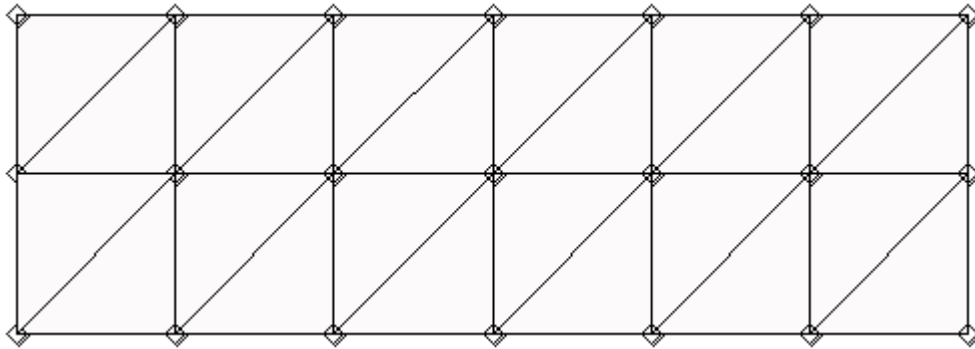
**Contents of the file results:**

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 meshes 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.

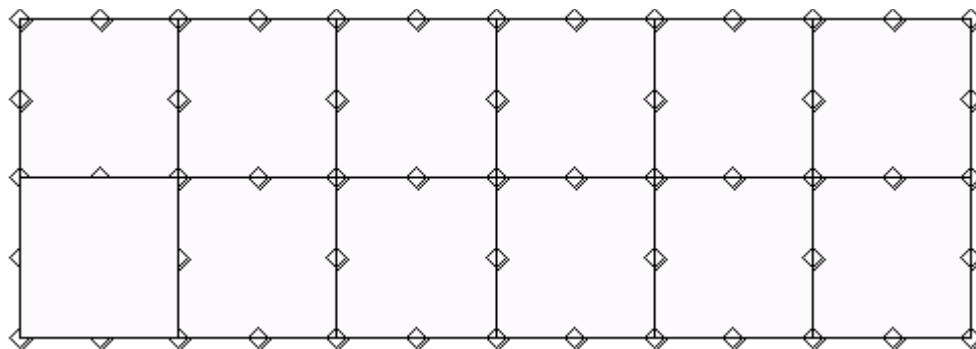
**Contents of the file results:**

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 meshes 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:**

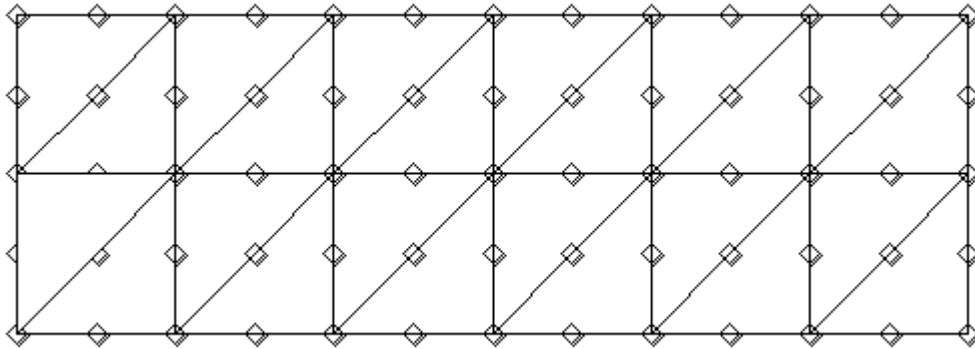
Value of the first Eigen frequency of vibration of the coupled system.



## 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 meshes 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.

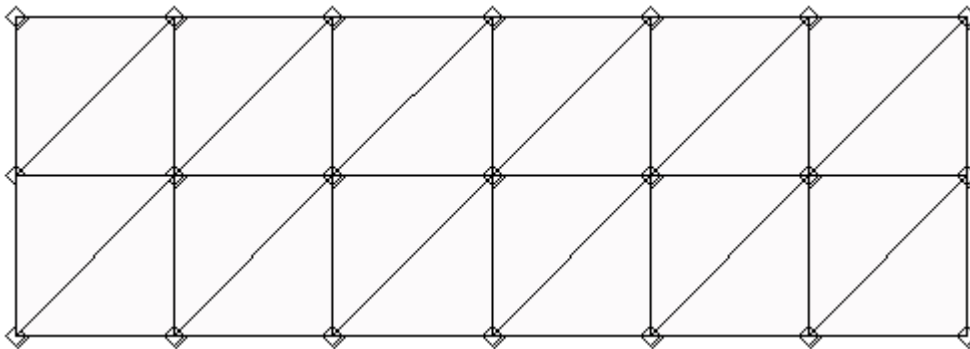
**Contents of the file results:**

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 meshes 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 meshes 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\_HEX20, MEFL\_HEX20, 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 meshes 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

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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.