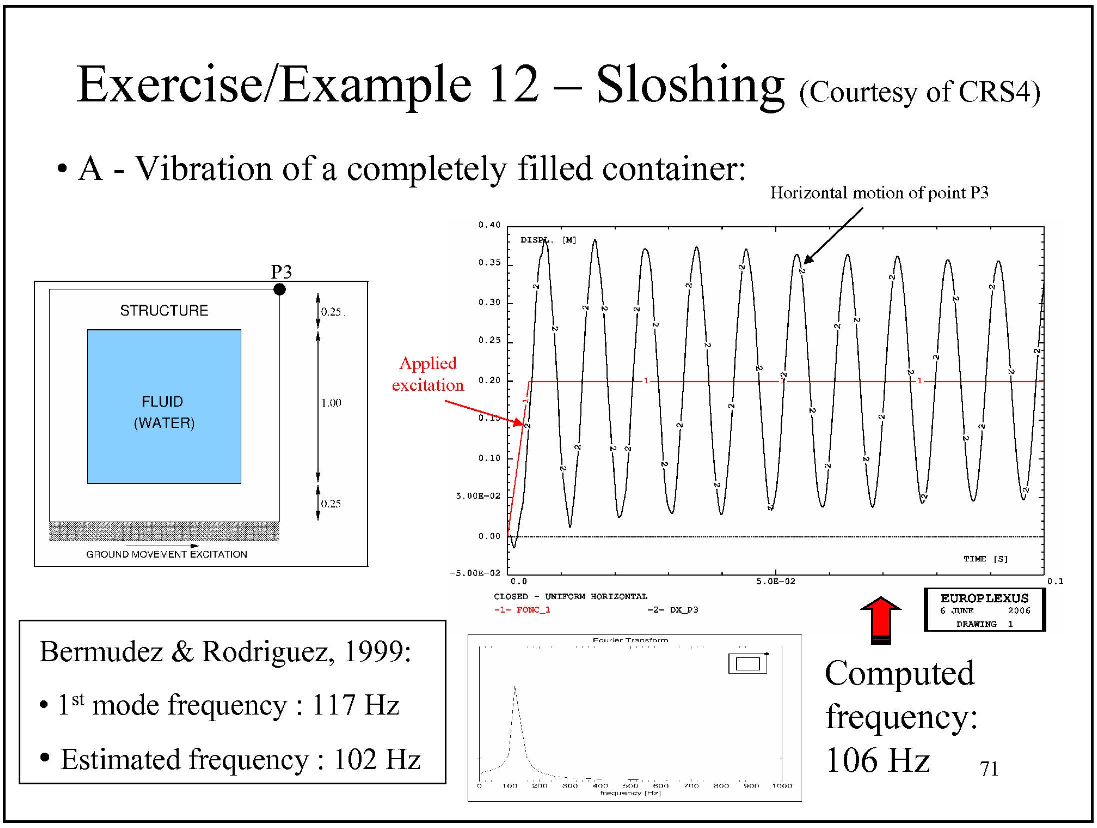


PROBLEM:
A deformable tank completely filled with a liquid is accelerated by a linear ramp-like excitation in the horizontal direction applied to the base.

MESH:
The fluid is meshed by CAR1 elements, the deformable tank also by CAR1 elements. The calculation is plane strain (DPLA) and is declared of the NAVI type. In this way, incompressibility is automatically enforced for all CAR1 elements that are associated with a LIQU material (the fluid mesh, in this case).

MATERIALS:
The fluid is modelled by the LIQU material (density 1000), while the tank uses a linear elastic material (LINE).

BOUNDARY CONDITIONS:
The motion of the tank base is imposed in the horizontal direction. FSA fluid-structure interaction is used along the whole fluid-structure interface.

LOADING:
An imposed horizontal displacement with a ramp-like shape (20 cm in 4 ms) is imposed at the tank base.

CALCULATION:
The calculation is performed up to a final time of 100 ms. The NAVI condition would allow a very large stability step in the fluid elements, but in this case the integration step is dictated by the structural part.

RESULTS:
A paper by Bermudez and Rodriguez (1999) predicts a 1st mode oscillation frequency of 117 Hz according to a linearized theory, and an estimated frequency of 102 Hz. The numerically computed frequency is 106 Hz, in good agreement with the estimation.

POST-TREATMENT
Animations are produced.

<u>Numerical Solution</u>

CLOSED4

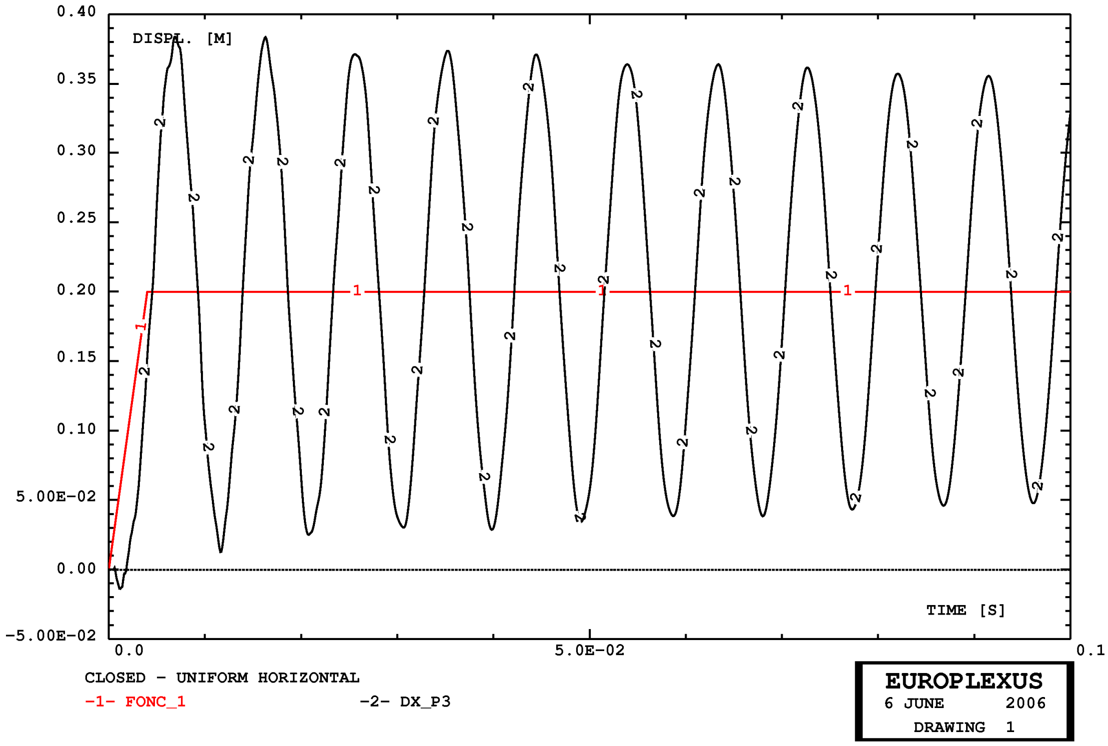
The Cast3m mesh generation file reads:

```
*%siz 200
*
opti echo 1;
opti titr 'CLOSE - D4';
*
opti trac psc ftra 'closed4_mesh.ps';
*
opti dime 2 elem qua4;
p1 = 0.00 0.00;
p2 = 1.50 0.00;
p3 = 1.50 1.50;
p4 = 0.00 1.50;
p5 = 0.00 0.25;
p6 = 1.50 0.25;
p7 = 0.00 1.25;
p8 = 1.50 1.25;
p9 = 0.25 0.25;
p10= 1.25 0.25;
p11= 1.25 1.25;
p12= 0.25 1.25;
*
p9f = p9 plus (0 0);
p10f = p10 plus (0 0);
p11f = p11 plus (0 0);
p12f = p12 plus (0 0);
*
fl1 = p9f d 16 p10f;
fl2 = p10f d 16 p11f;
fl3 = p11f d 16 p12f;
fl4 = p12f d 16 p9f;
flmesh = dall fl1 fl2 fl3 fl4 plan;
*
tol=0.001;
*
sel1 = p1 d 24 p2;
s2 = p2 d 4 p6;
s3 = p6 d 4 p10 d 16 p9 d 4 p5;
s4 = p5 d 4 p1;
stmesh1 = dall sel1 s2 s3 s4 plan;
*
s1 = p3 d 24 p4;
s2 = p4 d 4 p7;
s3 = p7 d 4 p12 d 16 p11 d 4 p8;
s4 = p8 d 4 p3;
stmesh2 = dall s1 s2 s3 s4 plan;
*
s1 = p10 d 4 p6;
s2 = p6 d 16 p8;
s3 = p8 d 4 p11;
s4 = p11 d 16 p10;
stmesh3 = dall s1 s2 s3 s4 plan;
*
s1 = p5 d 4 p9;
s2 = p9 d 16 p12;
s3 = p12 d 4 p7;
s4 = p7 d 16 p5;
stmesh4 = dall s1 s2 s3 s4 plan;
*
stmesh = stmesh1 et stmesh2 et stmesh3 et stmesh4;
elim tol stmesh;
*
* obstacles
*
op1 = 0.00 0.25;
op2 = -0.10 0.30;
op3 = -0.10 0.20;
ob1 = manu tri3 op1 op2 op3;
op4 = 1.70 0.25;
op5 = 1.80 0.20;
op6 = 1.80 0.30;
ob2 = manu tri3 op4 op5 op6;
*
mesh = flmesh et stmesh et ob1 et ob2;
*
tass mesh;
*
opti sauv form 'closed4.msh';
sauv form mesh;
*
trac mesh;
trac qual mesh;
*
opti donn 5;
```

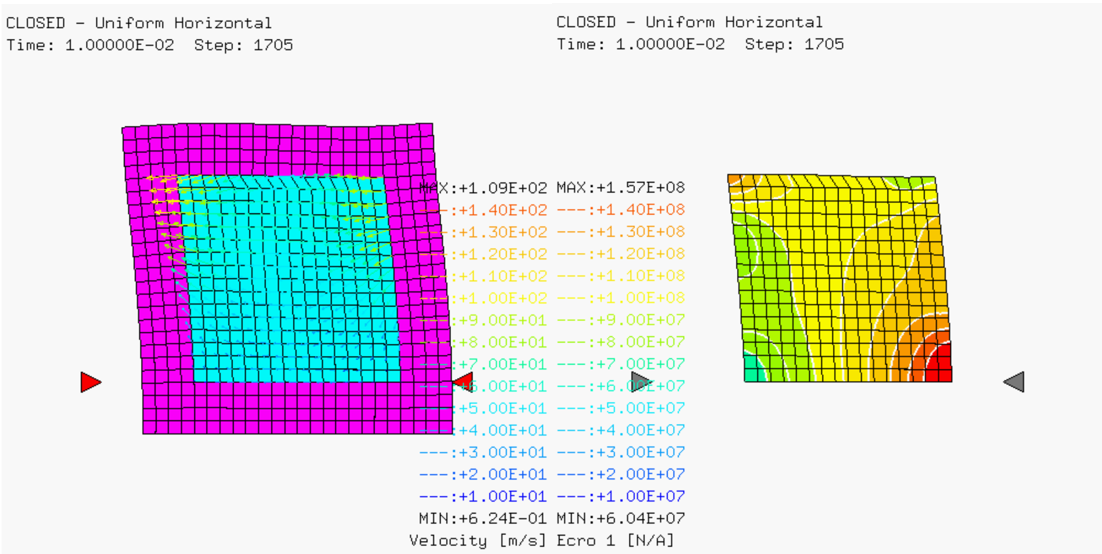
The EUROPLEXUS input file reads:

```
CLOSED - Uniform Horizontal
ECHO
!CONV win
DPLA NONL NAVI ALE
CAST MESH
DIME
 PT2L 695 CAR1 576 TRIA 2 ZONE 3
 NALE 25 NBLE 1
 FSA  68 IFSA 240
 TABL 1 3
 NDVC 900
 DEPL 25
 BLOQ 25
TERM
GEOM CAR1 FLMESH CAR1 STMESH TRIA OB1 OB2 TERM
COMP COUL TURQ LECT FLMESH TERM
          ROSE LECT STMESH TERM
          ROUG LECT OB1 OB2 TERM
GRIL LAGR LECT STMESH OB1 OB2 TERM
     ALE  LECT FLMESH TERM
     MEAN NOEU LECT FLMESH TERM
MATE LINE RO 7700. YOUNG 144.E9 NU 0.35
          LECT STMESH TERM
     LIQU RO 1000.
          LECT FLMESH TERM
     FANT 1.0 LECT OB1 OB2 TERM
LIAI BLOQ 2 LECT SEL1 TERM
     FSA  LECT FL1 FL2 FL3 FL4 TERM
CHAR 1 FACT 2 DEPL 1 0.20
       LECT SEL1 TERM
       TABL 3 0.0 0.0 0.0040 1.0 2.0 1.0
ECRI DEPL ECRO TFRE 0.005
     FICH ALIC TFRE 0.0001
OPTI NOTE CSTA 0.5
 LOG 100
CALC TINI 0 TEND 0.10 NMAX 10000000
FIN
```

The applied displacement and the computed oscillation of point P3 are presented below:

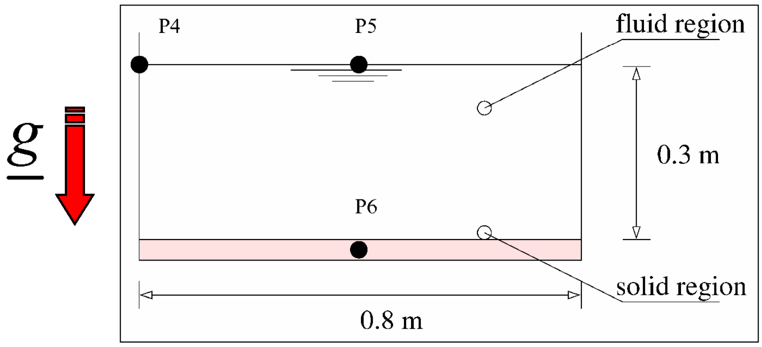


The final distribution of velocity and pressure in the fluid are shown below:



Exercise/Example 12 – Sloshing (3) (Courtesy of CRS4)

- B - Vibration of a partially filled container:



- Excitation : gravity starting at initial time

73

PROBLEM:
A rigid tank with a deformable bottom is partially filled with a liquid. At the initial time, gravity is applied and we want to compute the oscillations of the tank bottom and the sloshing waves produced at the liquid free surface.
MESH:
The fluid is meshed by CAR1 elements, the flexible tank bottom by ED01 elements. The calculation is plane strain (DPLA) and is declared of the NAVI type. In this way, incompressibility is automatically enforced for all CAR1 elements that are associated with a LIQU material (the fluid mesh, in this case).
MATERIALS:
The fluid is modelled by the LIQU material (density 1000), while the tank uses a linear elastic material (VM23).
BOUNDARY CONDITIONS:
FSA fluid-structure interaction is used along the fluid-structure interface between the liquid and the tank bottom. SLIP is prescribed along the free fluid surface.
LOADING:
Gravity starts to act at the initial time.
CALCULATION:
The calculation is performed up to a final time of 2 s. The NAVI condition would allow a very large stability step in the fluid elements, but in this case the integration step is dictated by the deformable structural part (tank bottom).
RESULTS:
Linear theory predicts a 1st symmetric sloshing mode with a frequency of 1.41 Hz for a <u>rigid</u> tank. All monitored points (P4, P5, P6) show a numerically computed harmonic component at 11.7 Hz (driven by the flexible bottom oscillations). In addition, surface points (P4, P5) also exhibit a lower harmonic component at 1.3 Hz.

This result is in good agreement with the linear theory, if one cosiders that a <u>flexible</u> bottom is expected to somewhat reduce the value of the first sloshing frequency.

POST-TREATMENT

Animations are produced.

<u>Numerical Solution</u>

GRAV05

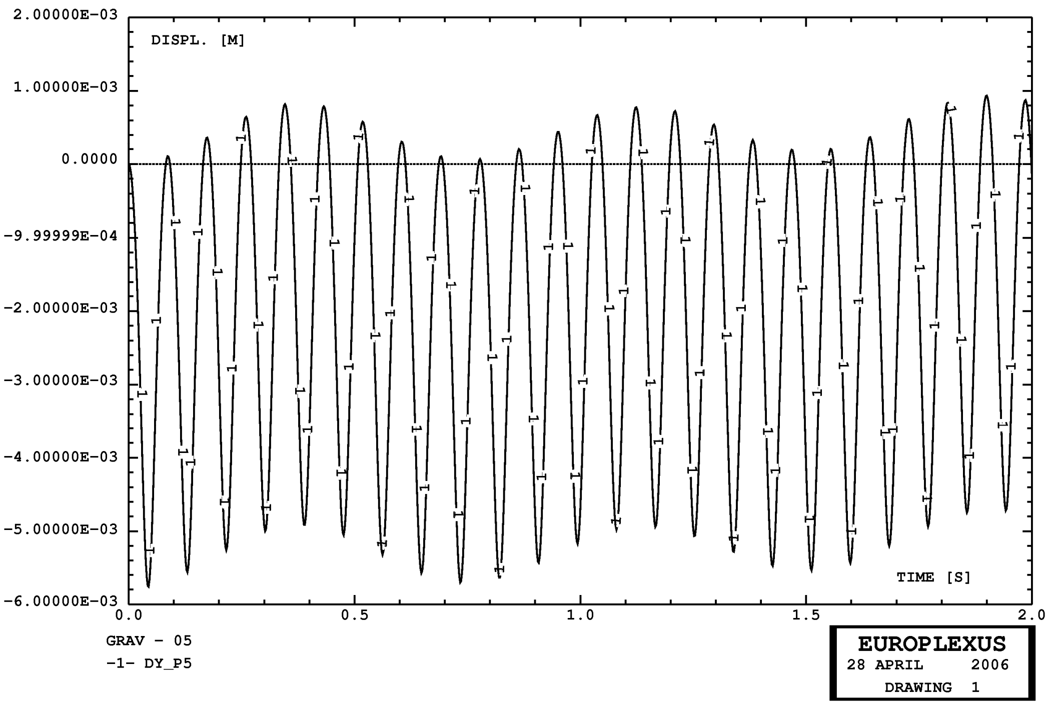
The Cast3m mesh generation file reads:

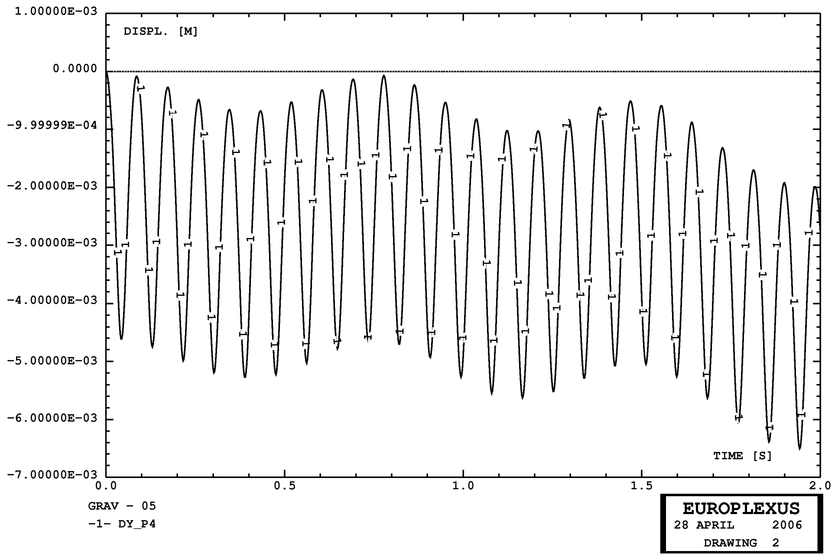
```
*%siz 200
*
opti echo 1;
opti donn 'D:\Users\Folco\Plexis3c\Proc\Pxordpoi.proc';
opti titr 'GRAV - 05';
*
opti trac psc ftra 'grav05_mesh.ps';
*
opti dime 2 elem qua4;
p1 = 0.00 0.00;
p2 = 0.80 0.00;
p3 = 0.80 0.30;
p4 = 0.00 0.30;
p5 = 0.40 0.30;
p6 = 0.40 0.00;
*
p1s = p1 plus (0 0);
p2s = p2 plus (0 0);
*
fl1 = p1 d 5 p6 d 5 p2;
fl2 = p2 d 4 p3;
fl3 = p3 d 5 p5 d 5 p4;
fl4 = p4 d 4 p1;
flmesh = dall fl1 fl2 fl3 fl4 plan;
*
tol=0.001;
*
stmesh = p1s d 10 p2s;
*
* obstacles
*
op1 = 0.00 -0.05;
op2 = 0.00 0.40;
ob1 = manu seg2 op1 op2;
op4 = 0.80 -0.05;
op5 = 0.80 0.40;
ob2 = manu seg2 op4 op5;
*
pfl3 = chan 'POI1' fl3;
surf = pxordpoi pfl3 p3;
*
mesh = flmesh et stmesh et ob1 et ob2 et surf;
*
tass mesh;
*
opti sauv form 'grav05.msh';
sauv form mesh;
*
trac mesh;
trac qual mesh;
*
opti donn 5;
```

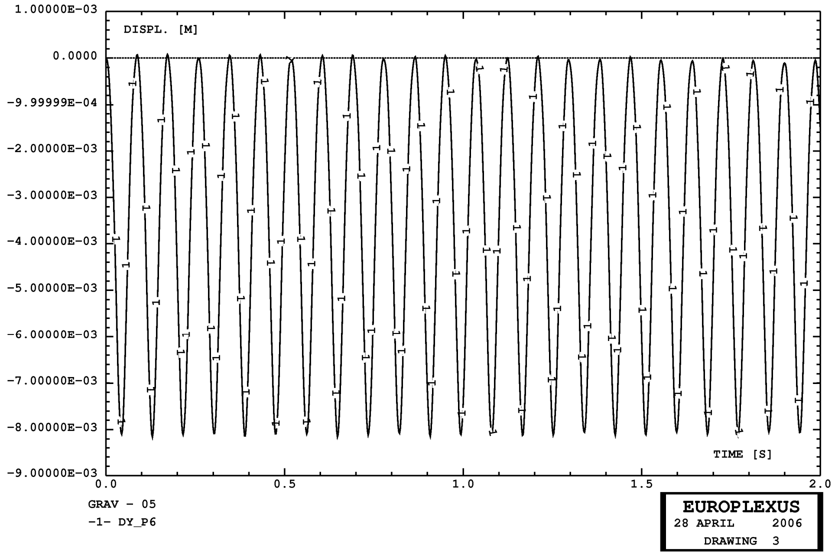
The EUROPLEXUS input file reads:

```
GRAV - 05
ECHO
!CONV win
DPLA NONL NAVI ALE
CAST MESH
DIME
 PT2L 55 PT3L 15 CAR1 40 ED01 12 ZONE 2
 NALE 4 NBLE 1
 FSA  13 IFSA 36
 NDVC 157
 BLOQ 14
 SLPC 1
 SLPN 11
TERM
GEOM CAR1 flmesh ED01 stmesh ob1 ob2 TERM
COMP EPAI 0.005 LECT stmesh  TERM
          1.0   LECT ob1 ob2 TERM
     COUL TURQ LECT flmesh TERM
          ROSE LECT stmesh TERM
          ROUG LECT ob1 ob2 TERM
GRIL LAGR LECT stmesh surf ob1 ob2 TERM
     EULE LECT fl1 TERM
     ALE  LECT flmesh TERM
     SLIP EQUI LECT surf TERM
     MEAN AUTR
MATE VM23 RO 2700. YOUNG 70.E9 NU 0.30 ELAS 70.E9
          TRAC 1 70.E9 1.E0
          LECT stmesh TERM
     LIQU RO 1000.
          LECT flmesh TERM
     FANT 1.0 LECT ob1 ob2 TERM
LIAI BLOQ 2 LECT p1s p2s ob1 ob2 TERM
     BLOQ 1 LECT p1s p2s fl2 fl4 TERM
     FSA  LECT fl1 TERM
CHAR CONST GRAV 0.0 -9.81
ECRI DEPL ECRO TFRE 0.02
     FICH ALIC TFRE 0.002
OPTI NOTE CSTA 0.5
 LOG 100
CALC TINI 0 TEND 2.0 NMAX 10000000
FIN
```

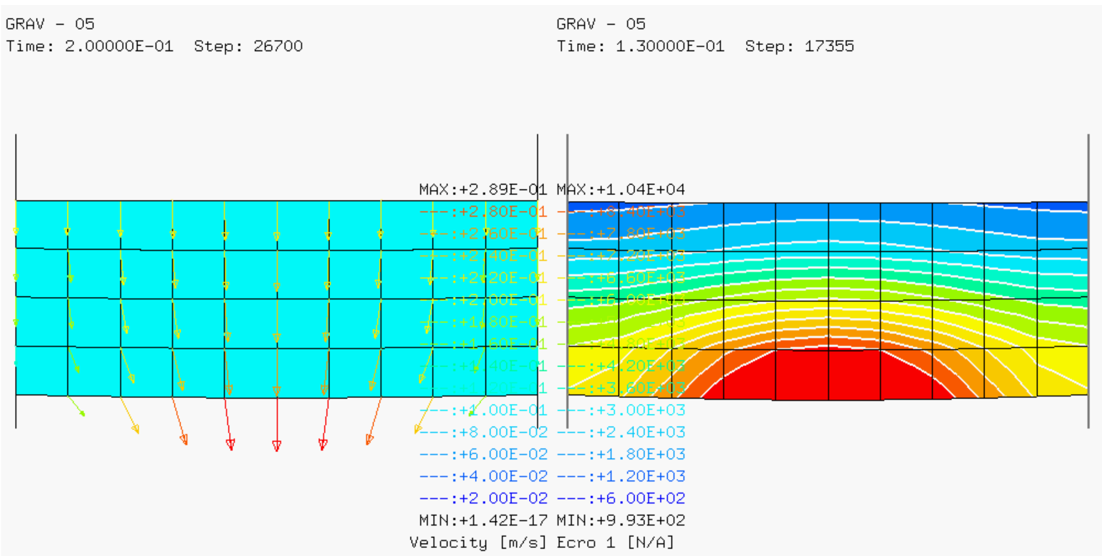
The vertical motions of points P5, p4 and P6 are presented below:





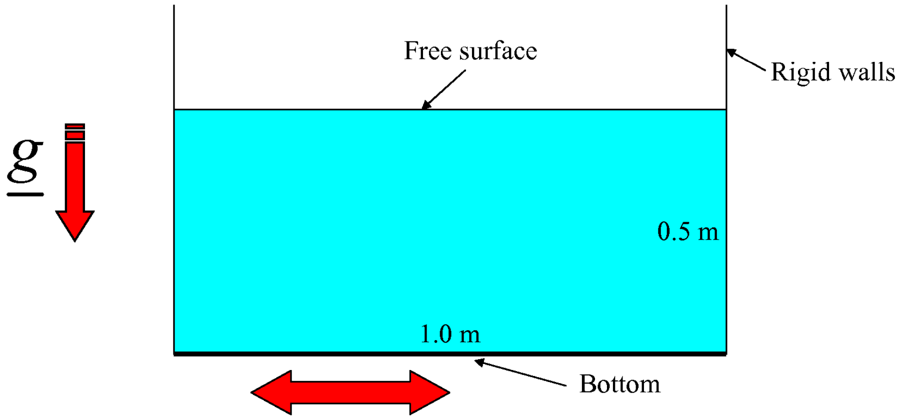


The velocity at 200 ms and the fluid pressure at 130 ms are presented below:



Exercise/Example 12 – Sloshing (7) (Courtesy of CRS4)

- C - Vibration of a partially filled container:



- Excitation : imposed harmonic horizontal displacement
- Container bottom may be either rigid or flexible

77

PROBLEM:
A rigid tank with rigid or deformable bottom and partially filled with a liquid is subjected to gravity and accelerated by a harmonic excitation in the horizontal direction applied to the base.
MESH:
The fluid is meshed by CAR1 elements, the tank by COQU elements. The calculation is plane strain (DPLA) and is declared of the NAVI type. In this way, incompressibility is automatically enforced for all CAR1 elements that are associated with a LIQU material (the fluid mesh, in this case).
MATERIALS:
The fluid is modelled by the LIQU material (density 1000), while the tank uses a linear elastic material (LINE).
BOUNDARY CONDITIONS:
The motion of the tank base is imposed in the horizontal direction. FSA fluid-structure interaction is used along the whole fluid-structure interface. SLIP sliding conditions are prescribed along the free fluid surface.
LOADING:
An imposed horizontal displacement with a harmonic shape (9.3 mm aplitude) is imposed at the tank base. This imposed displacement starts at t = 1 s. Gravity acts on the system starting at t = 0. The initial 1 s of the calculation is used to let the code compute a reasonable initial distribution of pressure and deformation (in the elastic bottom case) before starting the forced oscillations.
The chosen frequency for the imposed displacement is 5.311 Hz, which is very close to the first sloshing frequency of the completely rigid tank predicted by the linear theory (5.316 Hz)
CALCULATION:

The calculation is performed up to a final time of 6 s. The NAVI condition would allow a very large stability step in the fluid elements, but in the case with flexible bottom the integration step is dictated by the structural part.

RESULTS:

Sloshing is computed for the rigid and flexible bottom cases..

POST-TREATMENT

Animations are produced.

<u>Numerical Solution (rigid bottom)</u>

TANK6R

The EUROPLEXUS input file reads:

```
TANK - 5mm Uniform Horizontal
$
$ FONDO RIGIDO, TABELLA DETTAGLIATA,
$ AMPIEZZA DI OSCILLAZIONE 9.3mm
$
 ECHO
!CONV win
$ 2D Plane Strain + NonLinear + ALE
 DPLA NONL NAVI ALE
$
DIME
 PT2L 256
 PT3L 4
 CAR1 200
 COQU 30
 TRIA 2
 ED01 2
$obsolete:    MATE 20
 NALE 100 NBLE 500
 FSA  100 IFSA 500
 SLPN 200
 SLPC 100
 NDVC 400
 TABL 200 200
 MTPO 200
 BLOQ 100
 DDLI 100
 FCOE 100
 FNOM 10
 FTAB 800
 FORC 24
 ZONE 10
TERM
$
GEOM LIBR POIN 157 CAR1 100 COQU 20 TRIA 2 ED01 2 TERM
$
$ 1
0.00 0.00
 . . . (skip for brevity)

$
COMP EPAI 0.005 LECT 101 102 103 104 105
                     106 107 108 109 110
                     111 112 113 114 115
                     116 117 118 119 120 TERM
          1.0   LECT 123 124 TERM
$
GRIL LAGR LECT 127 128 129 130 131
               132 133 134 135 136
               137 138 139 140 141
               142 143 144 145 146 147
                   107 108 109 110
               111 112 113 114 115
               116 117 118 119 120
               121 122 123 124 125
               1  21 106 126
               148 PAS 1 157
               TERM
$
     ALE  LECT 1  2  3  4  5  6  7  8  9  10
               11 12 13 14 15 16 17 18 19 20
               21 22 23 24 25 26 27 28 29 30
               31 32 33 34 35 36 37 38 39 40
               41 42 43 44 45 46 47 48 49 50
               51 52 53 54 55 56 57 58 59 60
               61 62 63 64 65 66 67 68 69 70
               71 72 73 74 75 76 77 78 79 80
               81 82 83 84 85 86 87 88 89 90
               91 92 93 94 95 96 97 98 99 100 TERM
$
     SLIP EQUI LECT 126 125 124 123 122 121
                    120 119 118 117 116
                    115 114 113 112 111
                    110 109 108 107 106 TERM
$
     SLIP EQUI LECT 1   22  43  64  85  106 TERM
     SLIP EQUI LECT 21  42  63  84  105 126 TERM
$
     MEAN NOEU LECT 23 24 25 26 27 28 29 30 31 32
                    33 34 35 36 37 38 39 40 41
                    44 45 46 47 48 49 50 51 52 53
                    54 55 56 57 58 59 60 61 62
                    65 66 67 68 69 70 71 72 73 74
                    75 76 77 78 79 80 81 82 83
                    86 87 88 89 90 91 92 93 94 95
                    96 97 98 99 100 101 102 103 104
                    TERM
$
MATE LINE RO 7800. YOUNG 200.E9 NU 0.3
          LECT 101 102 103 104 105
               106 107 108 109 110
               111 112 113 114 115
               116 117 118 119 120 TERM
$
     LIQU RO 1000.
          LECT 1  2  3  4  5  6  7  8  9  10
               11 12 13 14 15 16 17 18 19 20
               21 22 23 24 25 26 27 28 29 30
               31 32 33 34 35 36 37 38 39 40
               41 42 43 44 45 46 47 48 49 50
               51 52 53 54 55 56 57 58 59 60
               61 62 63 64 65 66 67 68 69 70
               71 72 73 74 75 76 77 78 79 80
               81 82 83 84 85 86 87 88 89 90
               91 92 93 94 95 96 97 98 99 100 TERM
     FANT 1.0 LECT 121 PAS 1 124 TERM
$
LIAI FREQ 1
     BLOQ 2 LECT 1 21 127 PAS 1 147
                 148 PAS 1 157
          TERM
$
     DEPL 1 -0.0093 FONC 1
          LECT 1   21  22  42  43  63  64
               84  85  105 106 126 127 147
               154 155 156 157
               TERM
$
     FSA  LECT    2  3  4  5  6  7  8  9  10 11
               12 13 14 15 16 17 18 19 20     TERM
$
FONC 1 TABL 642
    0    0
 . . . (skip for brevity)
    12.8304    -0.0006
$
$ Carichi
$
CHAR
     1 FACT 2 FORCE 2 264
          LECT 127 128 129 130 131 132 133
               134 135 136 137 138 139 140
               141 142 143 144 145 146 147 TERM
       TABL 3 0.0 1.0 1.0 0.0 20.0 0.0
$
     CONST GRAV 0.0 -9.81
$
ECRI
     DEPL POINT LECT 127 128 129 130 131 132 133
                     134 135 136 137 138 139 140
                     141 142 143 144 145 146 147
                TERM TFRE 0.25
!    FICH FORM AVS TFRE 0.025
!    VARI DEPL VITE ECRO
!    fich alic temp TFRE 5.E-5
!                   poin lect 11 106 126 term
!                   elem lect 1 term
     FICH ALIC TFRE 10.E-3
OPTI NOTEST
  log 100
CALCUL TINI 0 TEND 6.0 NMAX 50000000
*=================================================================
SUIT
Post-treatment
ECHO
*
!RESU ALIC TEMP GARD PSCR
 RESU ALIC      GARD PSCR
*
FONC 1 TABL 642
    0    0
    1    0
    1.018485    0.098016
 . . . (skip for brevity)
    12.8304    -0.0006
*
SORT GRAP
*
AXTE 1.0 'Time [s]'
*
COUR 1 'dx_11'    DEPL COMP 1 NOEU LECT 11  TERM
COUR 2 'dy_11'    DEPL COMP 2 NOEU LECT 11  TERM
COUR 3 'dx_106'   DEPL COMP 1 NOEU LECT 106 TERM
COUR 4 'dy_106'   DEPL COMP 2 NOEU LECT 106 TERM
COUR 5 'dx_126'   DEPL COMP 1 NOEU LECT 126 TERM
COUR 6 'dy_126'   DEPL COMP 2 NOEU LECT 126 TERM
DCOU 7 'fonc_1'   FONC 1
*
trac 1 2 3 4 5 6    axes 1.0 'DISPL. [M]'
trac 7              axes 1.0 'FUNCTION 1'
*
QUAL DEPL COMP 1 LECT  11 TERM REFE  0.00000E+0 TOLE 5.E-3
     DEPL COMP 2 LECT  11 TERM REFE -2.97067E-4 TOLE 5.E-3
     DEPL COMP 1 LECT 106 TERM REFE  0.00000E+0 TOLE 5.E-3
     DEPL COMP 2 LECT 106 TERM REFE -1.81780E-4 TOLE 5.E-3
     DEPL COMP 1 LECT 126 TERM REFE  0.00000E+0 TOLE 5.E-3
     DEPL COMP 2 LECT 126 TERM REFE -1.81780E-4 TOLE 5.E-3
*=================================================================
FIN
```

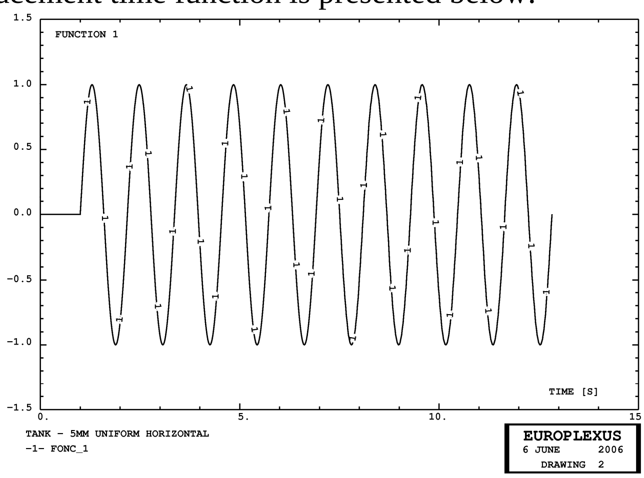
<u>Numerical Solution (flexible bottom)</u>

TANK6F

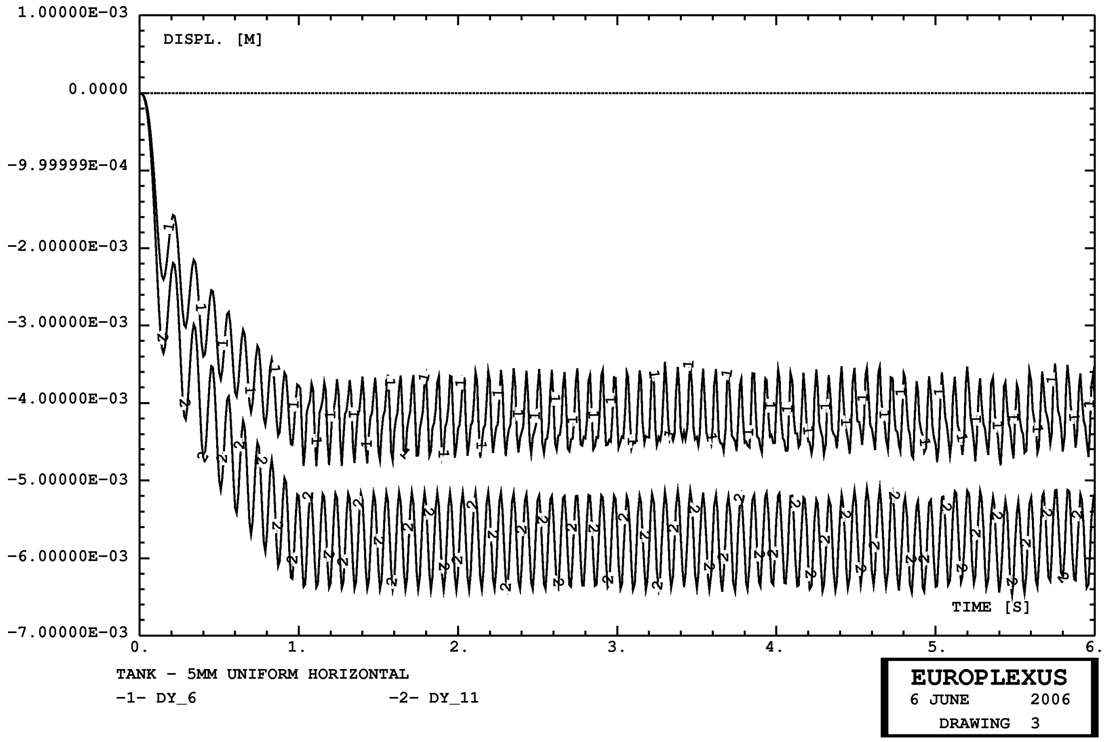
The EUROPLEXUS input file reads:

```
TANK - 5mm Uniform Horizontal
$
$ FONDO FLESSIBILE, TABELLA DETTAGLIATA,
$ AMPIEZZA DI OSCILLAZIONE 9.3mm
$
 ECHO
!CONV win
$ 2D Plane Strain + NonLinear + ALE
 DPLA NONL NAVI ALE
$
DIME
 PT2L 256
 PT3L 4
 CAR1 200
 COQU 30
 TRIA 2
 ED01 2
$obsolete:    MATE 20
 NALE 100 NBLE 500
 FSA  100 IFSA 500
 SLPN 200
 SLPC 100
 NDVC 400
 TABL 200 200
 MTPO 200
 BLOQ 100
 DDLI 100
 FCOE 100
 FNOM 10
 FTAB 800
 FORC 24
 ZONE 10
TERM
$
GEOM LIBR POIN 157 CAR1 100 COQU 20 TRIA 2 ED01 2 TERM
$
$ 1
0.00 0.00
 . . . (skip for brevity)
$
COMP EPAI 0.005 LECT 101 102 103 104 105
                     106 107 108 109 110
                     111 112 113 114 115
                     116 117 118 119 120 TERM
          1.0   LECT 123 124 TERM
$
GRIL LAGR LECT 127 128 129 130 131
               132 133 134 135 136
               137 138 139 140 141
               142 143 144 145 146 147
                   107 108 109 110
               111 112 113 114 115
               116 117 118 119 120
               121 122 123 124 125
               1  21 106 126
               148 PAS 1 157
               TERM
$
     ALE  LECT 1  2  3  4  5  6  7  8  9  10
               11 12 13 14 15 16 17 18 19 20
               21 22 23 24 25 26 27 28 29 30
               31 32 33 34 35 36 37 38 39 40
               41 42 43 44 45 46 47 48 49 50
               51 52 53 54 55 56 57 58 59 60
               61 62 63 64 65 66 67 68 69 70
               71 72 73 74 75 76 77 78 79 80
               81 82 83 84 85 86 87 88 89 90
               91 92 93 94 95 96 97 98 99 100 TERM
$
     SLIP EQUI LECT 126 125 124 123 122 121
                    120 119 118 117 116
                    115 114 113 112 111
                    110 109 108 107 106 TERM
$
     SLIP EQUI LECT 1   22  43  64  85  106 TERM
     SLIP EQUI LECT 21  42  63  84  105 126 TERM
$
     MEAN NOEU LECT 23 24 25 26 27 28 29 30 31 32
                    33 34 35 36 37 38 39 40 41
                    44 45 46 47 48 49 50 51 52 53
                    54 55 56 57 58 59 60 61 62
                    65 66 67 68 69 70 71 72 73 74
                    75 76 77 78 79 80 81 82 83
                    86 87 88 89 90 91 92 93 94 95
                    96 97 98 99 100 101 102 103 104
                    TERM
$
MATE LINE RO 7800. YOUNG 200.E9 NU 0.3
          LECT 101 102 103 104 105
               106 107 108 109 110
               111 112 113 114 115
               116 117 118 119 120 TERM
$
     LIQU RO 1000.
          LECT 1  2  3  4  5  6  7  8  9  10
               11 12 13 14 15 16 17 18 19 20
               21 22 23 24 25 26 27 28 29 30
               31 32 33 34 35 36 37 38 39 40
               41 42 43 44 45 46 47 48 49 50
               51 52 53 54 55 56 57 58 59 60
               61 62 63 64 65 66 67 68 69 70
               71 72 73 74 75 76 77 78 79 80
               81 82 83 84 85 86 87 88 89 90
               91 92 93 94 95 96 97 98 99 100 TERM
     FANT 1.0 LECT 121 PAS 1 124 TERM
$
LIAI FREQ 1
     BLOQ 2 LECT 1 21 127 147
                148 PAS 1 157
            TERM
$
     DEPL 1 -0.0093 FONC 1
            LECT 1   21  22  42  43  63  64
                 84  85  105 106 126 127 147
                 154 155 156 157
                 TERM
$
     FSA  LECT    2  3  4  5  6  7  8  9  10 11
               12 13 14 15 16 17 18 19 20     TERM
$
FONC 1 TABL 642
    0    0
    1    0
    1.018485    0.098016
 . . . (skip for brevity)
    12.8304    -0.0006
$
$ Carichi
$
CHAR
     1 FACT 2 FORCE 2 264
            LECT 127 128 129 130 131 132 133
                 134 135 136 137 138 139 140
                 141 142 143 144 145 146 147 TERM
       TABL 3 0.0 1.0 1.0 0.0 20.0 0.0
$
     CONST GRAV 0.0 -9.81
$
ECRI
     DEPL POINT LECT 127 128 129 130 131 132 133
                     134 135 136 137 138 139 140
                     141 142 143 144 145 146 147
                TERM TFRE 0.25
!    FICH FORM AVS TFRE 0.025
!    VARI DEPL VITE ECRO
!    fich alic temp TFRE 5.E-5
!                  poin lect 11 106 126 term
!                  elem lect 1 term
     FICH ALIC TFRE 10.E-3
OPTI NOTEST
  log 100
CALCUL TINI 0 TEND 6.0 NMAX 50000000
*================================================================
SUIT
Post-treatment
ECHO
*
!RESU ALIC TEMP GARD PSCR
 RESU ALIC      GARD PSCR
*
FONC 1 TABL 642
    0    0
    1    0
    1.018485    0.098016
 . . . (skip for brevity)
    12.8304    -0.0006
*
SORT GRAP
*
AXTE 1.0 'Time [s]'
*
COUR 1 'dx_11'    DEPL COMP 1 NOEU LECT 11  TERM
COUR 2 'dy_11'    DEPL COMP 2 NOEU LECT 11  TERM
COUR 3 'dx_106'   DEPL COMP 1 NOEU LECT 106 TERM
COUR 4 'dy_106'   DEPL COMP 2 NOEU LECT 106 TERM
COUR 5 'dx_126'   DEPL COMP 1 NOEU LECT 126 TERM
COUR 6 'dy_126'   DEPL COMP 2 NOEU LECT 126 TERM
DCOU 7 'fonc_1'   FONC 1
*
trac 1 2 3 4 5 6    axes 1.0 'DISPL. [M]'
trac 7              axes 1.0 'FUNCTION 1'
*
QUAL DEPL COMP 1 LECT  11 TERM REFE  0.00000E+0 TOLE 5.E-3
     DEPL COMP 2 LECT  11 TERM REFE -2.97067E-4 TOLE 5.E-3
     DEPL COMP 1 LECT 106 TERM REFE  0.00000E+0 TOLE 5.E-3
     DEPL COMP 2 LECT 106 TERM REFE -1.81780E-4 TOLE 5.E-3
     DEPL COMP 1 LECT 126 TERM REFE  0.00000E+0 TOLE 5.E-3
     DEPL COMP 2 LECT 126 TERM REFE -1.81780E-4 TOLE 5.E-3
*================================================================
FIN
```

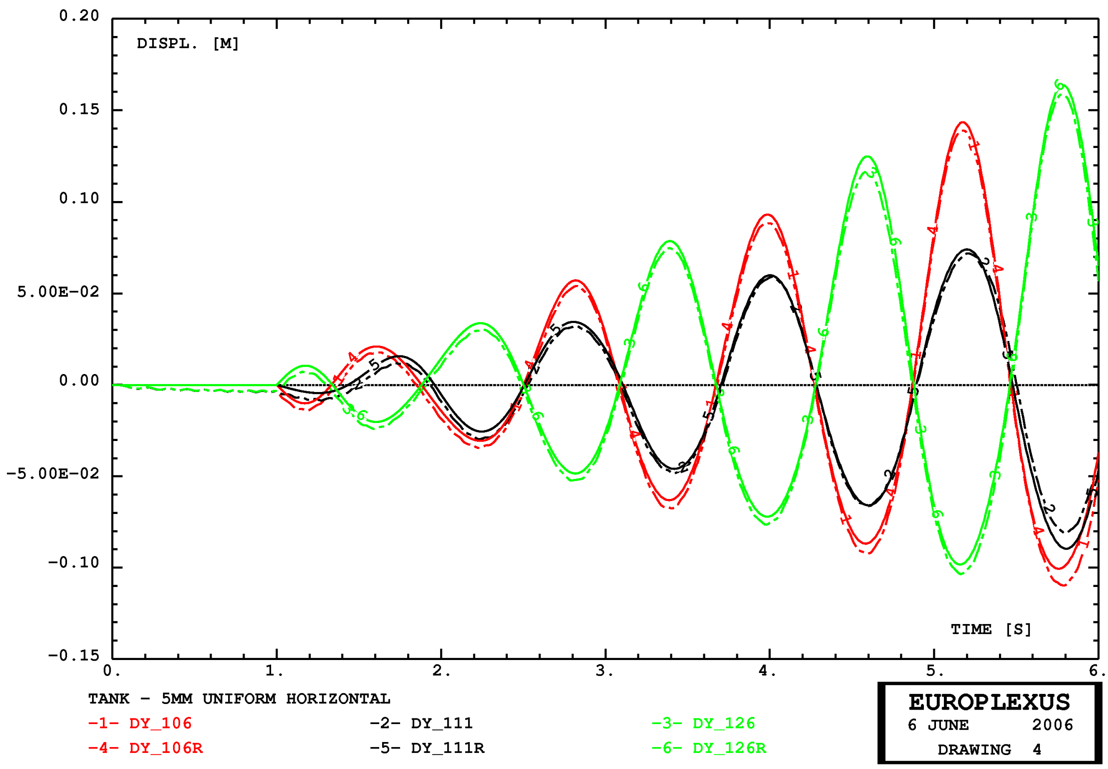
The applied displacement time function is presented below:



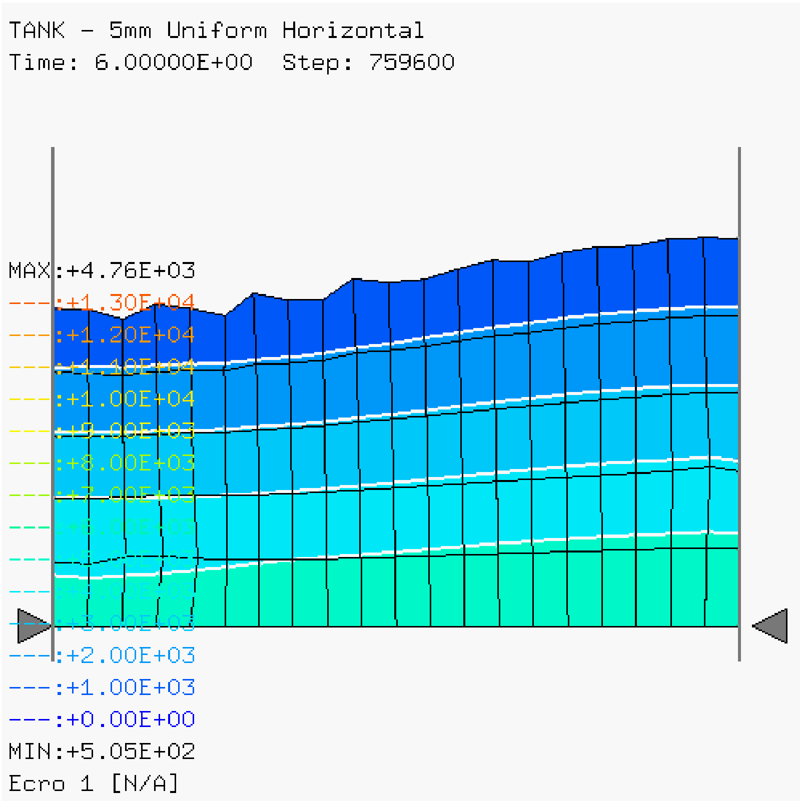
The computed displacements of the tank bottom (at ¼ length and ½ length, respectively) for the flexible bottom case are shown below:

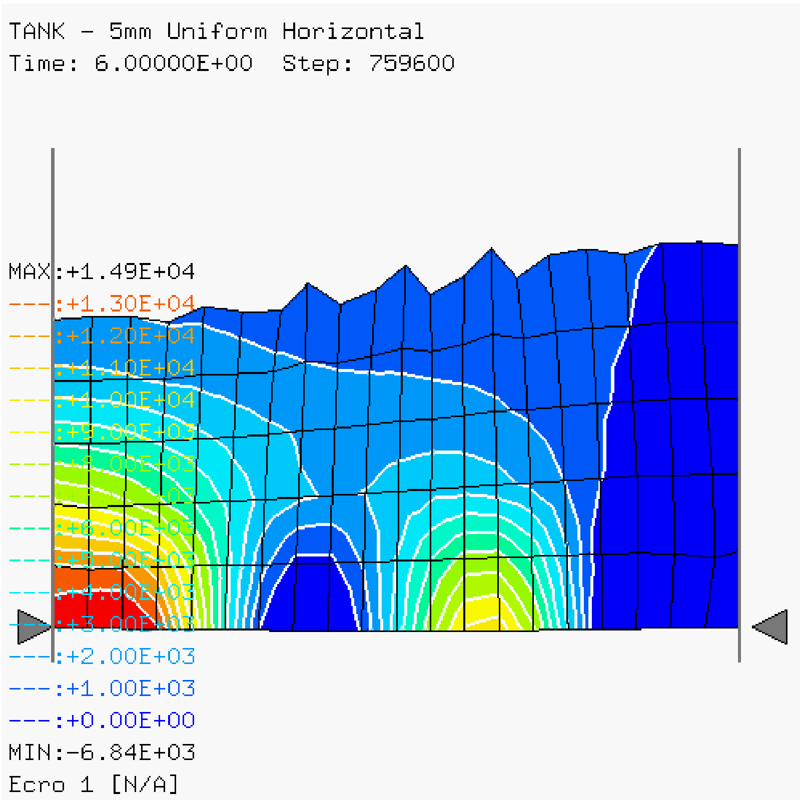


The computed displacements of the free surface (at both extremities and at the mid-point) as computed for the rigid bottom case (solid lines) and for the deformable bottom case (dashed lines) are shown below:



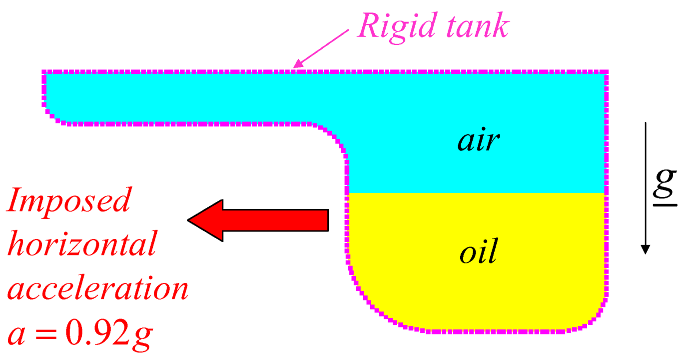
The final pressures in the rigid and flexible case, respectively, are shown below:





Exercise/Example 12 – Sloshing (11)
(Courtesy of Samtech)

- D – Accelerated oil cup:



95

TITLE:
OILCUP2: uniformly accelerated oil cup.

PROBLEM:
A rigid oil tank partially filled with mineral oil is accelerated uniformly at 0.92 g in the horizontal direction and is under the action of gravity in the vertical direction.

MESH:
The fluid is meshed by FL23/FL24 elements, the rigid tank by PMAT elements. These latter elements are used to impose a uniform acceleration to the container, while the FSA model takes care of prescribing suitable fluid velocities along the walls in a completely automatic way. Note that this is not the same as prescribing uniform acceleration directly to the fluid outer surface.

MATERIALS:
A multi-phase multi-component model (FLMP) is used for the two fluids, to avoid problems in representing a Lagrangian oil/air interface that is expected to undergo very large motions and deformations (formation of waves that successively break up). The oil is treated as a liquid with constant bulk modulus and the air as a perfect gas.

BOUNDARY CONDITIONS:
The tank is rigid so the same horizontal motion (constant acceleration) is prescribed to all its nodes. To model fluid-structure interaction appropriately, FSA conditions are associated with all fluid nodes on the fluid outer surface.

LOADING:
A constant gravity in the vertical direction acts on the fluids, while a constant horizontal acceleration directed leftwards is applied to the structure.

CALCULATION:
The calculation is performed up to a final time of 650 ms. Since <u>we do not use the NAVI condition</u> (incompressible fluid), unlike in the previous sloshing examples, the time step (driven by stability in the fluid mesh) is short and a lot of time steps are required to arrive to the final time (about 1 million). This is because we are modeling wave propagation in the problem, although these phenomena are negligible in reality. Using NAVI would require a multi-component fluid model compatible with this constraint, which is not currently available.

RESULTS:
They are analyzed below.

POST-TREATMENT
Animations are produced.

<u>Numerical Solution</u>

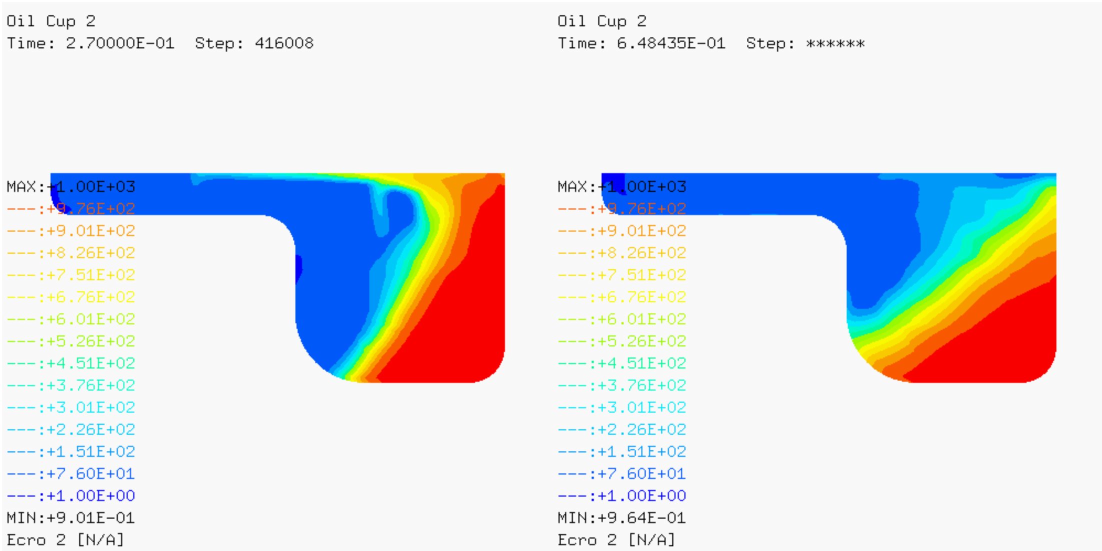
OILCUP2

The EUROPLEXUS input file reads:

```
Oil Cup 2
*---------------------------------------------------------Kind of problem
!conv win
 DPLA NONL ALE
 AMOR
*------------------------------------------------------------------Sizing
DIME
 PT2L 4324 FL23 3 FL24 3900 PMAT 281 ZONE 3
 NALE 1617 NBLE 1
 BLOQ 281 LIAI 1686
 DDLI 843 FCOE 843
 FSA  283 IFSA 1116
 TABL 1 2 FNOM 1 FTAB 2
 MTPO 281 MTEL 1
 ECRO 134388
TERM
*---------------------------------------------------------Geometry (Mesh)
GEOM '(2E22.15)' '(7I10)' POIN 4324
  FL23 3 FL24 3900 PMAT 281
TERM
*-------------------------------------------------------Nodal Coordinates
 0.000000000000000E+00-1.500000000000000E-02
  … (skip)
 3.250000000000000E-01-7.323529411764707E-02
      3661      3662      1821      3764      3765       339      3782
  … (skip)
      4317      4318      4319      4320      4321      4322      4323
      4324
*-----------------------------------------------------------------Options
OPTI REZO GAM0 0.5
     amor line 0.01
     log  100
*--------------------------------------------Additional geometrical data
COMP GROU 3
     'air' LECT
         1         4         5         6         7         8
  … (skip)

      2526      2527      2528      2529      2530      2531      2532
      2533
     TERM
     'oil' LECT
         2         3      1051      1052      1053      1054
  … (skip)
      3892      3893      3894      3895      3896      3897      3898
      3899      3900      3901      3902      3903
     TERM
     'stru' LECT 3904 PAS 1 4184 TERM
     NGRO 1
     'fsan' LECT
            1 PAS 1    6
           16 PAS 1   76
          141 PAS 1  203
          237 PAS 1  249
          274 PAS 1  281
         3616 PAS 1 3723
         3772 PAS 1 3793
     TERM
     COUL jaun LECT oil  TERM
          turq LECT air  TERM
          rose LECT stru TERM
*----------------------------------------------------Mesh motion in ALE
GRIL LAGR LECT 4044 PAS 1 4324 TERM
     ALE  LECT 1 4 PAS 1 1050 1384 PAS 1 2533 TERM
     suiv base lect 4044 term list lect    7 term
  … (skip)
     suiv base lect 4044 term list lect 4043 term
*---------------------------------------------------------------Materials
MATE FLMP NLIQ 1 NGAS 1
     FLUT RO 1.E3 EINT 0 GAMM 2.E9 PB 1.e05 ITER 1 ALF0 1 BET0 1 KINT 0
          AHGF 0 CL 0.5 CQ 2.56 PMIN 0 NUM 9
          LECT oil TERM
     FLUT RO 1.E0 EINT 2.5E5 GAMM 1.4 PB 0 ITER 1 ALF0 1 BET0 1 KINT 0
          AHGF 0 CL 0.5 CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     MASS 0.1E-03
          LECT stru TERM
*---------------------------------------------------------------Couplings
LIAI BLOQ 2                LECT stru TERM
     VITE 1 0.1E+01 FONC 1 LECT stru TERM
     FSA                   LECT fsan TERM
*---------------------------------------------------------------Functions
FONC 1 TABL 2 0.0     0.0
             4.001  -36.0
*----------------------------------------------------------External loads
CHAR CONS GRAV 0. -9.81 LECT oil air TERM
*-----------------------------------------------------------------Storage
ECRI VITE TFRE 0.05
     FICH ALIC TFRE 1.E-03
*--------------------------------------------------------------Time Steps
CALC TINI 0.0E+00 TFIN 0.65
FIN
```

Some results: intermediate and final average fluid density:



Intermediate and final oil mass fraction: