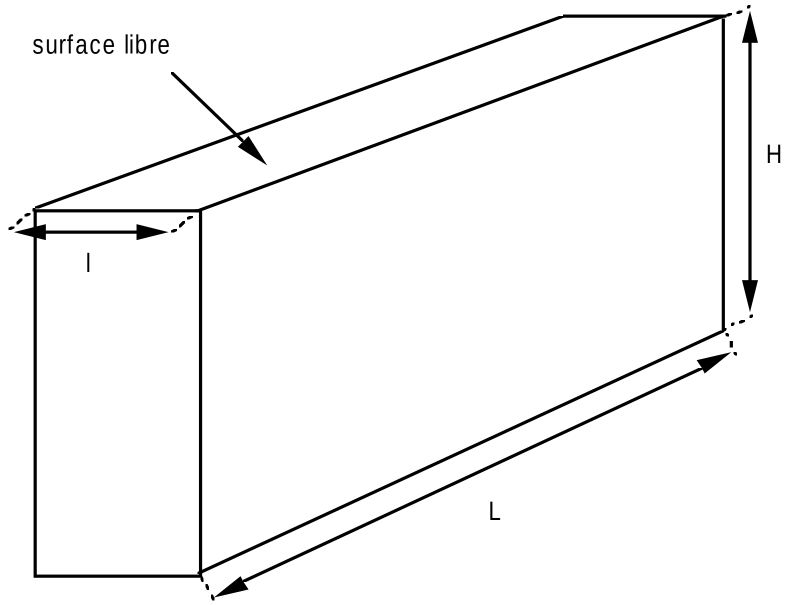
ADLV101 - Modes of shaking of a tank filled with water

Summarized:

This test, of the acoustic and fluid field, relates to the search of the eigenfrequencies of a rectangular tank filled with a fluid including a free surface. The modal analysis thus determines the first modes of shaking of the surface of the fluid filling the tank. The first three eigenfrequencies are found with less than 1% of the analytically calculated frequencies.

1 Problem of reference

1.1 Geometry



dimensions of the tank:

height: $H=0.3\,m$

length: $L=0.8\,m$

width: $l=0.1\,m$

1.2 Properties of the materials

the modelled material is the fluid contained in the tank:

density: $\rho_c=1000\,kg/m^3$

speed of sound: $c=1400\,m/s$

1.3 Boundary conditions and loading

One imposes the gravity field on the group of the fluid model

```
charges = AFFE_CHAR_MECA       ( …
                          PESANTEUR = (9.81, 0. , 0. , - 1.));
```

2 Reference solution

2.1 Method of calculating used for the reference solution

the reference [bib3] provides the general formula of the modes of shaking in a parallelepipedic tank:

$$f_{ij}=\frac{1}{2\pi}\sqrt{\pi g\sqrt{\frac{i^2}{L^2}+\frac{j^2}{l^2}}th\left[\pi H\sqrt{\frac{i^2}{L^2}+\frac{j^2}{l^2}}\right]}$$

where i and j are the orders of the longitudinal and transverse modes (many nodal lines in each direction).

In the typical case or $-\frac{L}{l}$ is large, the formula is simplified for the longitudinal modes [bib1], [bib2].

2.2 Results of reference

For $\frac{L}{l}=8.$ and the $h=0.3$ first four modes are with frequencies 0.898,1.384,1.709 and 1.975.

2.3 Bibliographical references

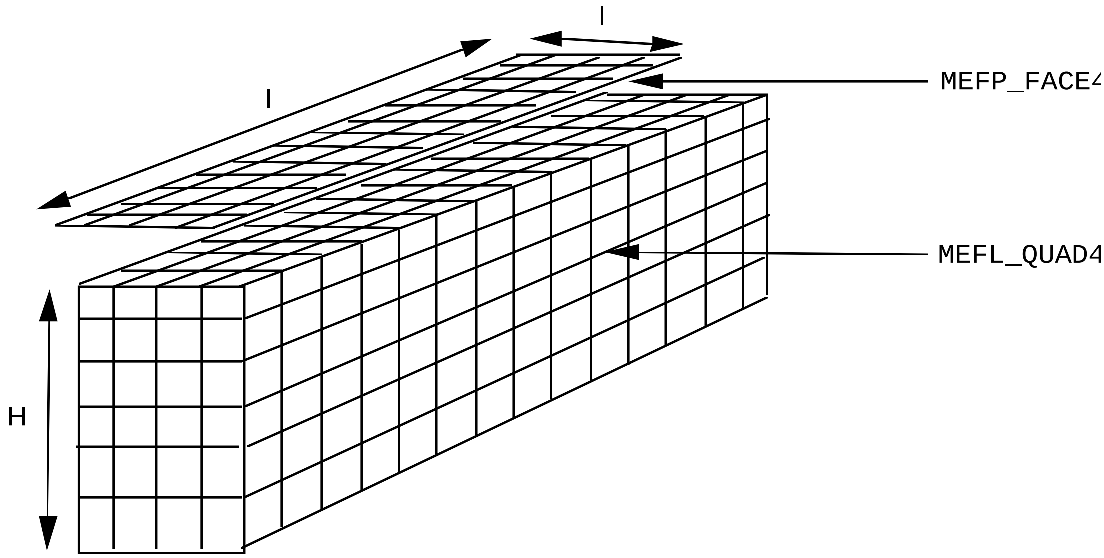
1) WAECKEL F., internal LEPOUTERE C. Note EDF/DER “Effect of gravity on the free face of a fluid coupled to a structure”, HP-61/93/139.

2) MUTO, KASA, NAKAHARA, Experimental ISHIDA “tests one sloshing response of has toilets pool with submerged blocks” - ASME, flight PVP 98, (1985).

3) BLEVINS R.D. Formulated for natural frequency and shape mode. ED Krieger

3 Modelization A

3.1 Characteristic of the modelization



the free face is modelled by 57 elements MEFP_FACE4 (modelization 2D_FLUI_PESA) quadrangle with 4 nodes,
fluid volume is modelled by 513 fluid elements (modelization 3D_FLUIDE) cubic with 8 nodes.

3.2 Characteristics of the mesh

The mesh contains: 513 HEXA8
57 QUAD4

3.3 Values tested

Identification	Reference
mode1	8.98250e-01
mode 2	1.38452e+00
mode 3	1.70952e+00
mode 4	1.97551e+00

4 Modelization B

4.1 Characteristic of the modelization

This modelization differ from the modelization A only by the free type of surface element and the type of element from fluid:

the free face is modelled by 57 elements `MEFP_FACE8` (modelization `2D_FLUI_PESA`) quadrangle with 8 nodes,
fluid volume is modelled by 513 fluid elements (modelization `3D_FLUIDE`) cubic with 20 nodes.

4.2 Characteristics of the mesh

the mesh contains: 513 HEXA20
57 QUAD8

4.3 Values tested

Identification	Reference
mode1	8.98250e-01
mode 2	1.38452e+00
mode 3	1.70952e+00
mode 4	1.97551e+00

5 Modelization C

5.1 Characteristic of the modelization

This modelization differ from the modelization A only by the free type of surface element and the type of element from fluid:

the free face is modelled by 57 elements `MEFP_FACE9` (modelization `2D_FLUI_PESA`) quadrangle with 9 nodes,
fluid volume is modelled by 513 fluid elements (modelization `3D_FLUIDE`) cubic with 27 nodes.

5.2 Characteristics of the mesh

the mesh contains: 513 HEXA27
57 QUAD9

5.3 Values tested

Identification	Reference
mode1	8.98250e-01
mode 2	1.38452e+00
mode 3	1.70952e+00
mode 4	1.97551e+00

6 Modelization D

6.1 Characteristic of the modelization

This modelization differ from the modelization A by the type of element used. Each mesh of the modelization A is cut into two by a vertical plane.

the free face is modelled by 114 elements `MEFP_FACE3` (modelization `2D_FLUI_PESA`) triangle with 3 nodes,
fluid volume is modelled by 1026 fluid elements (modelization `3D_FLUIDE`) pentaedric with 6 nodes.

6.2 Characteristics of the mesh

the mesh contains: 1026 PENTA6
114 TRIA3

6.3 Values tested

Identification	Reference
mode 1	8.98250e-01
mode 2	1.38452e+00
mode 3	1.70952e+00
mode 4	1.97551e+00

7 Modelization E

7.1 Characteristic of the modelization

This modelization differ from the modelization B by the type of element used. Each mesh of the modelization B is cut by a vertical plane.

the free face is modelled by 114 elements MEFP_FACE6 (modelization 2D_FLUI_PESA) triangle with 6 nodes,
fluid volume is modelled by 1026 fluid elements (modelization 3D_FLUIDE) pentaedric with 15 nodes.

7.2 Characteristics of the mesh

the mesh contains: 1026 PENTA15
114 TRIA6

7.3 Values tested

Identification	Reference
mode 1	8.98250e-01
mode 2	1.38452e+00
mode 3	1.70952e+00
mode 4	1.97551e+00

8 Summary of the results

The modelization A implement fluid elements of the Hexa8 TYPE and surface elements free of quad4 TYPE. Result obtained reveals a maximum error of 1.52% compared to the analytical solution.

The modelization B utilized fluid elements of the Hexa20 TYPE and surface elements free of quad8 TYPE. The results correlate perfectly with the analytical solution.

Elements fluid of the Hexa27 TYPE and fluid weighing of Quad9 TYPE are used for the modelization C. the got results are identical to the reference solution.

The modelization D allows to validate elements fluid of the Penta6 TYPE and surface elements free of Tria3 TYPE. The got results reveal a relative error of 1.479% compared to the reference solution.

The modelization E allows to validate the surface elements free of Tria6 TYPE. They are connected to fluid elements of the Penta15 TYPE. There is perfect coincidence of the results with the analytical solution.

Generally, it is observed that the results got by elements with quadratic interpolation (HEXA20, HEXA27) are in excellent agreement with the analytical results. Nevertheless the elements with linear interpolation have an acceptable accuracy on the results.