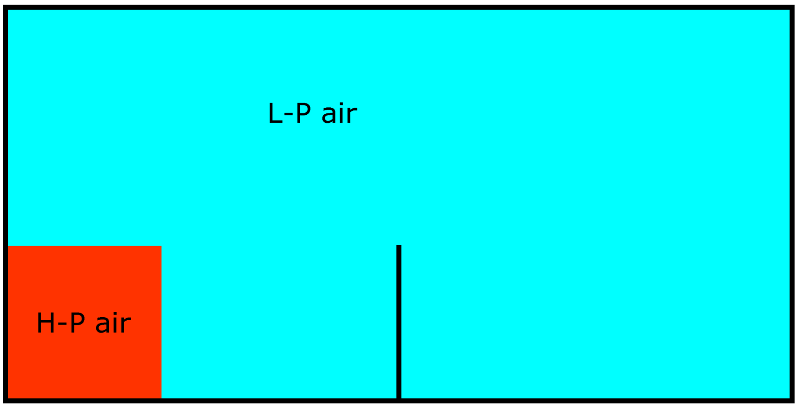
Exercise/Example 10b – Comparison FE/FV

- Compare FE (strong), N-C FV (strong) and C-C FV (weak) in a simple 2D explosion test with conforming F-S mesh



Elasto-plastic structure

75

TITLE:
Elfi00/Vfnca1/Vfcc00: explosion in a 2D deformable container with an internal diaphragm.

PROBLEM:
The purpose is to compare Finite Element, Finite Volume (Node-Centred) and Finite Volume (Cell-Centred) solutions of this problem and to highlight the particularities of each model.

MESH:
The model is 2D plane strain and contains 20 x 10 finite elements (or finite volumes) in the fluid. The structural mesh is conforming to the fluid mesh.

MATERIALS:
The structure is an elasto-plastic VM23 material. The explosive and the gas (air) are rep;resented by perfect gases at high and low pressures, respectively. The two gases may mix up.

BOUNDARY CONDITIONS:
The fluid-structure interaction along the deformable container walls is automatically modelled by the FSA directive in the FE and N-C FV solutions. The C-C FV solution requires no specific directive and the fluid and structure nodes are merged together.

LOADING:
The system is initially at rest, but not in equilibrium.

CALCULATION:
The calculation is performed up to 5 ms. This time is sufficient to see propagation of the pressure waves to the top of the box and several reflections.

RESULTS:
Although no comparison with experiments can be done on this problem, the results appear physically correct.

POST-TREATMENT
Several animations of the computed results are presented. Time curves of the fluid pressures and structure displacements are compared.

<u>Numerical Solutions (Finite Elements)</u>

ELFI00

The mesh generation file (K2000) is:

```
opti echo 1;
opti titr 'ELFI00';
opti sauv form 'elfi00.msh';
opti trac psc ftra 'elfi00_mesh.ps';
*
opti dime 2 elem qua4;
*
p1 = 0 0;
p2 = 2 0;
p3 = 2 1;
p4 = 0 1;
p5 = 0.4 0;
p6 = 0.4 0.4;
p7 = 0 0.4;
p8 = 0.4 1;
*
tol = 0.001;
*
c1 = p1 d 4 p5;
c2 = p5 d 4 p6;
c3 = p6 d 4 p7;
c4 = p7 d 4 p1;
expl = dall c1 c2 c3 c4 plan;
*
p9l = 1 0;
p9r = 1 0;
p10 = 1 0.4;
p11 = 2 0.4;
*
c1 = p5 d 6 p9l;
c2 = p9l d 4 p10;
c3 = p10 d 6 p6;
c4 = p6 d 4 p5;
air1a = dall c1 c2 c3 c4 plan;
*
c1 = p9r d 10 p2;
c2 = p2 d 4 p11;
c3 = p11 d 10 p10;
c4 = p10 d 4 p9r;
air1b = dall c1 c2 c3 c4 plan;
*
c1 = p6 d 6 p10 d 10 p11;
c2 = p11 d 6 p3;
c3 = p3 d 16 p8;
c4 = p8 d 6 p6;
air1c = dall c1 c2 c3 c4 plan;
*
elim tol (air1a et air1c);
elim tol (air1b et air1c);
air1 = air1a et air1b et air1c;
*
c1 = p7 d 4 p6;
c2 = p6 d 6 p8;
c3 = p8 d 4 p4;
c4 = p4 d 6 p7;
air2 = dall c1 c2 c3 c4 plan;
elim tol (air1c et air2);
elim tol (expl et air2);
elim tol (expl et air1a);
*
air = air1 et air2;
flui = expl et air;
*
e1 = expl elem cont p1;
e3 = air1 elem cont p3;
*
p1s = p1 plus p1;
p2s = p2 plus p1;
p3s = p3 plus p1;
p4s = p4 plus p1;
p9s = p9l plus p1;
p10s = p10 plus p1;
p12s = 1 1;
c1s = p1s d 10 p9s d 10 p2s;
c2s = p2s d 10 p3s;
c3s = p3s d 10 p12s d 10 p4s;
c4s = p4s d 10 p1s;
c5s = p9s d 4 p10s;
stru = c1s et c2s et c3s et c4s et c5s;
*
nfsa = cont flui;
*
mesh = flui et stru et e1 et e3 et nfsa;
*
sauv form mesh;
trac qual mesh;
*
list (nbel mesh);
list (nbno mesh);
*
fin;
```

The EUROPLEXUS input file reads:

```
ELFI00
ECHO
!conv win
CAST mesh
DPLA ALE
DIME
 PT2L 235 PT3L 64 FL24 200 ED01 64 ZONE 2
 NALE 26 NBLE 167
TERM
GEOM FL24 flui ED01 stru TERM
COMP EPAI 0.01 LECT stru TERM
     COUL turq LECT air  TERM
          roug LECT expl TERM
          bleu LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT nfsa TERM
     AUTO AUTR
MATE FLUT RO 5.9485 EINT 4.20274E5 GAMM 1.4 PB 0 PREF 1.E5
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.1897 EINT 2.10137E5 GAMM 1.4 PB 0 PREF 1.E5
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     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
LINK COUP FSA LECT nfsa TERM
ECRI DEPL VITE ACCE FINT FEXT CONT ECRO TFRE 1.E-3
          POIN LECT p1 p5 p6 p7 p3 TERM
          ELEM LECT e1 e3 TERM
     FICH ALIC TFRE 5.E-5
     FICH ALIC TEMP FREQ 1
          POIN LECT p1 p5 p6 p7 p3 p1s p2s p3s p4s p9s p10s p12s TERM
          ELEM LECT e1 e3 TERM
OPTI NOTE LOG 1
     CSTA 0.5
CALC TINI 0.0 PAS1 1.E-5 TFIN 5.E-3
*=================================================================
PLAY
CAME   1 EYE   1.00000E+00  5.00000E-01  5.03115E+00
!        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
sler cam1 1 nfra 1
scen geom navi free
          face hfro
     vect scco fiel vite scal user prog 10 pas 10 140 term
          SUPP LECT air  TERM
     text vsca
     colo pape
freq 0 tfre 2.5e-3
go
trac offs fich bmp rend
go
trac offs fich bmp rend
ENDPLAY
*=================================================================
SUIT
Post treatment
ECHO
 conv win
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
*=================================================================
PLAY
CAME   1 EYE   1.00000E+00  5.00000E-01  5.03115E+00
!        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
sler cam1 1 nfra 1
scen geom navi free
     iso  fili fiel ecro 1 scal user prog 0.61E5 pas 0.2E5 3.21E5 term
          SUPP LECT flui TERM
     text isca
     vect scco fiel vite scal user prog 10 pas 10 140 term
          SUPP LECT flui TERM
     text vsca
     colo pape
trac offs fich avi     nocl nfto 101 fps 10 kfre 10 comp -1 rend
freq 1
gotr loop 99 offs fich avi cont nocl rend
```

```
go
trac offs fich avi cont rend
ENDPLAY
*=================================================================
SUIT
Post-treatment (time curves from alice temps file)
ECHO
*
RESU ALIC TEMP GARD PSCR
*
SORT GRAP
*
AXTE 1.0 'Time [s]'
*
COUR  3 'p_e1'    ECRO COMP 1 ELEM LECT e1 TERM
COUR  4 'p_e3'    ECRO COMP 1 ELEM LECT e3 TERM
COUR  5 'dx_p10s' DEPL COMP 1 POIN LECT p10s TERM
COUR  6 'dy_p12s' DEPL COMP 2 POIN LECT p12s TERM
COUR  7 'dx_p9s'  DEPL COMP 1 POIN LECT p9s TERM
COUR  8 'dy_p9s'  DEPL COMP 2 POIN LECT p9s TERM
*
TRAC 3 4 AXES 1.0 'PRESS [PA]'
TRAC 5 6 AXES 1.0 'DISPL. [M]'
TRAC 7 8 AXES 1.0 'DISPL. [M]'
LIST 3 4 AXES 1.0 'PRESS [PA]'
LIST 5 6 AXES 1.0 'DISPL. [M]'
LIST 7 8 AXES 1.0 'DISPL. [M]'
*
QUAL ECRO COMP 1 LECT e1 TERM REFE  1.63342E+5 TOLE 5.E-3
     ECRO COMP 1 LECT e3 TERM REFE  2.22104E+5 TOLE 5.E-3
*=================================================================
FIN
```

Numerical Solutions (Node-Centred Finite Volumes)

VFNCA1

The mesh generation file (K2000) is:

```
opti echo 1;
opti titr 'VFNCA1';
opti sauv form 'vfnca1.msh';
opti trac psc ftra 'vfnca1_mesh.ps';
*
opti dime 2 elem qua4;
*
p1 = 0 0;
p2 = 2 0;
p3 = 2 1;
p4 = 0 1;
p5 = 0.4 0;
p6 = 0.4 0.4;
p7 = 0 0.4;
p8 = 0.4 1;
*
tol = 0.001;
*
c1 = p1 d 4 p5;
c2 = p5 d 4 p6;
c3 = p6 d 4 p7;
c4 = p7 d 4 p1;
expl = dall c1 c2 c3 c4 plan;
*
p9l = 1 0;
p9r = 1 0;
p10 = 1 0.4;
p11 = 2 0.4;
*
c1 = p5 d 6 p9l;
c2 = p9l d 4 p10;
c3 = p10 d 6 p6;
c4 = p6 d 4 p5;
air1a = dall c1 c2 c3 c4 plan;
*
c1 = p9r d 10 p2;
c2 = p2 d 4 p11;
c3 = p11 d 10 p10;
c4 = p10 d 4 p9r;
air1b = dall c1 c2 c3 c4 plan;
*
c1 = p6 d 6 p10 d 10 p11;
c2 = p11 d 6 p3;
c3 = p3 d 16 p8;
c4 = p8 d 6 p6;
air1c = dall c1 c2 c3 c4 plan;
*
elim tol (air1a et air1c);
elim tol (air1b et air1c);
air1 = air1a et air1b et air1c;
*
c1 = p7 d 4 p6;
c2 = p6 d 6 p8;
c3 = p8 d 4 p4;
c4 = p4 d 6 p7;
air2 = dall c1 c2 c3 c4 plan;
elim tol (air1c et air2);
elim tol (expl et air2);
elim tol (expl et air1a);
*
air = air1 et air2;
flui = expl et air;
*
e1 = expl elem cont p1;
e3 = air1 elem cont p3;
*
p1s = p1 plus p1;
p2s = p2 plus p1;
p3s = p3 plus p1;
p4s = p4 plus p1;
p9s = p9l plus p1;
p10s = p10 plus p1;
p12s = 1 1;
c1s = p1s d 10 p9s d 10 p2s;
c2s = p2s d 10 p3s;
c3s = p3s d 10 p12s d 10 p4s;
c4s = p4s d 10 p1s;
c5s = p9s d 4 p10s;
stru = c1s et c2s et c3s et c4s et c5s;
*
c1p = p2s d 10 p9s d 10 p1s;
c2p = p3s d 10 p2s;
c3p = p4s d 10 p12s d 10 p3s;
c4p = p1s d 10 p4s;
pext = c4p et c3p et c2p et c1p;
elim tol (stru et pext);
*
nfsa = cont flui;
*
mesh = flui et stru et pext et e1 et e3 et nfsa;
*
sauv form mesh;
trac qual mesh;
*
list (nbel mesh);
list (nbno mesh);
*
fin;
```

The EUROPLEXUS input file reads:

```
VFNCA1
ECHO
!conv win
CAST mesh
DPLA ALE
DIME
 PT2L 235 PT3L 64 MC24 200 ED01 64 CL22 60 ZONE 3
 NALE 26 NBLE 167 NDVC 868
TERM
GEOM MC24 flui ED01 stru CL22 pext TERM
COMP EPAI 0.01 LECT stru TERM
     COUL turq LECT air  TERM
          roug LECT expl TERM
          bleu LECT stru TERM
          jaun LECT pext TERM
GRIL LAGR LECT stru TERM
     EULE LECT nfsa TERM
     AUTO AUTR
MATE MCGP NCOM 1 R 8.3143E3
          COMP 'Air' PM 29.0 CV1 2.07585E4 CV2 0 CV3 0
          LECT flui TERM
     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
     IMPE PIMP RO 1.1897 PRES 1.E5 PREF 0
          LECT pext TERM
INIT MCOM COMP 'Air' MFRA 1.0 LECT flui TERM
          PRES 1.E6 LECT expl TERM
          PRES 1.E5 LECT air  TERM
          TEMP 586.36 LECT expl TERM
          TEMP 293.16 LECT air  TERM
          VEL1 0.0 LECT flui TERM
          VEL2 0.0 LECT flui TERM
          VEL3 0.0 LECT flui TERM
LINK COUP FSA LECT nfsa TERM
ECRI DEPL VITE ACCE FINT FEXT CONT ECRO MCVA TFRE 1.E-3
          POIN LECT p1 p5 p6 p7 p3 TERM
          ELEM LECT e1 e3 TERM
     FICH ALIC TFRE 5.E-5
     FICH ALIC TEMP FREQ 1
          POIN LECT p1 p4 p5 p6 p7 p3 p1s p2s p3s p4s p9s p10s p12s TERM
          ELEM LECT e1 e3 TERM
OPTI NOTE LOG 1
     CSTA 0.5
     MC ORDR 2 NUFL ROE
CALC TINI 0.0 PAS1 1.E-5
     TFIN 5.E-3
*=================================================================
PLAY
CAME   1 EYE   1.00000E+00  5.00000E-01  5.03115E+00
!        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
sler cam1 1 nfra 1
scen geom navi free
          face hfro
     vect scco fiel vite scal user prog 10 pas 10 140 term
          SUPP LECT air  TERM
     text vsca
     colo pape
freq 0 tfre 2.5e-3
go
trac offs fich bmp rend
go
trac offs fich bmp rend
ENDPLAY
*=================================================================
SUIT
Post treatment
ECHO
 conv win
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
*=================================================================
PLAY
CAME   1 EYE   1.00000E+00  5.00000E-01  5.03115E+00
!        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
sler cam1 1 nfra 1
scen geom navi free
     iso  fili fiel mcpr scal user prog 0.61E5 pas 0.2E5 3.21E5 term
          SUPP LECT flui TERM
     text isca
     vect scco fiel vite scal user prog 10 pas 10 140 term
          SUPP LECT flui TERM
     text vsca
     colo pape
trac offs fich avi     nocl nfto 101 fps 10 kfre 10 comp -1 rend
freq 1
gotr loop 99 offs fich avi cont nocl rend
go
trac offs fich avi cont rend
ENDPLAY
*=================================================================
SUIT
Post-treatment (time curves from alice temps file)
ECHO
*
RESU ALIC TEMP GARD PSCR
*
SORT GRAP
*
AXTE 1.0 'Time [s]'
*
COUR  3 'p_e1'    MCPR COMP 1 NOEU LECT p1 TERM
COUR  4 'p_e3'    MCPR COMP 1 NOEU LECT p3 TERM
COUR  5 'dx_p10s' DEPL COMP 1 POIN LECT p10s TERM
COUR  6 'dy_p12s' DEPL COMP 2 POIN LECT p12s TERM
COUR  7 'dx_p9s'  DEPL COMP 1 POIN LECT p9s TERM
COUR  8 'dy_p9s'  DEPL COMP 2 POIN LECT p9s TERM
```

```
COUR 101 'p_p4'    MCPR COMP 1 NOEU LECT p4 TERM
COUR 102 'r_p4'    MCRO COMP 1 NOEU LECT p4 TERM
COUR 103 't_p4'    MCTE COMP 1 NOEU LECT p4 TERM
COUR 104 'y1_p4'   MCMF COMP 1 NOEU LECT p4 TERM
*
RCOU 13 'p_e1' FICH 'vfncan.pun' RENA 'p_e1_an'
RCOU 14 'p_e3' FICH 'vfncan.pun' RENA 'p_e3_an'
RCOU 15 'dx_p10s' FICH 'vfncan.pun' RENA 'dx_p10s_an'
RCOU 16 'dy_p12s' FICH 'vfncan.pun' RENA 'dy_p12s_an'
RCOU 17 'dx_p9s' FICH 'vfncan.pun' RENA 'dx_p9s_an'
RCOU 18 'dy_p9s' FICH 'vfncan.pun' RENA 'dy_p9s_an'
*
TRAC 3 4 13 14 AXES 1.0 'PRESS [PA]'
     COLO noir noir roug roug
TRAC 5 6 15 16 AXES 1.0 'DISPL. [M]'
     COLO noir noir roug roug
TRAC 7 8 17 18 AXES 1.0 'DISPL. [M]'
     COLO noir noir roug roug
TRAC 101 AXES 1.0 'PRESS. [PA]'
TRAC 102 AXES 1.0 'DENS. [KG/M3]'
TRAC 103 AXES 1.0 'TEMP. [K]'
TRAC 104 AXES 1.0 'FRAC. [-]'
LIST 3 4 AXES 1.0 'PRESS [PA]'
LIST 5 6 AXES 1.0 'DISPL. [M]'
LIST 7 8 AXES 1.0 'DISPL. [M]'
*
QUAL MCPR COMP 1 LECT p1 TERM REFE  1.56019E+5 TOLE 5.E-3
     MCPR COMP 1 LECT p3 TERM REFE  3.16715E+5 TOLE 5.E-3
*=================================================================
FIN
```

Numerical Solutions (Cell-Centred Finite Volumes)

VFCC00

The mesh generation file (K2000) is:

```
opti echo 1;
opti titr 'VFCC00';
opti sauv form 'vfcc00.msh';
opti trac psc ftra 'vfcc00_mesh.ps';
*
opti dime 2 elem qua4;
*
p1 = 0 0;
p2 = 2 0;
p3 = 2 1;
p4 = 0 1;
p5 = 0.4 0;
p6 = 0.4 0.4;
p7 = 0 0.4;
p8 = 0.4 1;
*
tol = 0.001;
*
c1 = p1 d 4 p5;
c2 = p5 d 4 p6;
c3 = p6 d 4 p7;
c4 = p7 d 4 p1;
expl = dall c1 c2 c3 c4 plan;
*
c1 = p5 d 16 p2;
c2 = p2 d 10 p3;
c3 = p3 d 16 p8;
c4 = p8 d 6 p6 d 4 p5;
air1 = dall c1 c2 c3 c4 plan;
*
c1 = p7 d 4 p6;
c2 = p6 d 6 p8;
c3 = p8 d 4 p4;
c4 = p4 d 6 p7;
air2 = dall c1 c2 c3 c4 plan;
*
air = air1 et air2;
flui = expl et air;
elim tol flui;
*
e1 = expl elem cont p1;
e3 = air1 elem cont p3;
*
p1s = p1 plus p1;
p2s = p2 plus p1;
p3s = p3 plus p1;
p4s = p4 plus p1;
p9s = 1 0;
p10s = 1 0.4;
p12s = 1 1;
c1s = p1s d 10 p9s d 10 p2s;
c2s = p2s d 10 p3s;
c3s = p3s d 10 p12s d 10 p4s;
c4s = p4s d 10 p1s;
c5s = p9s d 4 p10s;
stru = c1s et c2s et c3s et c4s et c5s;
*
elim tol (flui et stru);
*
mesh = flui et stru et e1 et e3;
*
sauv form mesh;
trac qual mesh;
*
list (nbel mesh);
list (nbno mesh);
*
fin;
```

The EUROPLEXUS input file reads:

```
VFCC00
ECHO
!conv win
CAST mesh
DPLA ALE
DIME
 PT2L 231 PT3L 64 Q4VF 200 ED01 64 ZONE 2
 NALE 26 NBLE 167
TERM
GEOM Q4VF flui ED01 stru TERM
COMP EPAI 0.01 LECT stru TERM
     COUL turq LECT air  TERM
          roug LECT expl TERM
          bleu LECT stru TERM
GRIL LAGR LECT stru TERM
     AUTO AUTR
MATE GAZP RO 5.9485 GAMMA 1.4 CV 716.75 PINI 1.E6 PREF 1.E5
          LECT expl TERM
     GAZP RO 1.1897 GAMMA 1.4 CV 716.75 PINI 1.E5 PREF 1.E5
          LECT air TERM
     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
ECRI DEPL VITE ACCE FINT FEXT CONT ECRO TFRE 1.E-3
          POIN LECT p1 p5 p6 p7 p3 TERM
          ELEM LECT e1 e3 TERM
     FICH ALIC TFRE 5.E-5
     FICH ALIC TEMP FREQ 1
          POIN LECT p1 p5 p6 p7 p3 p1s p2s p3s p4s p9s p10s p12s TERM
          ELEM LECT e1 e3 TERM
OPTI NOTE LOG 1
     CSTA 0.5
     VFCC FCON 1 ! rusanov
CALC TINI 0.0 PAS1 1.E-5 TFIN 5.E-3
*=================================================================
PLAY
CAME   1 EYE   1.00000E+00  5.00000E-01  5.03115E+00
!        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
sler cam1 1 nfra 1
scen geom navi free
          face hfro
     vect scco fiel vcvi scal user prog 10 pas 10 140 term
          SUPP LECT air  TERM
     text vsca
     colo pape
freq 0 tfre 2.5e-3
go
trac offs fich bmp rend
go
trac offs fich bmp rend
ENDPLAY
*=================================================================
SUIT
Post treatment
ECHO
 conv win
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
*=================================================================
PLAY
CAME   1 EYE   1.00000E+00  5.00000E-01  5.03115E+00
!        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
sler cam1 1 nfra 1
scen geom navi free
     iso  fili fiel ecro 1 scal user prog 0.61E5 pas 0.2E5 3.21E5 term
          SUPP LECT flui TERM
     text isca
     vect scco fiel vcvi scal user prog 10 pas 10 140 term
          SUPP LECT flui TERM
     text vsca
     colo pape
trac offs fich avi     nocl nfto 101 fps 10 kfre 10 comp -1 rend
freq 1
gotr loop 99 offs fich avi cont nocl rend
go
trac offs fich avi cont rend
ENDPLAY
*=================================================================
SUIT
Post-treatment (time curves from alice temps file)
ECHO
*
RESU ALIC TEMP GARD PSCR
*
SORT GRAP
*
AXTE 1.0 'Time [s]'
*
COUR  1 'vcvi_e1' VCVI NORM ELEM LECT e1 TERM
COUR  2 'vcvi_e3' VCVI NORM ELEM LECT e3 TERM
COUR  3 'p_e1'    ECRO COMP 1 ELEM LECT e1 TERM
COUR  4 'p_e3'    ECRO COMP 1 ELEM LECT e3 TERM
COUR  5 'dx_p10s' DEPL COMP 1 POIN LECT p10s TERM
COUR  6 'dy_p12s' DEPL COMP 2 POIN LECT p12s TERM
COUR  7 'dx_p9s'  DEPL COMP 1 POIN LECT p9s TERM
COUR  8 'dy_p9s'  DEPL COMP 2 POIN LECT p9s TERM
*
TRAC 1 2 AXES 1.0 'VELOC. [M/S]'
TRAC 3 4 AXES 1.0 'PRESS [PA]'
TRAC 5 6 AXES 1.0 'DISPL. [M]'
TRAC 7 8 AXES 1.0 'DISPL. [M]'
LIST 1 2 AXES 1.0 'VELOC. [M/S]'
LIST 3 4 AXES 1.0 'PRESS [PA]'
LIST 5 6 AXES 1.0 'DISPL. [M]'
LIST 7 8 AXES 1.0 'DISPL. [M]'
*
! J'ai l'impression che la qualification de VCVi ne marche pas ...
!QUAL VCVI COMP 1 LECT e1 TERM REFE  0.00000E+0 TOLE 5.E-3
!     VCVI COMP 2 LECT e3 TERM REFE  0.00000E+0 TOLE 5.E-3
QUAL ECRO COMP 1 LECT e1 TERM REFE  1.72471E+5 TOLE 5.E-3
     ECRO COMP 1 LECT e3 TERM REFE  2.18842E+5 TOLE 5.E-3
*=================================================================
FIN
```

Comparison of Numerical Solutions

EFVFA1

The EUROPLEXUS input file is:

```
EFVFA1
ECHO
*
RESU ALIC TEMP 'vfcc00.alt' GARD PSCR
*
SORT GRAP
*
AXTE 1.0 'Time [s]'
*
COUR 33 'p_e1_cc'    ECRO COMP 1 ELEM LECT e1 TERM
COUR 34 'p_e3_cc'    ECRO COMP 1 ELEM LECT e3 TERM
COUR 35 'dx_p10s_cc' DEPL COMP 1 POIN LECT p10s TERM
COUR 36 'dy_p12s_cc' DEPL COMP 2 POIN LECT p12s TERM
COUR 37 'dx_p9s_cc'  DEPL COMP 1 POIN LECT p9s TERM
COUR 38 'dy_p9s_cc'  DEPL COMP 2 POIN LECT p9s TERM
*
RCOU 13 'p_e1'    FICH 'elfi00.pun' RENA 'p_e1_ef'
RCOU 14 'p_e3'    FICH 'elfi00.pun' RENA 'p_e3_ef'
RCOU 15 'dx_p10s' FICH 'elfi00.pun' RENA 'dx_p10s_ef'
RCOU 16 'dy_p12s' FICH 'elfi00.pun' RENA 'dy_p12s_ef'
RCOU 17 'dx_p9s'  FICH 'elfi00.pun' RENA 'dx_p9s_ef'
RCOU 18 'dy_p9s'  FICH 'elfi00.pun' RENA 'dy_p9s_ef'
*
RCOU 23 'p_e1'    FICH 'vfnca1.pun' RENA 'p_e1_nc'
RCOU 24 'p_e3'    FICH 'vfnca1.pun' RENA 'p_e3_nc'
RCOU 25 'dx_p10s' FICH 'vfnca1.pun' RENA 'dx_p10s_nc'
RCOU 26 'dy_p12s' FICH 'vfnca1.pun' RENA 'dy_p12s_nc'
RCOU 27 'dx_p9s'  FICH 'vfnca1.pun' RENA 'dx_p9s_nc'
RCOU 28 'dy_p9s'  FICH 'vfnca1.pun' RENA 'dy_p9s_nc'
*
TRAC 13 14 23 24 33 34 AXES 1.0 'PRESS [PA]'
     COLO noir noir roug roug vert vert
TRAC 15 16 25 26 35 36 AXES 1.0 'DISPL. [M]'
     COLO noir noir roug roug vert vert
TRAC 17 18 27 28 37 38 AXES 1.0 'DISPL. [M]'
     COLO noir noir roug roug vert vert
*================================================================
```

The initial conditions of the gases in the Finite Element model (FLUT material) are:

	$\gamma = c_P / c_V$	ρ	i	p
Low-pressure	1.4	1.1897 Kg/m^3	2.10137E5 J/Kg	1.0E5 Pa
High-pressure	1.4	5.9485 Kg/m^3	4.20274E5 J/Kg	1.0E6 Pa

The FE model is built, as usual, by keeping the fluid and structural nodes distinct (although superposed). All fluid nodes along the F-S interface are subjected to the LINK FSA condition.

The Node-Centered Finite Volume input mesh is basically the same as for the FE model, since the N-C volumes are built up automatically by the code. The only notable difference is the presence of an additional layer of CL22 boundary condition elements placed along the external envelope of the structure (merged nodes with the structure). These elements are used to simulate the presence of the external atmosphere to the structure, by means of a constant imposed pressure of 1.0E5 Pa (assigned via the IMPE PIMP material model). In the FE (and in the C-C FV) model this is not necessary because the fluid material (FLUT or GAZP, respectively) admits a PREF parameter (reference pressure) which can be set to 1.0E5 Pa. However, unfortunately this does not seem to be possible with the MCGP material used by N-C Finite Volumes.

The initial conditions of the gases in the Node-Centered Finite Volume model are:

w	R	c_V
29 Kg/Kmol	8314.3 J/Kmol·K	20785.75 J/ Kmol·K

and:

	T	p
Low-pressure	293.16 K	1.0E5 Pa
High-pressure	586.36 K	1.0E6 Pa

As concerns fluid-structure interaction, the same LINK FSA condition as used in the FE model is repeated here.

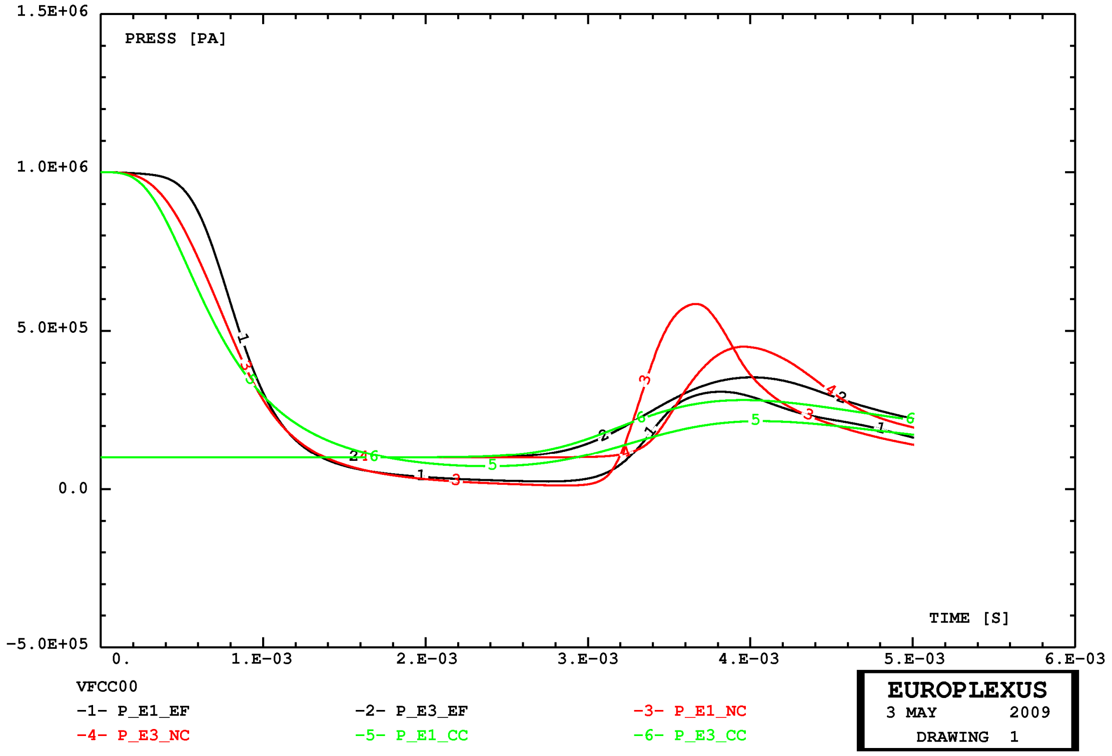
The Cell-Centered Finite Volume input mesh is similar to the FE model, but the structure and fluid nodes are merged together (`ELIM` command in Cast3m). No FSA condition is needed in this case.

The initial conditions of the gases in the Cell-Centered Finite Volume model (`GAZP` material) are similar to those for FE (`FLUT` material):

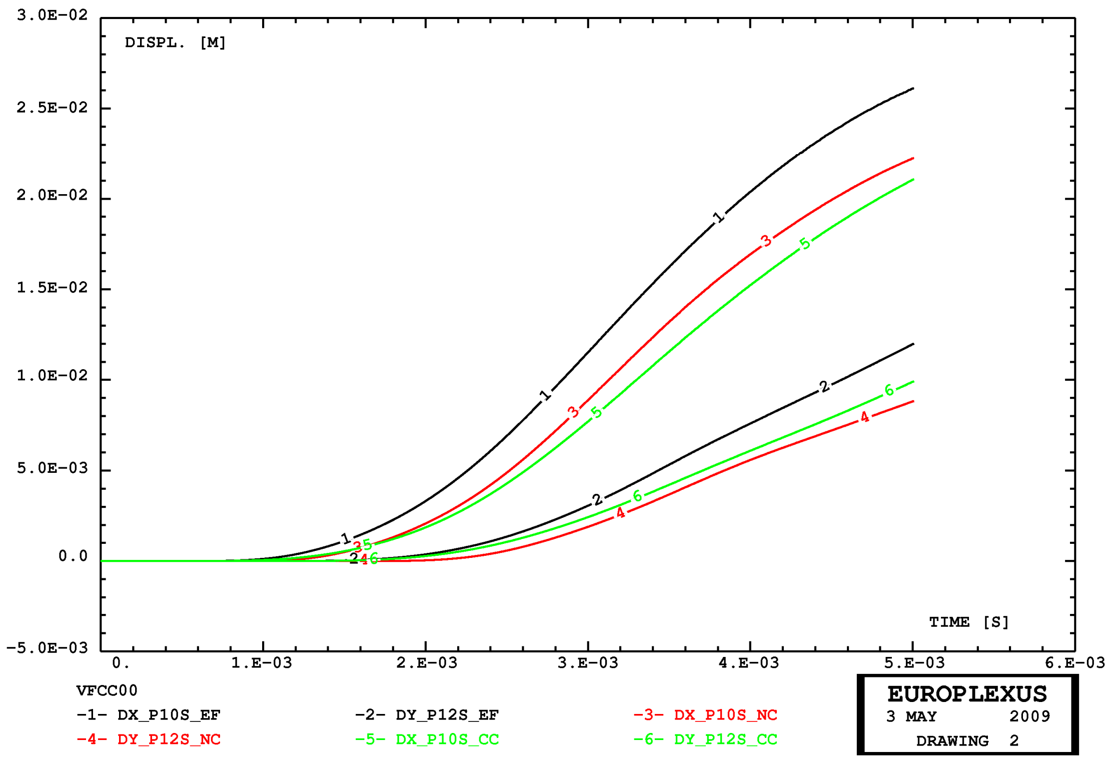
	$\gamma = c_P / c_V$	ρ	c_V	p
Low-pressure	1.4	1.1897 Kg/m^3	716.75 J/ Kg·K	1.0E5 Pa
High-pressure	1.4	5.9485 Kg/m^3	716.75 J/ Kg·K	1.0E6 Pa

Note that the initial pressure is given directly rather than specifying the specific internal energy. Furthermore, the (optional) specific heat at constant volume c_V is specified. This has no effect on the solution, but is used to compute and print the temperatures.

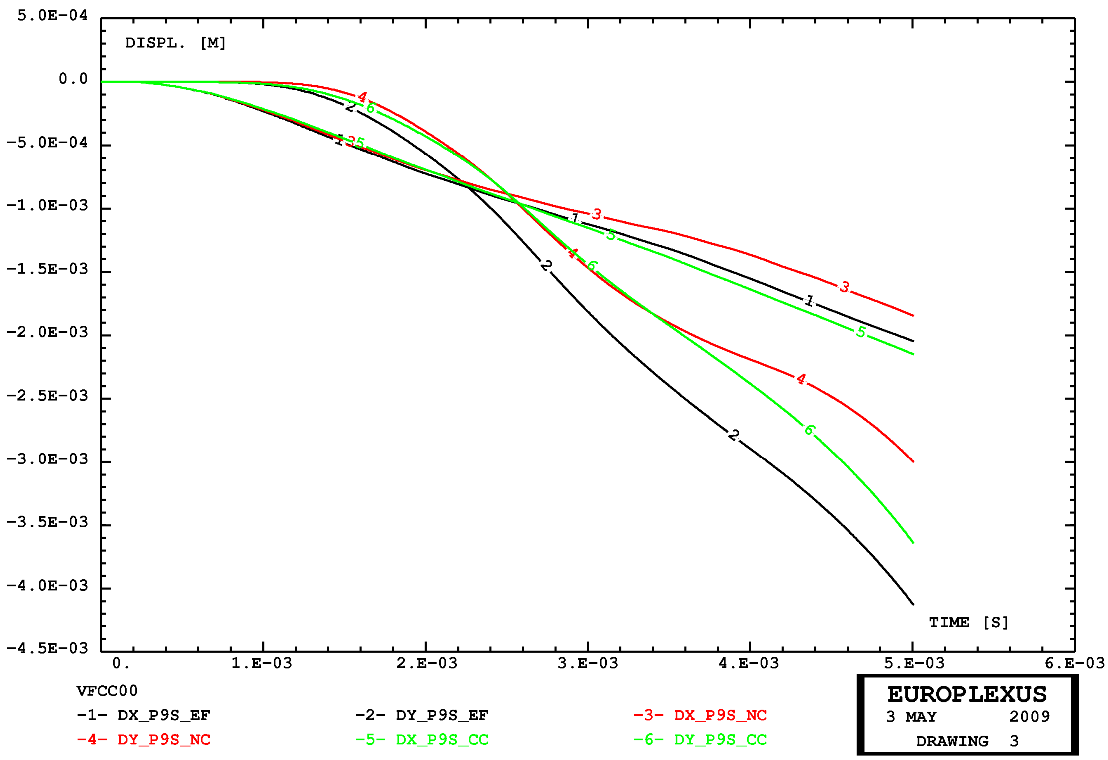
As already mentioned, both in the FE and in the C-C FV models a reference pressure value of `PREF 1.E5` is specified for both gases.
Some results: fluid pressures:



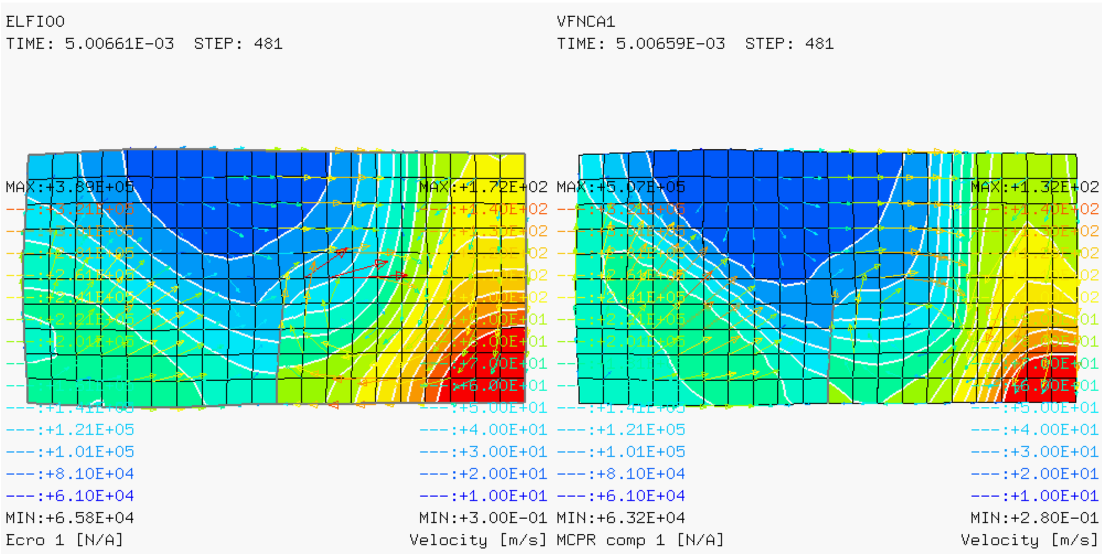
Structural displacements:



Structural displacements in another point:



Final solution with Finite Elements and with Node-Centred Finite Volumes:



Final solution with Cell-Centred Finite Volumes: