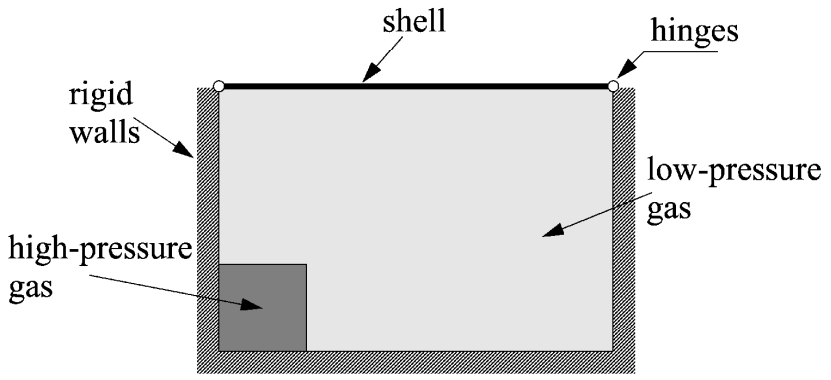
Example 4 – Explosion in a 2D box



19

Geometric data and materials:

The box is 4 units wide and 3 units high. The bubble is square in shape and has unit sides. The walls are rigid except the top, which is sealed by a metallic lamina.

The fluids are perfect gases. The structure is steel with an elasto-plastic law.

Numerical Solutions

INFS01

This model uses conforming FSI. The fluid mesh uses 4 by 3 elements only and the structure is discretized by 4 elements of the ED01 type.

The mesh generation file is:

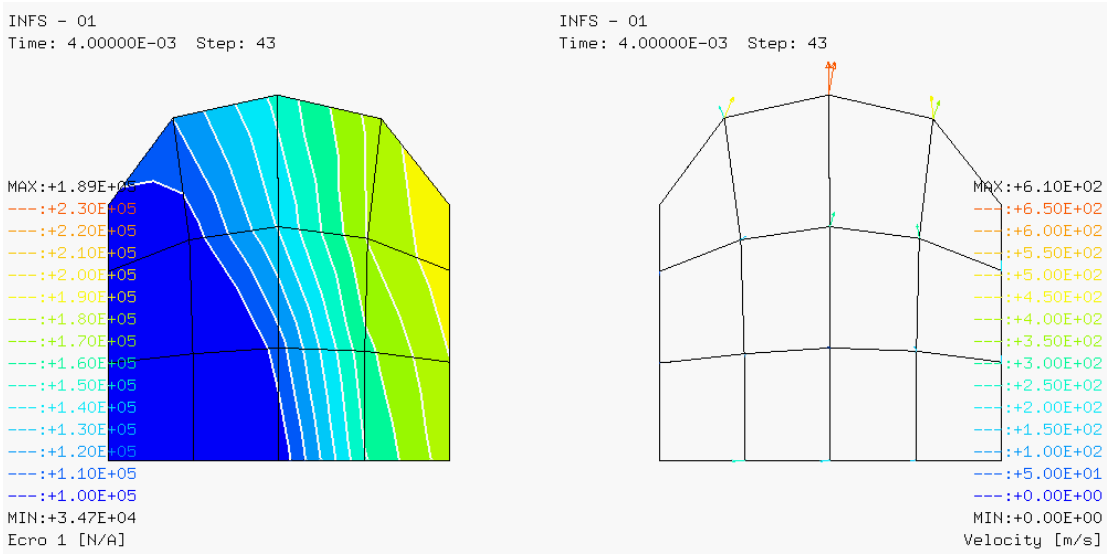
```
*%siz 50
*
opti titr 'INFS - 01';
opti echo 1;
*
opti dime 2 elem qua4;
*
p1=0 0;
p2=4 0;
p3=0 3;
p4=4 3;
p5=1 0;
p6=0 1;
p7=1 1;
p8=4 1;
p3s=p3 plus (0 0);
p4s=p4 plus (0 0);
tol=0.001;

c1=p1 d 1 p5;
c2=p5 d 1 p7;
c3=p7 d 1 p6;
c4=p6 d 1 p1;
bull=daller c1 c2 c3 c4 plan;

c1=p5 d 3 p2;
c2=p2 d 1 p8;
c3=p8 d 3 p7;
c4=p7 d 1 p5;
gas1=daller c1 c2 c3 c4 plan;

c1=p6 d 1 p7 d 3 p8;
c2=p8 d 2 p4;
c3=p4 d 4 p3;
c4=p3 d 2 p6;
gas2=daller c1 c2 c3 c4 plan;

gas = gas1 et gas2;

stru=p3s d 4 p4s;

flui=bull et gas;
elim tol flui;

mesh = flui et stru;

bloqx=mesh poin droi p1 p3 tol;
bloqx=bloqx et (mesh poin droi p2 p4 tol);
bloqy=mesh poin droi p1 p2 tol;
bloqy=bloqy et p3 et p4  et p3s et p4s;

fsan=flui poin droi p3 p4 tol;

mesh=mesh et bloqx et bloqy et fsan;
tass mesh;

opti sauv form 'infs01.msh';
sauv form mesh;

opti trac psc ftra 'infs01_mesh.ps';
trac mesh;
```

The input file is:

```
INFS - 01
*-----------------------------------------------------------------------
 ECHO
 CONV win
CAST MESH
*-----------------------------------------------------------Problem type
DPLA NONL ALE
*-----------------------------------------------------------Dimensioning
DIME
 PT3L 5 PT2L 20 FL24 12 ED01 4 ZONE 2
 NALE 5 NBLE 20
 MTPO 6 MTEL 1
TERM
*-------------------------------------------------------------Geometry
GEOM FL24 FLUI ED01 STRU TERM
*-----------------------------------------------Geometric Complements
COMP EPAI 0.0001 LECT STRU TERM
     coul blan lect flui term
*---------------------------------------------------------Grid motion
GRIL LAGR LECT stru TERM
     EULE LECT fsan TERM
     ALE  LECT FLUI TERM
     AUTO AUTR
*-------------------------------------------------------Material data
MATE VM23 RO 7800. YOUNG 1.6E11 NU 0.333 ELAS 1.05E8
          TRAC 2 1.05E8 .656256E-3 1.6105E10 1.00066
          LECT STRU TERM
     FLUT RO 1.22 EINT 3.046E6 GAMM 1.269 PB 0 ITER 1 ALF0 1
          BET0 1 KINT 0 AHGF 0 CL 0.5 CQ 2.56 PMIN 0 NUM 1
          LECT BULL TERM
     FLUT RO 0.1237 EINT 3.046E6 GAMM 1.269 PB 0 ITER 1 ALF0 1
          BET0 1 KINT 0 AHGF 0 CL 0.5 CQ 2.56 PMIN 0 NUM 1
          LECT GAS TERM
*-----------------------------------------------Boundary conditions
LINK COUP
     BLOQ 1 LECT BLOQX TERM
          2 LECT BLOQY TERM
     FSA  LECT fsan TERM
*-----------------------------------------------------------------Outputs
ECRI COOR DEPL VITE CONT ECRO FINT FEXT TFRE 1.0E-3
     FICH K200 TFRE 1.E-3
               POIN TOUS
               VARI DEPL VITE FEXT ECRO ECRC LECT 1 TERM
     FICH TPLO FREQ 1 DESC 'INFS01'
               POIN LECT 16 18 19 22 23 24 TERM
               ELEM LECT 1 TERM
     FICH ALIC TEMP FREQ 1
               POIN LECT 16 18 19 22 23 24 TERM
               ELEM LECT 1 TERM
*-------------------------------------------------------------Options
OPTI NOTE
 csta 0.5
 liaj
```

```
 log 1
 REZO GAM0 0.5
*-----------------------------------------------------Transient calculation
CALC TINI 0 TEND 4.E-3
*=================================================================ANIMATION
PLAY
CAME   1 EYE   2.00000E+00  2.14602E+00  1.46675E+01
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
SCEN GEOM NAVI FREE
     !ISO  FILI FIEL ECRO 1 SCAL USER PROG 1.0D5 PAS 1.0D4 2.3D5 TERM
     !TEXT ISCA
      VECT SCCO SCAL USER PROG 0 PAS 50 650 TERM
      TEXT VSCA
      colo pape
sler cam1 1       nfra 1
trac offs fich avi                nocl nfto 44  fps 5 kfre 10 comp -1
                                                !obje lect flui term
                                                                REND
FREQ 1
GOTR LOOP 42  OFFS FICH AVI CONT NOCL
                                                !obje lect flui term
                                                                REND
GOTR          OFFS FICH AVI CONT
                                                !obje lect flui term
                                                                REND
ENDPLAY
*=========================================================POST-TREATMENT
SUIT
Post-treatment
ECHO
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1000.0 'Time [ms]'
*-----------------------------------------------------Curve definitions
COUR 1 'dy_16'  DEPL COMP 2 NOEU LECT 16  TERM
COUR 2 'dy_18'  DEPL COMP 2 NOEU LECT 18  TERM
COUR 3 'dy_19'  DEPL COMP 2 NOEU LECT 19  TERM
COUR 4 'vx_18'  VITE COMP 1 NOEU LECT 18  TERM
COUR 5 'vy_18'  VITE COMP 2 NOEU LECT 18  TERM
*-------------------------------------------------------------------Plots
trac 1 2 3   axes 1.0 'DISPL. [M]'
trac 4 5     axes 1.0 'V [M/S]'
*-----------------------------------------------Results qualification
QUAL DEPL COMP 2 LECT  16 TERM REFE  1.02416E+0 TOLE 5.E-3
     DEPL COMP 2 LECT  18 TERM REFE  1.29205E+0 TOLE 5.E-3
     DEPL COMP 2 LECT  19 TERM REFE  1.01223E+0 TOLE 5.E-3
*=================================================================
FIN
```

The deformed final mesh at 4 ms with superposed fluid pressures and the velocities are:



INFS02

We use a twice finer fluid mesh but the same structural mesh. Therefore, the F-S interface is non-conforming.

The mesh generation file is:

```
*%siz 50
*
opti titr 'INFS - 02';
opti echo 1;
*
opti dime 2 elem qua4;
*
p1=0 0;
p2=4 0;
p3=0 3;
p4=4 3;
p5=1 0;
```

```
p6=0 1;
p7=1 1;
p8=4 1;
p3s=p3 plus (0 0);
p4s=p4 plus (0 0);
tol=0.001;

c1=p1 d 2 p5;
c2=p5 d 2 p7;
c3=p7 d 2 p6;
c4=p6 d 2 p1;
bull=daller c1 c2 c3 c4 plan;
```

```
c1=p5 d 6 p2;
c2=p2 d 2 p8;
c3=p8 d 6 p7;
c4=p7 d 2 p5;
gas1=daller c1 c2 c3 c4 plan;

c1=p6 d 2 p7 d 6 p8;
c2=p8 d 4 p4;
c3=p4 d 8 p3;
c4=p3 d 4 p6;
gas2=daller c1 c2 c3 c4 plan;

gas = gas1 et gas2;

stru=p3s d 4 p4s;

flui=bull et gas;
elim tol flui;
```

```
mesh = flui et stru;

bloqx=mesh poin droi p1 p3 tol;
bloqx=bloqx et (mesh poin droi p2 p4 tol);
bloqy=mesh poin droi p1 p2 tol;
bloqy=bloqy et p3 et p4  et p3s et p4s;

fsan=flui poin droi p3 p4 tol;

mesh=mesh et bloqx et bloqy et fsan;
tass mesh;

opti sauv form 'infs02.msh';
sauv form mesh;

opti trac psc ftra 'infs02_mesh.ps';
trac mesh;
```

The input file:

```
INFS - 02
*------------------------------------------------------------------------
 ECHO
 CONV win
 CAST MESH
*-------------------------------------------------------------Problem type
DPLA NONL ALE
*---------------------------------------------------------Dimensioning
DIME
 PT3L 5 PT2L 63 FL24 48 ED01 4 ZONE 2
 NALE 9 NBLE 63
 MTPO 6 MTEL 1
TERM
*-----------------------------------------------------------Geometry
GEOM FL24 FLUI ED01 STRU TERM
*-----------------------------------------------Geometric Complements
EPAI 0.0001 LECT STRU TERM
     coul blan lect flui term
*-------------------------------------------------------Grid motion
GRIL LAGR LECT stru TERM
     EULE LECT fsan TERM
     ALE  LECT FLUI TERM
     AUTO AUTR
*-------------------------------------------------------Material data
MATE VM23 RO 7800. YOUNG 1.6E11 NU 0.333 ELAS 1.05E8
          TRAC 2 1.05E8 .656256E-3 1.6105E10 1.00066
          LECT STRU TERM
     FLUT RO 1.22 EINT 3.046E6 GAMM 1.269 PB 0 ITER 1 ALF0 1
          BET0 1 KINT 0 AHGF 0 CL 0.5 CQ 2.56 PMIN 0 NUM 1
          LECT BULL TERM
     FLUT RO 0.1237 EINT 3.046E6 GAMM 1.269 PB 0 ITER 1 ALF0 1
          BET0 1 KINT 0 AHGF 0 CL 0.5 CQ 2.56 PMIN 0 NUM 1
          LECT GAS TERM
*-----------------------------------------------------Boundary conditions
LINK COUP
     BLOQ 1 LECT BLOQX TERM
          2 LECT BLOQY TERM
     FSA  NCFS LECT fsan TERM
*------------------------------------------------------------------Outputs
ECRI COOR DEPL VITE CONT ECRO FINT FEXT TFRE 1.0E-3
     FICH K200 TFRE 1.E-3
               POIN TOUS
               VARI DEPL VITE FEXT ECRO ECRC LECT 1 TERM
     FICH TPLO FREQ 1 DESC 'INFS02'
               POIN LECT 57 59 61 65 66 67 TERM
               ELEM LECT 1 TERM
     FICH ALIC TEMP FREQ 1
               POIN LECT 57 59 61 65 66 67 TERM
               ELEM LECT 1 TERM
*-------------------------------------------------------------------Options
OPTI NOTE
 csta 0.5
 liaj
 log 1
```

```
 REZO GAM0 0.5
*-----------------------------------------------------Transient calculation
CALCUL TINI 0 TEND 4.E-3
*=================================================================ANIMATION
PLAY
CAME   1 EYE   2.00000E+00  2.14602E+00  1.46675E+01
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
SCEN GEOM NAVI FREE
     !ISO  FILI FIEL ECRO 1 SCAL USER PROG 1.0D5 PAS 1.0D4 2.3D5 TERM
     !TEXT ISCA
     VECT SCCO SCAL USER PROG 0 PAS 50 650 TERM
     TEXT VSCA
     colo pape
sler cam1 1        nfra 1
trac offs fich avi               nocl nfto 62  fps 5 kfre 10 comp -1
                                               !obje lect flui term
                                                REND
FREQ 1
GOTR LOOP 60  OFFS FICH AVI CONT NOCL
                                               !obje lect flui term
                                                REND
GOTR          OFFS FICH AVI CONT
                                               !obje lect flui term
                                                REND
ENDPLAY
*=============================================================POST-TREATMENT
SUIT
Post-treatment
ECHO
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1000.0 'Time [ms]'
*-----------------------------------------------------Curve definitions
COUR 1 'dy_65'  DEPL COMP 2 NOEU LECT 65  TERM
COUR 2 'dy_66'  DEPL COMP 2 NOEU LECT 66  TERM
COUR 3 'dy_67'  DEPL COMP 2 NOEU LECT 67  TERM
COUR 4 'vx_59'  VITE COMP 1 NOEU LECT 59  TERM
COUR 5 'vy_59'  VITE COMP 2 NOEU LECT 59  TERM
*------------------------------------------------------------------Plots
trac 1 2 3   axes 1.0 'DISPL. [M]'
trac 4 5     axes 1.0 'V [M/S]'
*-----------------------------------------------Results qualification
QUAL DEPL COMP 2 LECT  65 TERM REFE  1.05700E+0 TOLE 5.E-3
     DEPL COMP 2 LECT  66 TERM REFE  1.33322E+0 TOLE 5.E-3
     DEPL COMP 2 LECT  67 TERM REFE  1.03977E+0 TOLE 5.E-3
*=================================================================
FIN
```

The final mesh and pressures and velocities are: