FDLV111 - Absorption of a wave of pressure in a fluid column

Summary:

One tests the fluid paraxial elements of order 1 intended to apply conditions absorbing to the border of a grid finite elements to simulate the infinite one in direct transitory calculations.

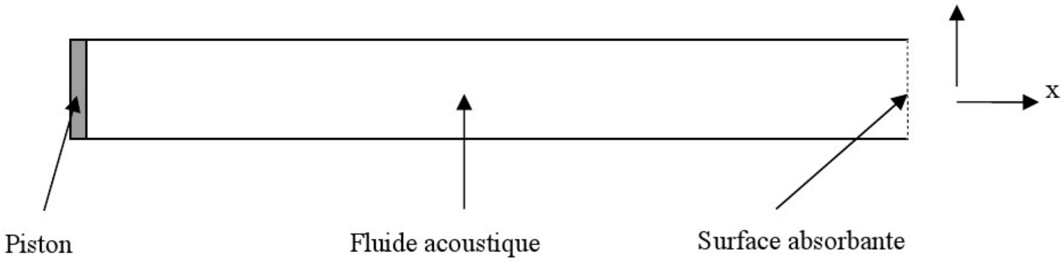
Are used they to model an infinite fluid column, in 3D or 2D, in which one creates a wave of pressure using a piston. One is interested in nonthe reflection of the wave at the "infinite" end of the column.

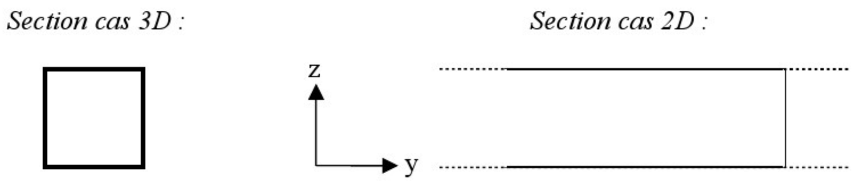
One tests successively the two direct transitory operators of *Code_Aster*, namely DYNA_VIBRA and DYNA_NON_LINE.

1 Problem of reference

1.1 Geometry

The system considered in the case 3D is that of a column of fluid with square section and of of a the same piston section actuated by a movement of rigid body according to the axis of the column. The side surface of the column consists of a motionless rigid guide. One places the elements absorbents on the face opposed to the piston to simulate the infinite character of the column in this direction. In the case 2D, the principle is identical with a very broad supposed column and a piston which one models only one vertical section (see diagram).





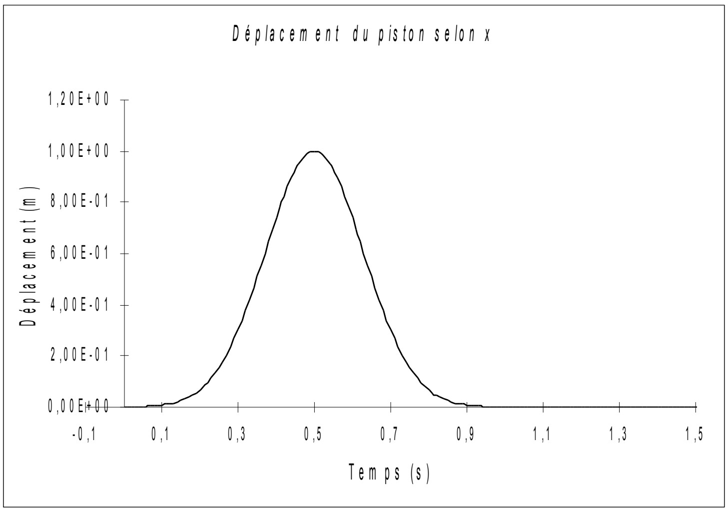
1.2 Properties of materials

Piston: concrete		**Acoustic fluid:** water	
Density:	$2400\,kg.m^{-3}$	Density:	$1000\,kg.m^{-3}$
Young modulus:	$3{,}6.10^{10}\,Pa$	Celerity:	$1500\,m.s^{-1}$
Poisson's ratio:	$0{,}48$		

1.3 Boundary conditions and loadings

One has on side surface of the column the elements fluid-structure which one blocks the degrees of freedom of displacements to zero to reproduce the condition of rigid wall.

One imposes on all the nodes of the face of the piston in contact with the fluid a displacement according to x with the function of following temporal excitation:



1.4 Initial conditions

The displacement of the piston is null at the initial moment and the fluid is at rest.

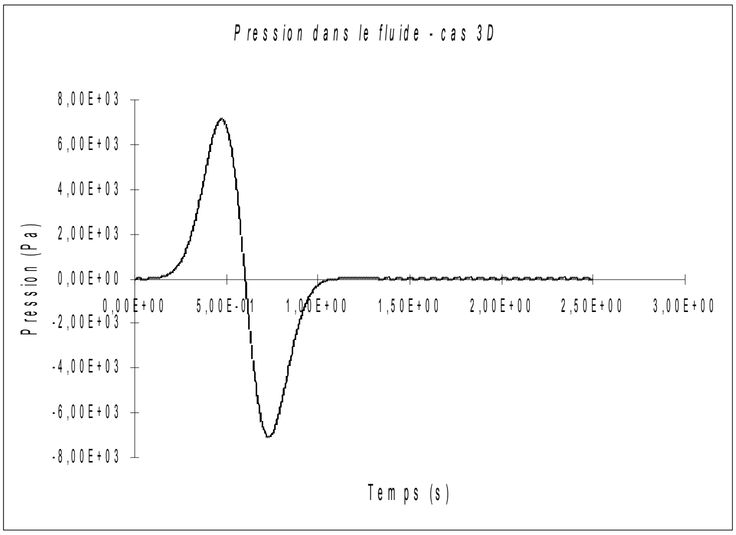
2 Reference solution

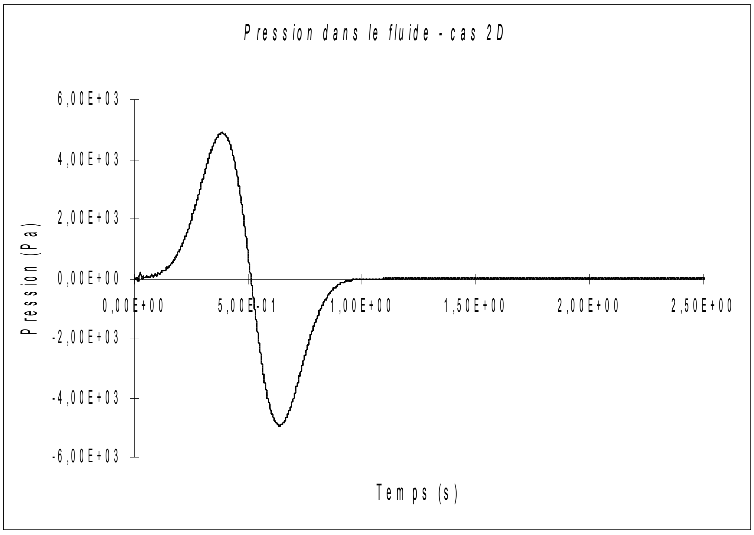
The solution must show the absorption of an acoustic wave by absorbing surface. The movement of the piston is a uniform translation according to the axis of x . Taking into account the symmetry of the problem around this axis, one will obtain an identical field of pressure in all the plans $x=Cte$. Moreover, the absorbing border is orthogonal with this axis. One thus studies the absorption of plane waves of pressure under normal incidence. The theory [bib1] known as that with a fluid paraxial border of order 1, this absorption is perfect. It is what one must check with this reference solution.

One thus goes, by observing the evolution of the pressure in a given point of the grid, to endeavour to find in the signal obtained the duration of excitation and the return at rest after the passage of the wave, characteristic of his absorption.

2.1 Results of reference

One gives in this paragraph the results got with *Code_Aster* in this configuration. It is checked that they are satisfactory and one takes them as reference for the future.
They concern, for the case 3D, the evolution of pressure in a point of the fluid located at $150\,m$ piston in the direction x and in the center of the section in the plan yz. For the case 2D, the point is located at $40\,m$ piston according to x and in the middle of the section in the direction y (in 2D, one takes a shorter and refined grid).





As envisaged, the width of the signal measured in both cases is identical to that of the function of excitation. Physically, one observes well compression due to the projection of the piston, then the depression corresponding to his retreat to return to his initial position. One also clearly notes the return at rest immediately after the passage of the wave and the absence of signal thought of the end of the grid.

2.2 Uncertainties

It is about a digital result of the study. The qualitative forecasts are found. The digital values are related to the precision of calculation. Only the return at rest is clearly given by the analysis.

2.3 Bibliographical references

1. B. ENGQUIST, A. MAJDA "Absorbing boundary conditions for the numerical simulation of waves." Mathematics of Computation (1977).

3 Modeling a: case 3D

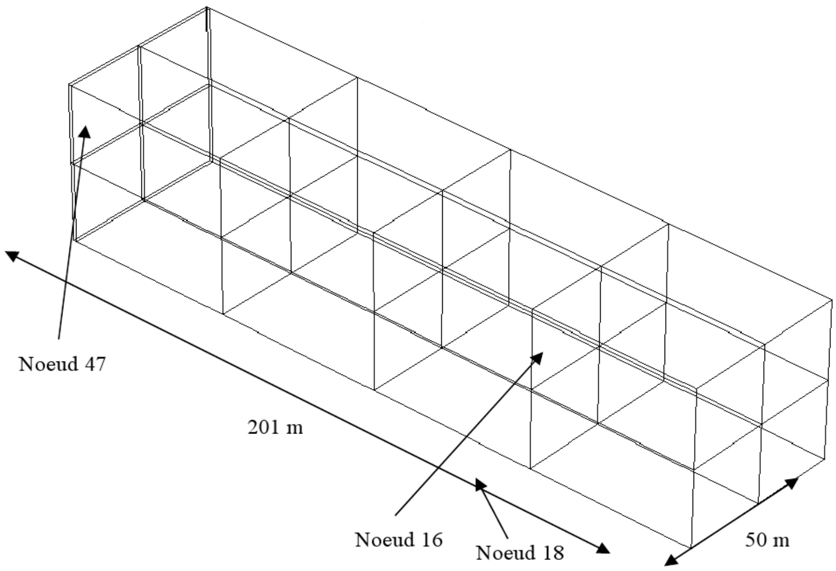
3.1 Characteristics of modeling

Piston: `PHENOMENON: 'MECHANICAL'`
`MODELING: '3D'`

Fluid: `PHENOMENON: 'MECHANICAL'`
`MODELING: '3D_FLUIDE'`

3.2 Characteristics of the grid

Many nodes: 54
Many meshs and types: 20 HEXA8
40 QUA4 (faces of HEXA8)



3.3 Values tested

One tests the values of the pressure to nodes 16.18 and 47 (see grid). For node 16, one tests the two maximum ones (compression and depression) and the return at rest. For nodes 18 and 47, one tests the maximum in compression.

- DYNA_VIBRA :

Node	Moment (s)	Calculation with *Code_Aster* (Pressure in Pa)
$N16$	4.71250D-01	7.13737D+03
	7.27500D-01	– 7.08305D+03
	1.27375D+00	0,182
$N18$	4.71250D-01	7.13737D+03
$N47$	3.72500E-01	7.09321E+03

Energy	Moment (s)	Calculation with *Code_Aster* (Energy in J)
TRAV_EXT	6.0D-01	1.61742D+04
ENER_CIN	6.0D-01	8.70823D+03
ENER_TOT	6.0D-01	1.6432D+03
TRAV_AMOR	6.0D-01	0.0D+00
TRAV_LIAI	6.0D-01	5.82278D+03
DISS_SCH	6.0D-01	3.38028D-04
TRAV_EXT	1.2D+00	2.59604D+04
ENER_CIN	1.2D+00	2.18903D+00
ENER_TOT	1.2D+00	1.35116D-01
TRAV_AMOR	1.2D+00	0.0D+00
TRAV_LIAI	1.2D+00	2.59581D+04
DISS_SCH	1.2D+00	-2.72389D-04

- DYNA_NON_LINE :

Node	Moment (s)	Calculation with *Code_Aster* (Pressure in Pa)
$N16$	4.71000E-01	7.11473E+03
	7.26000E-01	– 7.00022E+03
	1.20000E+00	37.5
$N18$	4.71000E-01	7.11473E+03
$N47$	3.72000E-01	7.08110E+03

Energy	Moment (s)	Calculation with *Code_Aster* (Energy in J)
TRAV_EXT	6.0D-01	1.61 825 D+04
ENER_CIN	6.0D-01	8. 54463 D+03
ENER_TOT	6.0D-01	1.6 5942 D+03
TRAV_AMOR	6.0D-01	0.0D+00
TRAV_LIAI	6.0D-01	5. 97874 D+03
DISS_SCH	6.0D-01	3.3 2745 D-0 1
TRAV_EXT	1.2D+00	2.5 8781 D+04
ENER_CIN	1.2D+00	4.05194 D -01
ENER_TOT	1.2D+00	3 . 14213 D-0 2
TRAV_AMOR	1.2D+00	0.0D+00
TRAV_LIAI	1.2D+00	2.5 8775 D+04
DISS_SCH	1.2D+00	1 . 47130 D-0 1

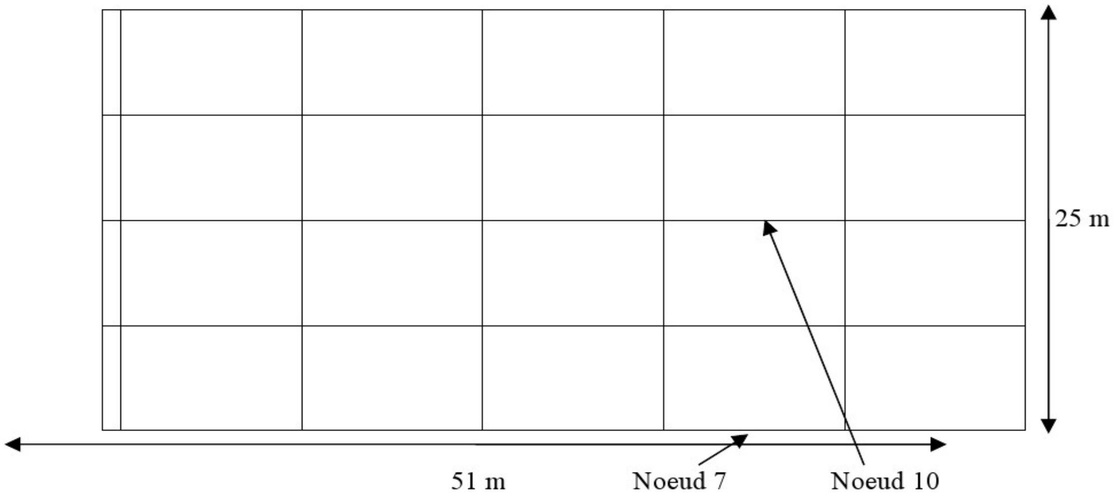
4 Modeling b: case 2D

4.1 Characteristics of modeling

Piston: `PHENOMENON: 'MECHANICAL'`
`MODELING: 'D_PLAN'`

Fluid: `PHENOMENON: 'MECHANICAL'`
`MODELING: '2D_FLUIDE'`

4.2 Characteristics of the grid



Many nodes: 35
Many meshs and types: 24 QUA4
18 SEG2 (faces of QUA4)

4.3 Values tested

One tests the values of the pressure to nodes 7 and 10 (see grid). For node 10, one tests the two maximum ones (compression and depression) and the return at rest. For node 7, one tests the maximum in compression.

- `DYNA_VIBRA`

Node	Moment (s)	Calculation with *Code_Aster* (Pressure in Pa)
$N10$	3.86000E-01	4.88962E+03
	6.37000E-01	– 4.93961E+03
	1.15600E+00	0,434
$N7$	3.86000E-01	4.89074E+03

- `DYNA_NON_LINE` :

Node	Moment (s)	Calculation with *Code_Aster* (Pressure in Pa)
$N10$	3.84000E-01	4.87451E+03

	6.44000E-01	– 4.88583E+03
	1.09400E+00	3.1
$N7$	3.84000E-01	4.88877E+03

5 Summary of the results

One finds by calculation with two modelings qualitatively, the maximum ones of pressure at the good moments and the return at rest after the passage of the wave.

Results got with the operators DYNA_VIBRA and DYNA_NON_LINE are very close. The difference comes from obtaining to each step in time from the state from balance from the efforts from the second member with the operator DYNA_NON_LINE. This difference remains however tiny because the step of time used with DYNA_VIBRA is sufficiently small.