
AHLV100 - Guide of wave at anechoic exit

Summary:

A rectilinear guide of wave at anechoic exit, with rigid walls, whose propagation medium is "normal" air, is excited by a harmonically vibrating piston.

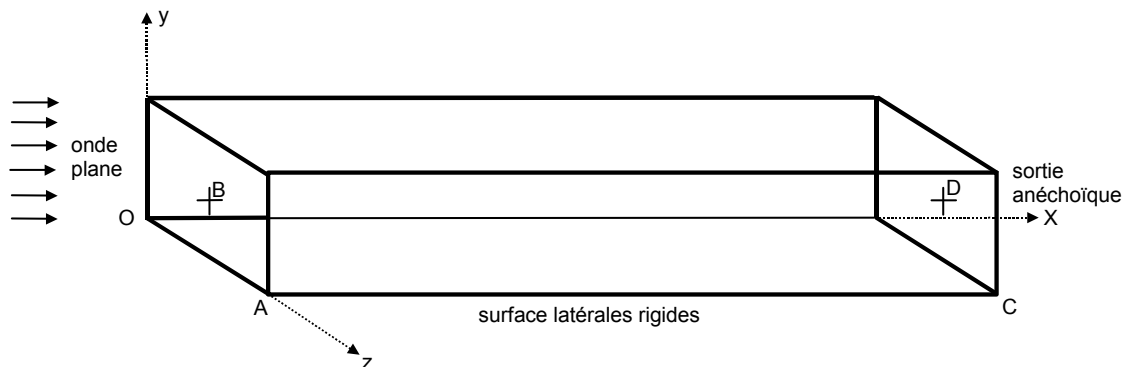
One calculates by an acoustic formulation the acoustic field of pressure of the harmonic answer for 13 different modelings. The results are tested in 2 points at the entry and 2 points at the exit.

They make it possible to validate the matrices of rigidity, mass, damping (impedance), the vector source (imposed normal speed) as well as the operators of postprocessings.

The results of reference come from an analytical calculation.

1 Problem of reference

1.1 Geometry



Tube with rectangular section:

length: $L = l_x = 1.0 \text{ m}$

height: $h = l_y = 0.1 \text{ m}$

width: $l = l_z = 0.2 \text{ m}$

Coordinates of the points (in m):

	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>
<i>x</i>	0.	0.	1.00	1.00
<i>y</i>	0.	0.05	0.	0.05
<i>z</i>	0.20	0.10	0.20	0.10

1.2 Properties of materials

Air:

$$\rho_c = 1.3 \text{ kg} \cdot \text{m}^{-3}$$

$$c_0 = 343 \text{ m} \cdot \text{s}^{-1}$$

1.3 Boundary conditions and loading

Normal speed at the entry

$$V = V_n \times \exp(i \omega t) \text{ with } V_n = 0.014 \text{ m} \cdot \text{s}^{-1}$$

$$f = 500 \text{ Hz}$$

Impedance at the end *CD*

$$Z = \rho_0 \cdot c_0 = 445.9 \text{ kg} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$$

2 Reference solution

2.1 Method of calculating used for the reference solution

The general analytical solution for a guide of wave is written:

$(\mathbf{e}_x, \mathbf{e}_y, \mathbf{e}_z)$ being the orthonormal reference mark associated with the Cartesian coordinates (x, y, z)

- for the pressure:

$$p(x, y, z) = A \exp(ikx) + B \exp(-ikx)$$

- for vibratory speed:

$$\mathbf{V}(x, y, z) = -\frac{1}{\rho_0 \cdot c_0} [A \exp(ikx) - B \exp(-ikx)] \mathbf{e}_x$$

- With A and B are determined by the boundary conditions:

$$\text{en } x=0 \quad V_n = V_{n0}$$

$$\text{en } x=L \quad p(L, y, z) = Z \cdot \mathbf{V}(L, y, z) \cdot \mathbf{n}_L$$

$$A = B \frac{Z - \rho_0 \cdot c_0}{Z + \rho_0 \cdot c_0} \exp(-2ikL) \quad \text{et} \quad B = \frac{\rho_0 \cdot c_0 \cdot V_n}{\frac{Z - \rho_0 \cdot c_0}{Z + \rho_0 \cdot c_0} \exp(-2ikL) - 1} \quad \text{avec} \quad k = \frac{\omega}{c_0}$$

In the studied case, the exit of the guide is anechoic: $Z = \rho_0 c_0$. One thus has:

- for the pressure:

$$p(x, y, z) = \rho_0 c_0 V_n \exp(-ikx)$$

- for speed:

$$\mathbf{V}(x, y, z) = -V_n \exp(-ikx) \cdot \mathbf{e}_x$$

- and for the acoustic intensity:

$$\mathbf{I} = \frac{1}{2} p \mathbf{V}^* = \frac{1}{2} \rho_0 c_0 V_n^2 \cdot \mathbf{e}_x$$

I.e. acoustic Intensity activates uniform in all the guide and parallel with the axis.

The Eigen frequencies are given for the guide closed at the two ends by:

$$f_{m,n,p} = \frac{c_0}{2} \sqrt{\frac{m^2}{l_x^2} + \frac{n^2}{l_y^2} + \frac{p^2}{l_z^2}} \quad \text{where } m, n, p \text{ are positive entières.}$$

2.2 Results of reference

Pressure at the points A, B, C, D (for modelings A, B, C, D, E).

Acoustic intensity at the points A, B, C, D (for modelings A and C).

Eigen frequencies $n^{\circ 2}$ with $n^{\circ 9}$.

2.3 Uncertainty on the solution

Analytical solution

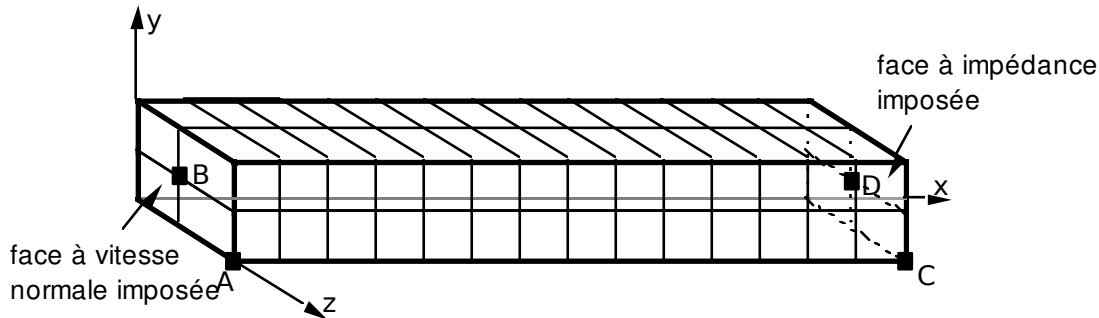
2.4 Bibliographical references

- BOUIZI A. Résolution of the equations of linear acoustics by a method finite elements mixed - Thesis (1989).

3 Modeling A

3.1 Characteristics of modeling

Formulation pressure elements 'ACOUSTIC' 3D (ACOU_HEXA20 and ACOU_FACE8)



Cutting = 15 meshes HEXA20 according to the axis of x
2 meshes HEXA20 according to the axis of y
2 meshes HEXA20 according to the axis of z

Limiting conditions:

VITE_FACE: (Group_ma: Entry Vnor: IH 0,014 0.)
IMPE_FACE: (Group_ma: Exit Impe: IH 445.9 0.)

Name of the nodes $A = No1$ $B = No780$ $C = No751$ $D = No763$

3.2 Characteristics of the grid

Many nodes: 471
Many meshes and types: 60 HEXA20 8 QUAD8

4 Results of modeling A

4.1 Values tested

Localization	Sizes	Reference	tolerance
A	$p(\text{réel})$	-6.2426	0.1%
	$p(\text{imag})$	0.0000	0.1%
	$p(\text{dB})$	109.9	0.1%
	Acoustic intensity (reality)	0.0437	3%
	Acoustic intensity (imag)	0	3.5E-4
	B	$p(\text{réel})$	-6.2426
$p(\text{imag})$		0.0000	0.1%
$p(\text{dB})$		109.9	0.1%
Acoustic intensity (reality)		0.0437	3%
Acoustic intensity (imag)		0	3.5E-4
C		$p(\text{réel})$	6.0237
	$p(\text{imag})$	1.6387	0.1%
	$p(\text{dB})$	109.9	0.1%
	Acoustic intensity (reality)	0.04037	3%
	Acoustic intensity (imag)	0	3.5E-4
	D	$p(\text{réel})$	6.0237
$p(\text{imag})$		1.6387	0.1%
$p(\text{dB})$		109.9	0.1%
Acoustic intensity (reality)		0.0437	3%

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Acoustic intensity (imag) 0 3.5E-4

Order of the clean mode <i>i</i>	Frequency			Reference	tolerance
	<i>m</i>	<i>n</i>	<i>p</i>		
2	1	0	0	171.5	0.01%
3	2	0	0	343.0	0.01%
4	3	0	0	514.5	0.1%
5	4	0	0	686.0	1%
6	5	0	0	857.5	0.1%
7	0	0	1	857.5	0.5%
8	1	0	1	874,482	0.5%
9	2	0	1	923,556	0.5%

4.2 Notice

One tests the results in two different ways:

- by the usual procedure while using `DYNA_LINE_HARM` ;
- by a calculation broken up into orders of linear algebra `COMB_MATR_ASSE`, `CREA_CHAMP`, `TO FACTORIZE`, `TO SOLVE`.

The tests are thus duplicated and it is checked that the results are coherent.

Code Aster

Version
default

Titre : AHLV100 - Guide d'onde à sortie anéchoïque
Responsable : DELMAS Josselin

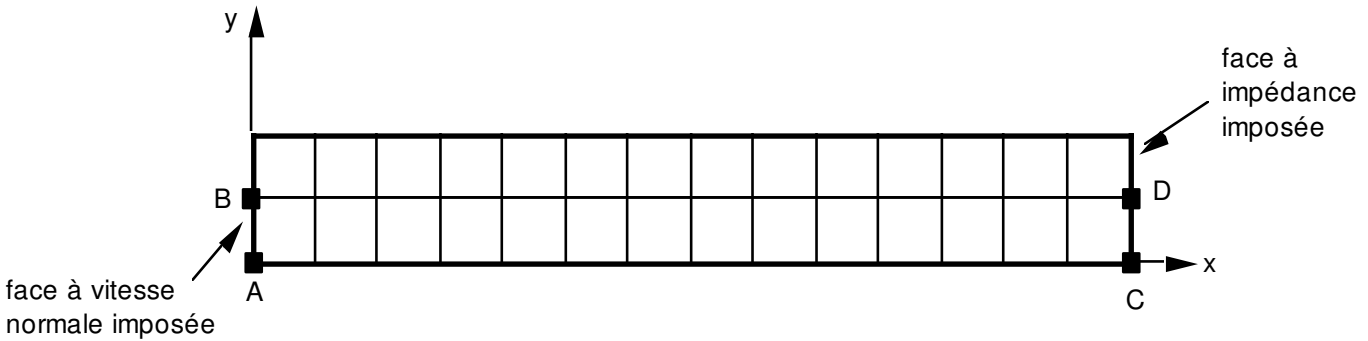
Date : 09/12/2013 Page : 7/25
Clé : V8.22.100 Révision :
5a48cdc7f17a

D	$ p $	6.2426	0.1%
	$p(\text{angle})$	15.2186°	0.1%
	$p(\text{dB})$	109.8867	0.1%

7 Modeling D

7.1 Characteristics of modeling

Formulation pressure potential of elements displacements '2D_FLUIDE' (MEFLSE3 and MEFLQU8)



Cutting = 15 meshes QUAD8 according to the axis of x
2 meshes QUAD8 according to the axis of y

Limiting conditions:

VITE_FACE: (GROUP_MA: Entry VNOR: 0,014)
IMPE_FACE: (GROUP_MA: Exit IMPE: 445.9)

Name of the nodes $A=No1$ $B=No780$ $C=No151$ $D=No153$

7.2 Characteristics of the grid

Many nodes: 125
Many meshes and types: 30 QUAD8 4 SEG3

8 Results of modeling D

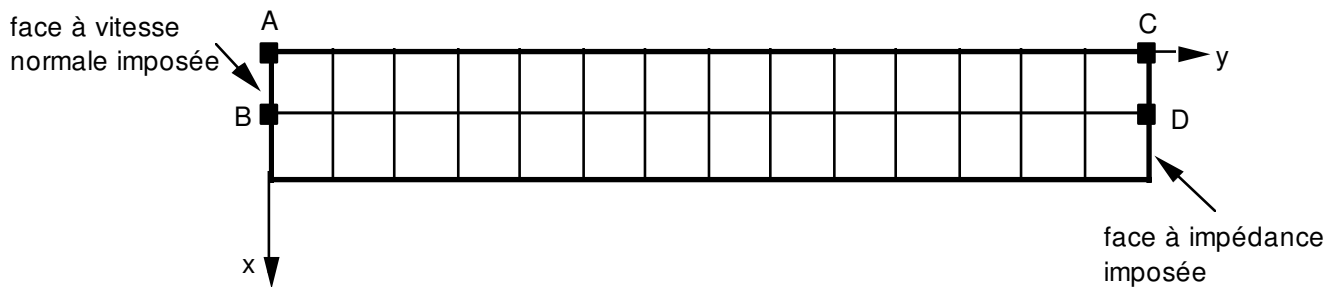
8.1 Values tested

Localization	Sizes	Reference	% difference
A	$p(\text{réel})$	-6.2426	0.1%
	$p(\text{imag})$	0.0	0.1%
	$p(\text{dB})$	109.8867	0.1%
B	$p(\text{réel})$	-6.2426	0.1%
	$p(\text{imag})$	0.0	0.1%
	$p(\text{dB})$	109.8867	0.1%
C	$p(\text{réel})$	6.0237	0.1%
	$p(\text{imag})$	1.6387	0.1%
	$p(\text{dB})$	109.8867	0.1%
D	$p(\text{réel})$	6.0237	0.1%
	$p(\text{imag})$	1.6387	0.1%
	$p(\text{dB})$	109.8867	0.1%

9 Modeling E

9.1 Characteristics of modeling

Formulation pressure potential of elements displacements 'AXIS_FLUIDE' (MEAXFLS3 and MEAXFLQ8)



Cutting = 15 meshes QUAD8 according to the axis of x
2 meshes QUAD8 according to the axis of y

Limiting conditions:

VITE_FACE: (GROUP_MA: Entry VNOR: 0,014)
IMPE_FACE: (GROUP_MA: Exit IMPE: 445.9)

Name of the nodes $A = No1$ $B = No780$ $C = No151$ $D = No153$

9.2 Characteristics of the grid

Many nodes: 125
Many meshes and types: 30 QUAD8 4 SEG3

10 Results of modeling E

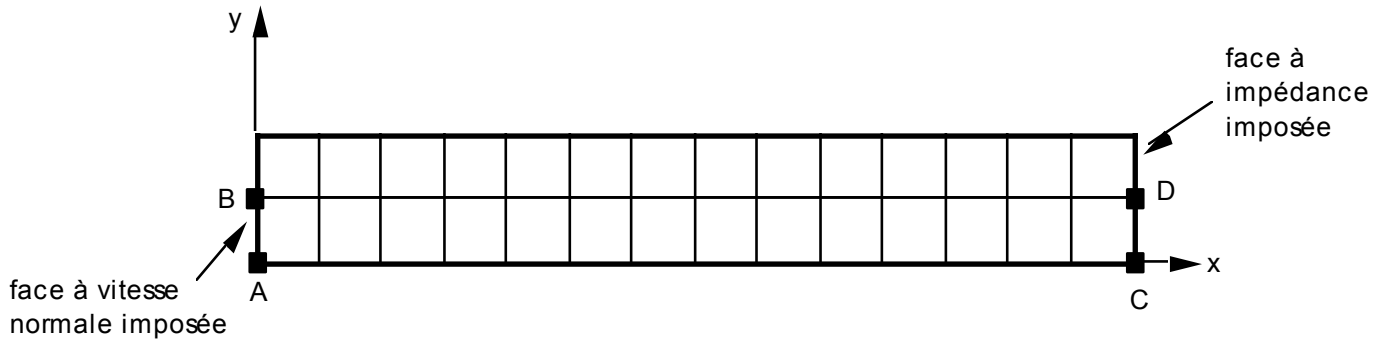
10.1 Values tested

Localization	Sizes	Reference	% difference
A	$p(\text{réel})$	- 6.2426	0.1%
	$p(\text{imag})$	0.0	0.1%
	$p(\text{dB})$	109.8867	0.1%
B	$p(\text{réel})$	- 6.2426	0.1%
	$p(\text{imag})$	0.0	0.1%
	$p(\text{dB})$	109.8867	0.1%
C	$p(\text{réel})$	6.0237	0.1%
	$p(\text{imag})$	1.6387	0.1%
	$p(\text{dB})$	109.8867	0.1%
D	$p(\text{réel})$	6.0237	0.1%
	$p(\text{imag})$	1.6387	0.1%
	$p(\text{dB})$	109.8867	0.1%

11 Modeling F

11.1 Characteristics of modeling

Formulation pressure elements 'ACOUSTIC' PLAN (SEG3 and QUAD8)



Cutting = 15 meshes QUAD8 according to the axis of x
2 meshes QUAD8 according to the axis of y

Limiting conditions:

VITE_FACE: (Group_ma: Entry Vnor: 0,014)
IMPE_FACE: (Group_ma: Exit Impe: 445.9)

Name of the nodes $A=No1$ $B=No33$ $C=No2$ $D=No34$

11.2 Characteristics of the grid

Many nodes: 125
Many meshes and types: 30 QUAD8 4 SEG3

12 Results of modeling F

12.1 Values tested

Localization	Sizes	Reference	tolerance
A	$p(\text{réel})$	-6.2426	0.1%
	$p(\text{imag})$	0.0000	0.1%
	Acoustic intensity (reality)	0.0437	3%
	Acoustic intensity (imag)	0	3.5E-4
B	$p(\text{réel})$	-6.2426	0.1%
	$p(\text{imag})$	0.0000	0.1%
	Acoustic intensity (reality)	0.0437	3%
	Acoustic intensity (imag)	0	3.5E-4
C	$p(\text{réel})$	6.0237	0.1%
	$p(\text{imag})$	1.6387	0.1%
	Acoustic intensity (reality)	0.04037	3%
	Acoustic intensity (imag)	0	3.5E-4
D	$p(\text{réel})$	6.0237	0.1%
	$p(\text{imag})$	1.6387	0.1%
	Acoustic intensity (reality)	0.0437	3%
	Acoustic intensity (imag)	0	3.5E-4

Order of the clean mode <i>i</i>	Frequency			Reference	tolerance
	<i>m</i>	<i>n</i>	<i>p</i>		
2	1	0	0	171.5	0.1%
3	2	0	0	343.0	0.2%
4	3	0	0	514.5	0.5%
5	4	0	0	686.0	1%
6	5	0	0	857.5	2%
7	0	0	1	857.5	3%
8	1	0	1	874,482	3%
9	2	0	1	923,556	3%

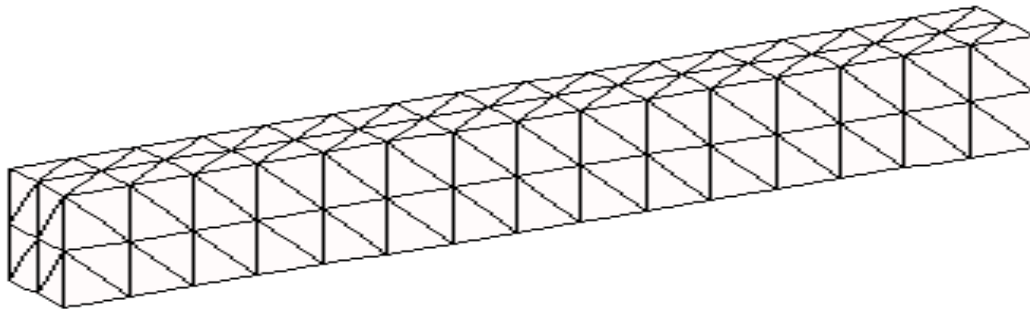
Order of the clean mode <i>i</i>	Frequency			Reference	tolerance
	<i>m</i>	<i>n</i>	<i>p</i>		
2	1	0	0	171.5	0.01%
3	2	0	0	343.0	0.01%
4	3	0	0	514.5	0.1%
5	4	0	0	686.0	0.1%
6	5	0	0	857.5	0.1%
7	0	0	1	857.5	0.5%
8	1	0	1	874,482	0.5%
9	2	0	1	923,556	0.5%

Order of the clean mode <i>i</i>	Frequency			Reference	tolerance
	<i>m</i>	<i>n</i>	<i>p</i>		
2	1	0	0	171.5	0.1%
3	2	0	0	343.0	0.2%
4	3	0	0	514.5	0.5%
5	4	0	0	686.0	1%
6	5	0	0	857.5	2%
7	0	0	1	857.5	3%
8	1	0	1	874,482	3%
9	2	0	1	923,556	3%

19 Modeling J

19.1 Characteristics of modeling

Formulation pressure elements 'ACOUSTIC' 3D (ACOU_TETRA10 and ACOU_FACE6)



Cutting = 15 meshes TETRA10 according to the axis of *x*
2 meshes TETRA10 according to the axis of *y*
2 meshes TETRA10 according to the axis of *z*

Limiting conditions:

VITE_FACE: (Group_ma: bicycle Vnor: IH 0,014 0.)
IMPE_FACE: (Group_ma: impe Impe: IH 445.9 0.)

Name of the nodes *A*=No4 *B*=No76 *C*=No7 *D*=No73

19.2 Characteristics of the grid

Many nodes: 870
Many meshes and types: 421 TETRA10 16 TRIA6

20 Results of modeling J

20.1 Values tested

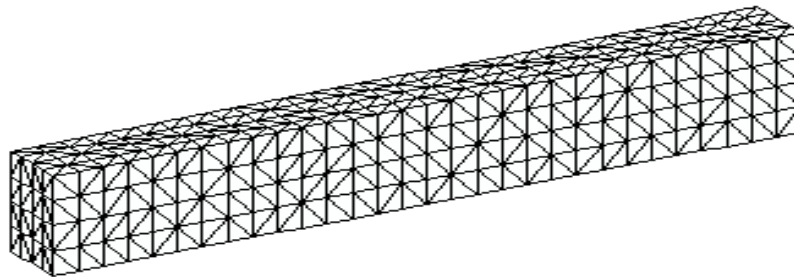
Localization	Sizes	Reference	tolerance
<i>A</i>	$p(\text{réel}, \text{imag})$	(- 6.2426, 0.0000)	0.3%
	Intensité_Acou	0.0437	3%
<i>B</i>	$p(\text{réel}, \text{imag})$	(- 6.2426, 0.0000)	0.3%
	Intensité_Acou	0.0437	4%
<i>C</i>	$p(\text{réel}, \text{imag})$	(6.0237, 1.6387)	0.2%
	Intensité_Acou	0.0437	2%
<i>D</i>	$p(\text{réel}, \text{imag})$	(6.0237, 1.6387)	0.2%
	Intensité_Acou	0.0437	3%

Order of the clean mode <i>i</i>	Frequency			Reference	tolerance
	<i>m</i>	<i>n</i>	<i>p</i>		
2	1	0	0	171.5	0.01%
3	2	0	0	343.0	0.01%
4	3	0	0	514.5	0.01%
5	4	0	0	686.0	0.1%
6	5	0	0	857.5	0.1%
7	0	0	1	857.5	0.5%
8	1	0	1	874,482	0.5%
9	2	0	1	923,556	0.5%

21 Modeling K

21.1 Characteristics of modeling

Formulation pressure elements 'ACOUSTIC' 3D (ACOU_TETRA4 and ACOU_FACE3)



Cutting = 30 meshes TETRA4 according to the axis of x
4 meshes TETRA4 according to the axis of y
4 meshes TETRA4 according to the axis of z

Limiting conditions:

VITE_FACE: (Group_ma: bicycle Vnor: IH 0,014 0.)
IMPE_FACE: (Group_ma: impe Impe: IH 445.9 0.)

Name of the nodes $A=No18$ $B=No521$ $C=No15$ $D=No1028$

21.2 Characteristics of the grid

Many nodes: 685
Many meshes and types: 2180 TETRA4 64 TRIA6

22 Results of modeling K

22.1 Values tested

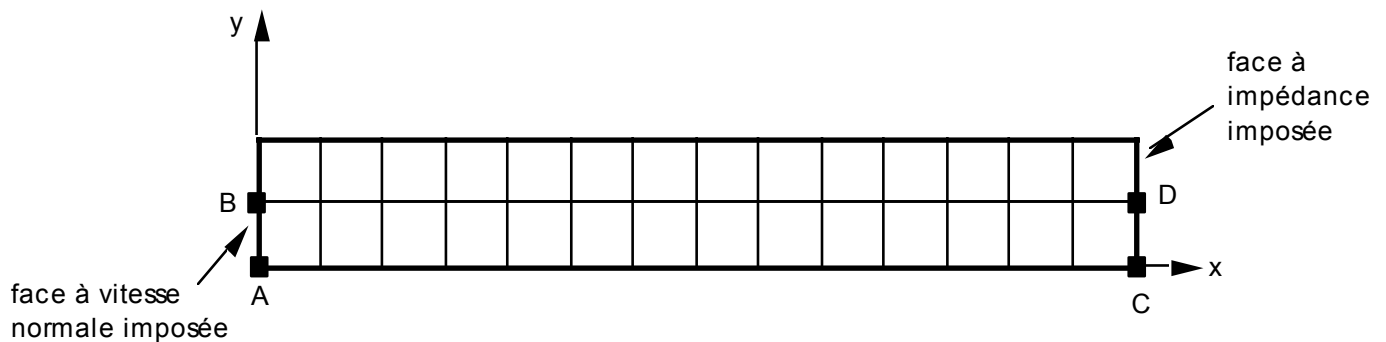
Localization	Sizes	Reference	tolerance
A	$p(\text{réel}, \text{imag})$	(- 6.2426, 0.0000)	1%
	Intensité_Acou	0.0437	3%
B	$p(\text{réel}, \text{imag})$	(- 6.2426, 0.0000)	2%
	Intensité_Acou	0.0437	3%
C	$p(\text{réel}, \text{imag})$	(6.0237, 1.6387)	5%
	Intensité_Acou	0.0437	3%
D	$p(\text{réel}, \text{imag})$	(6.0237, 1.6387)	5%
	Intensité_Acou	0.0437	3%

Order of the clean mode <i>i</i>	<i>m</i>	<i>n</i>	<i>p</i>	Frequency	
				Reference	tolerance
2	1	0	0	171.5	0.2%
3	2	0	0	343.0	0.3%
4	3	0	0	514.5	0.6%
5	4	0	0	686.0	1%
6	5	0	0	857.5	2%
7	0	0	1	857.5	3%
8	1	0	1	874,482	3%
9	2	0	1	923,556	4%

23 Modeling M

23.1 Characteristics of modeling

Formulation pressure elements 'ACOUSTIC' PLAN (SEG3 and QUAD8)



Cutting = 15 meshes QUAD8 according to the axis of *x*
2 meshes QUAD8 according to the axis of *y*

Limiting conditions:

VITE_FACE: (Group_ma: Entry Vnor: 0,014)
IMPE_FACE: (Group_ma: Exit Impe: 445.9)

Name of the nodes *A*=No1 *B*=No33 *C*=No2 *D*=No34

23.2 Characteristics of the grid

Many nodes: 125
Many meshes and types: 30 QUAD8 4 SEG3

24 Results of modeling M

24.1 Values tested

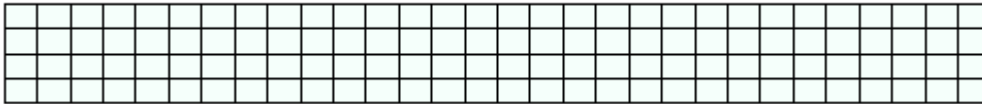
Localization	Sizes	Reference	tolerance
<i>A</i>	<i>p</i> (réel)	-6.2426	0.1%
	<i>p</i> (imag)	0.0000	0.1%
	Acoustic intensity (reality)	0.0437	3%
	Acoustic intensity (imag)	0	3.5E-4
<i>B</i>	<i>p</i> (réel)	-6.2426	0.1%

	$p(\text{imag})$	0.0000	0.1%
	Acoustic intensity (reality)	0.0437	3%
	Acoustic intensity (imag)	0	3.5E-4
<i>C</i>	$p(\text{réel})$	6.0237	0.1%
	$p(\text{imag})$	1.6387	0.1%
	Acoustic intensity (reality)	0.04037	3%
	Acoustic intensity (imag)	0	3.5E-4
<i>D</i>	$p(\text{réel})$	6.0237	0.1%
	$p(\text{imag})$	1.6387	0.1%
	Acoustic intensity (reality)	0.0437	3%
	Acoustic intensity (imag)	0	3.5E-4

25 Modeling Q

25.1 Characteristics of modeling

Formulation pressure elements 'ACOUSTIC' PLAN (SEG2 and QUAD4)



Cutting = 30 meshes QUAD4 according to the axis of x
4 meshes QUAD4 according to the axis of y

Limiting conditions:

VITE_FACE: (Group_ma: Entry Vnor: 0,014)
IMPE_FACE: (Group_ma: Exit Impe: 445.9)

Name of the nodes $A=No1$ $B=No237$ $C=No2$ $D=No205$

25.2 Characteristics of the grid

Many nodes: 155
Many meshes and types: 120 QUAD8 8 SEG2

26 Results of modeling Q

26.1 Values tested

Localization	Sizes	Reference	tolerance
A	$p(\text{réel})$	-6.2426	0.3%
	$p(\text{imag})$	0.0000	0.3%
	Acoustic intensity (reality)	0.0437	1.5%
	Acoustic intensity (imag)	0	6.5E-3
B	$p(\text{réel})$	-6.2426	0.3%
	$p(\text{imag})$	0.0000	0.3%
	Acoustic intensity (reality)	0.0437	1.5%
	Acoustic intensity (imag)	0	6.5E-3
C	$p(\text{réel})$	6.0237	4%
	$p(\text{imag})$	1.6387	4%
	Acoustic intensity (reality)	0.04037	1.5%
	Acoustic intensity (imag)	0	6.6E-4
D	$p(\text{réel})$	6.0237	4%
	$p(\text{imag})$	1.6387	4%
	Acoustic intensity (reality)	0.0437	1.5%
	Acoustic intensity (imag)	0	6.6E-3

27 Modeling R

27.1 Characteristics of modeling

Formulation pressure elements 'ACOUSTIC' PLAN (SEG3 and TRIA6)



Cutting = 15 meshes TRIA6 according to the axis of x
2 meshes TRIA6 according to the axis of y

Limiting conditions:

VITE_FACE: (Group_ma: Entry Vnor: 0,014)
IMPE_FACE: (Group_ma: Exit Impe: 445.9)

Name of the nodes $A=No1$ $B=No5$ $C=No2$ $D=No6$

27.2 Characteristics of the grid

Many nodes: 155
Many meshes and types: 60 TRIA6 4 SEG3

28 Results of modeling R

28.1 Values tested

Localization	Sizes	Reference	tolerance
A	$p(\text{réel})$	-6.2426	0.2%
	$p(\text{imag})$	0.0000	0.2%
	Acoustic intensity (reality)	0.0437	3.5%
	Acoustic intensity (imag)	0	5.0E-3
B	$p(\text{réel})$	-6.2426	0.1%
	$p(\text{imag})$	0.0000	0.1%
	Acoustic intensity (reality)	0.0437	3.5%
	Acoustic intensity (imag)	0	4.5E-3
C	$p(\text{réel})$	6.0237	0.3%
	$p(\text{imag})$	1.6387	0.3%
	Acoustic intensity (reality)	0.04037	2.0%
	Acoustic intensity (imag)	0	2.5E-4
D	$p(\text{réel})$	6.0237	0.1%
	$p(\text{imag})$	1.6387	0.1%
	Acoustic intensity (reality)	0.0437	2.5%
	Acoustic intensity (imag)	0	3.5E-4

29 Modeling S

29.1 Characteristics of modeling

Formulation pressure elements 'ACOUSTIC' PLAN (SEG2 and TRIA3)



Cutting = 30 meshes TRIA3 according to the axis of x
4 meshes TRIA3 according to the axis of y

Limiting conditions:

VITE_FACE: (Group_ma: Entry Vnor: 0,014)
IMPE_FACE: (Group_ma: Exit Impe: 445.9)

Name of the nodes $A=No1$ $B=No237$ $C=No2$ $D=No205$

29.2 Characteristics of the grid

Many nodes: 155
Many meshes and types: 240 TRIA3 8 SEG2

30 Results of modeling S

30.1 Values tested

Localization	Sizes	Reference	tolerance
A	$p(\text{réel})$	-6.2426	1.0%
	$p(\text{imag})$	0.0000	1.0%
	Acoustic intensity (reality)	0.0437	3.0%
	Acoustic intensity (imag)	0	6.0E-3
B	$p(\text{réel})$	-6.2426	0.1%
	$p(\text{imag})$	0.0000	0.1%
	Acoustic intensity (reality)	0.0437	2.5%
	Acoustic intensity (imag)	0	6.5E-3
C	$p(\text{réel})$	6.0237	7%
	$p(\text{imag})$	1.6387	7%
	Acoustic intensity (reality)	0.04037	1.0%
	Acoustic intensity (imag)	0	7.0E-3
D	$p(\text{réel})$	6.0237	6%
	$p(\text{imag})$	1.6387	6%
	Acoustic intensity (reality)	0.0437	2.5%
	Acoustic intensity (imag)	0	7.0E-3

31 Modeling T

31.1 Characteristics of modeling

One takes again modeling A completely by modifying only celerity `CELE_C` material: its real part remains unchanged with 343 m.s^{-1} whereas the imaginary part passes from 0 with 10 m.s^{-1} .

32 Results of modeling T

32.1 Values tested

One analyzes the same sizes as for modeling A, but only for tests of non- regression.

33 Summary of the results

Modelings give the expected results.

In modelings using of the tetrahedrons or the triangles, the distribution of the pressures is less uniform than in the other cases, consequence of the non-uniformity of the grid.