FDLV111 - Absorption of one pressure wave in a fluid column

Abstract:

One tests the fluid paraxial elements of order 1 intended to apply conditions absorbing to the border of a mesh finite elements to simulate the infinite one in direct transient computations.

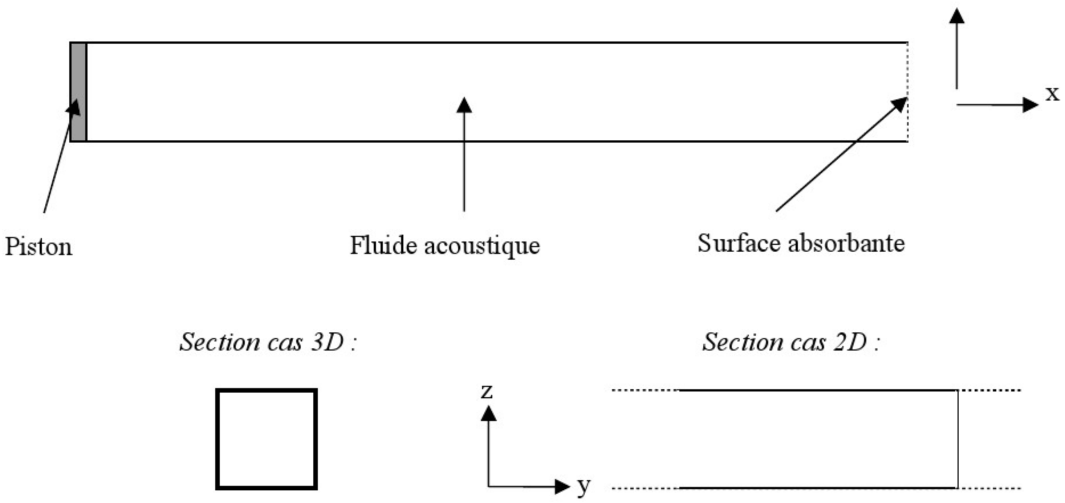
Are used they to model an infinite fluid column, in 3D or 2D, in which one creates one wave of pressure using a piston. One is interested in nonthe reflection of the wave at the “infinite” end of the column.

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 3D case is that of a fluid column with square section and of of a the same piston section actuated by a rigid body motion 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 the materials

Piston: acoustic

Density:	$2400\,kg.m^{-3}$
Young modulus:	$3{,}6.10^{10}\,Pa$
Poisson's ratio:	$0{,}48$

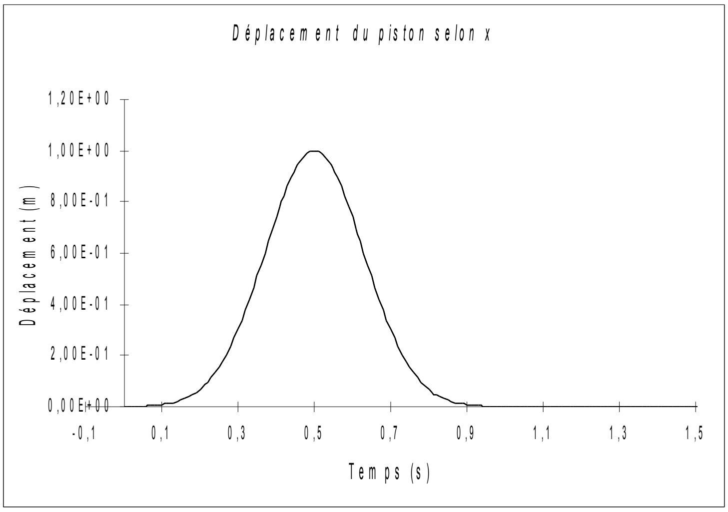
Fluid concrete: water

Density:	$1000\,kg.m^{-3}$
Celerity:	$1500\,m.s^{-1}$

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 following temporal forcing function:



1.4 Initial conditions

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

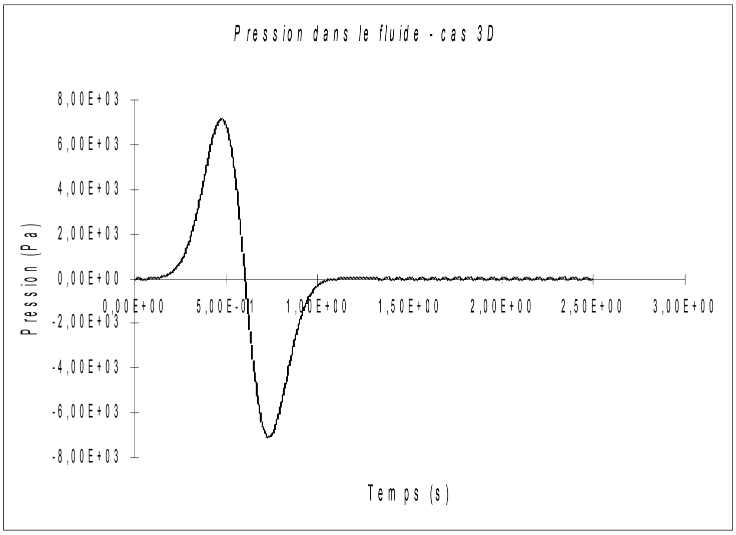
2 Reference solution

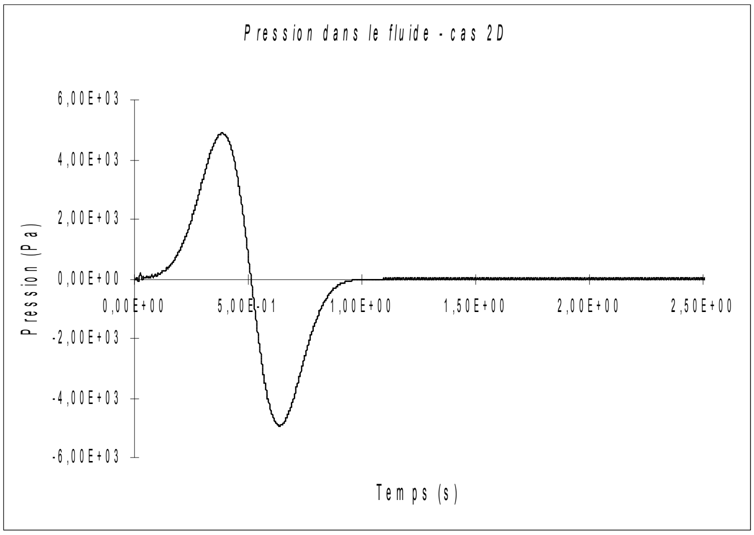
the solution must show the acoustic absorption of one wave by absorbing surface. The motion of the piston is a uniform translation according to the axis Des. x Taking into account the symmetry of the problem around this axis, one will obtain an identical field of pressure in all the planes $x=Cte$. Moreover, 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 mesh, to endeavor to find in the signal obtained the period of excitation and the return at rest after the transition 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 relate to, for 3D case, the evolution of pressure in a point of the fluid located at $150\,m$ piston in the direction x and the center of the section in the plane 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 mesh).





As envisaged, the width of the signal measured in both cases is identical to that of the forcing function. 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 transition of the wave and the absence of signal thought of the end of the mesh.

2.2 Uncertainties

It is about result of the numerical study. The qualitative forecasts are found. The numerical values are related to the accuracy of computation. 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 Modelization a: 3D case

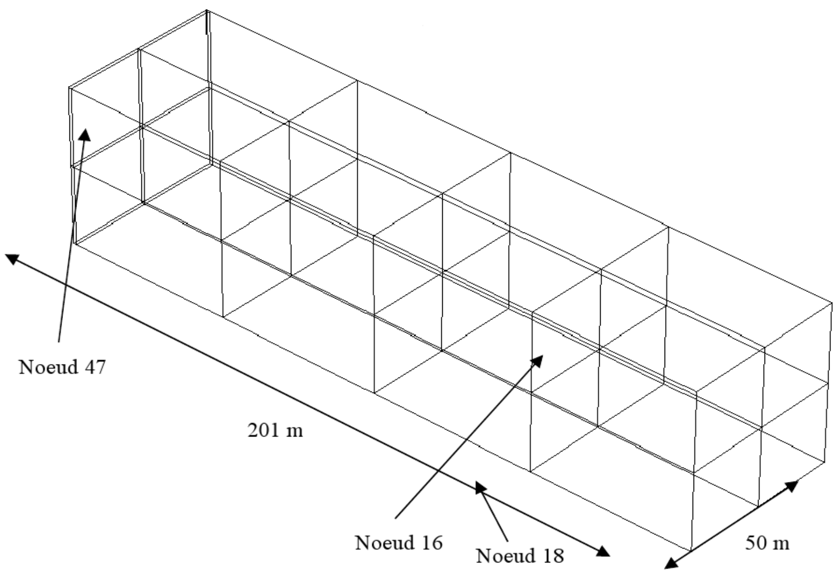
3.1 Characteristic of the modelization

Piston: `PHENOMENE: "MECHANICAL"`
`MODELISATION: "3D"`

Fluid: `PHENOMENE: "MECHANICAL"`
`MODELISATION: "3D_FLUIDE"`

3.2 Characteristics of the mesh

Many nodes: 54
Number of meshes and types: 20 HEXA8
40 QUA4 (sides of HEXA8)



3.3 Values tested

One test the values of the pressure to nodes 16,18 and 47 (see mesh). 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 :

Urgent	node (s)	Computation 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	Time (s)	Computation 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:

Urgen t	node (s)	Computation 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	Time (s)	Computation 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

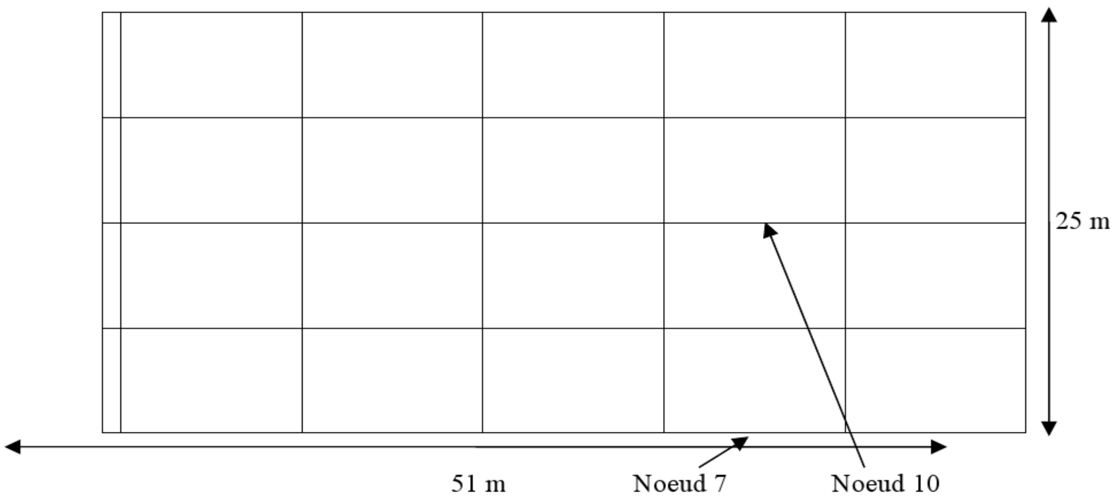
4 Modelization b: cases 2D

4.1 Characteristic of the modelization

Piston: PHENOMENE: "MECHANICAL"
MODELISATION: "D_PLAN"

Fluid: PHENOMENE: "MECHANICAL"
MODELISATION: "2D_FLUIDE"

4.2 Characteristics of the mesh



Many nodes: 35
Number of meshes and types: 24 QUA4
18 SEG2 (sides of QUA4)

4.3 Values tested

One test the values of the pressure to nodes 7 and 10 (see mesh). 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

Urgent	Node (s)	Computation 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 :

Urgent	node (s)	Computation 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 computation with the two modelizations qualitatively, the maximum ones of pressure at good times and the return at rest after the transition of the wave.

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