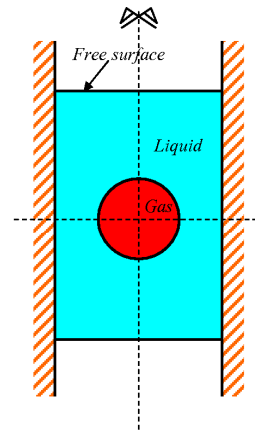


Exercise 3 – Bubble expansion in a Tube

This is also a purely fluid problem because the tank is rigid and therefore does not need to be modeled. However, unlike the previous example, there are two different fluids interacting with each other. The tube wall is vertical so the BC may be trivially imposed as a blockage in the horizontal direction.

- Try out fully Lagrangian solution
- Try out ALE solution with Lagrangian bubble surface (single-component fluid material)
- Try out fully ALE solution with ALE bubble surface (multi-phase multi-component fluid material)



41

Geometric data:

The calculation is 2-D axisymmetric. The tube is 26.4 units in diameter and the fluid zone is 40 units high. The explosive bubble is 6.29 units in diameter.

Materials

The explosive bubble is a perfect gas with $\gamma = 1.4$, initial density 100 and initial specific energy 2.5×10^5 , thus resulting in an initial pressure of:

$$p_0^{\text{bubble}} = (1.4 - 1) \cdot 100 \cdot 2.5 \times 10^5 = 1.0 \times 10^7$$

The surrounding liquid has a density of 1000 and a bulk modulus of 2.0×10^9 .

The tube is rigid and does not need to be modelled.

Thanks to symmetries with respect to the x- and y-axes, only $\frac{1}{4}$ of the geometry needs to be modelled.

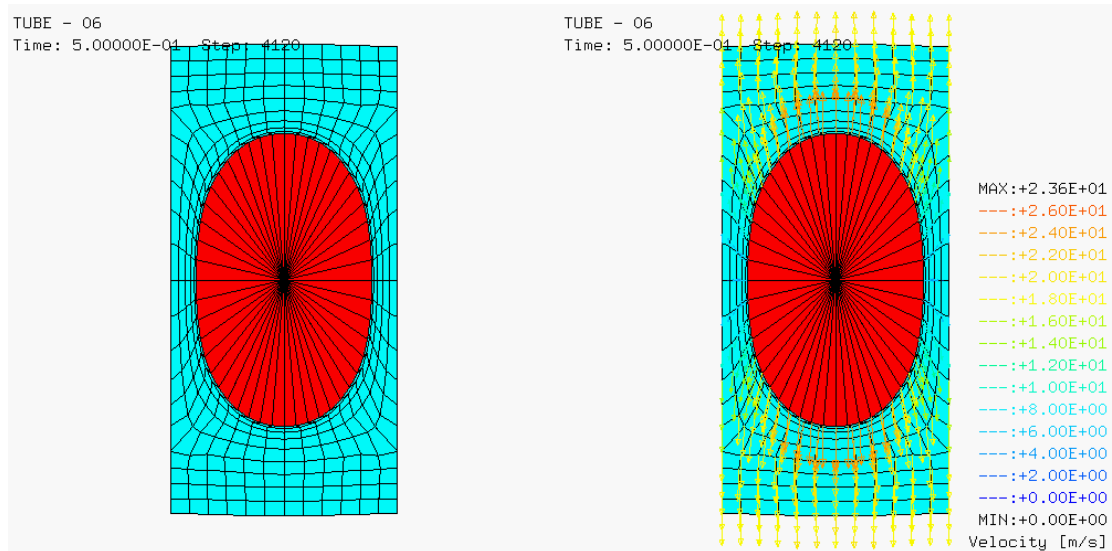
We want to study the effects of the explosion up to 500 ms of physical time.

Because the two fluids have different nature, they may not be freely intermixed with each other during the simulation, unlike in the previous example. Therefore, if one takes a single-component model for the fluid materials, the bubble surface needs to be modelled as Lagrangian.

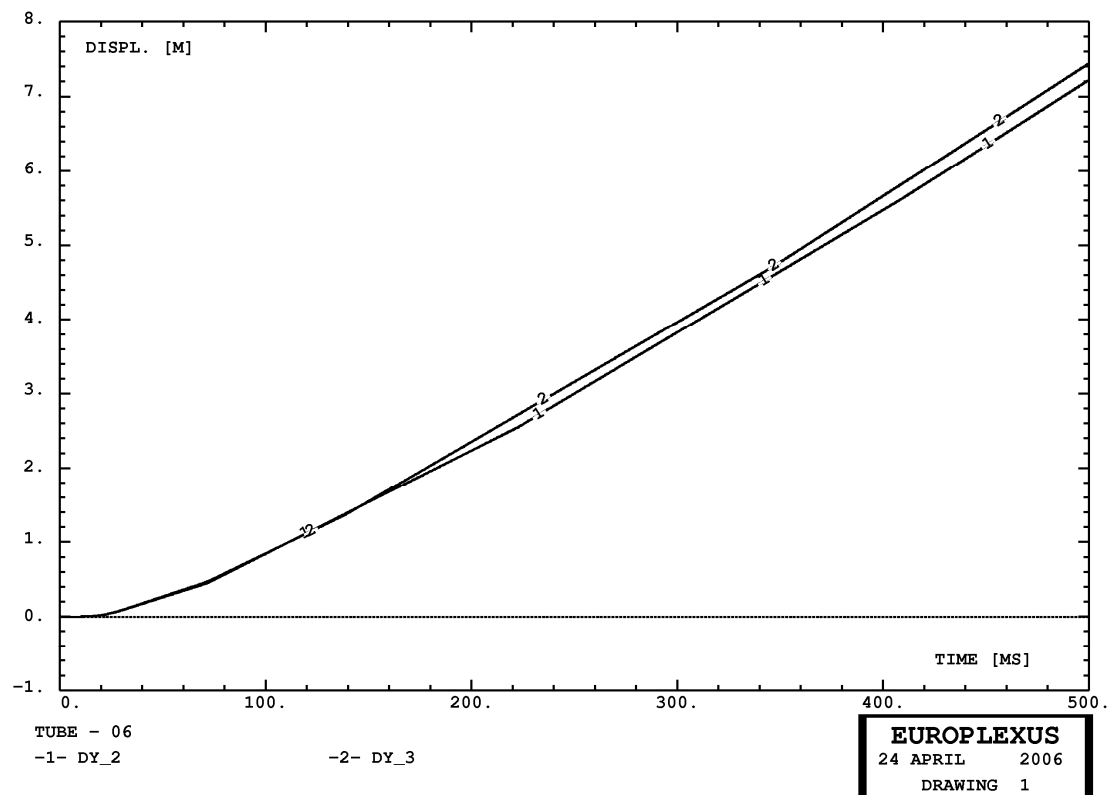
TUBE06

Lagrangian solution: the whole mesh is Lagrangian.

The numerical solution is able to proceed up to 500 ms. However, some large distortions in the fluid mesh occur due to the large growth of the bubble. The final mesh and the final velocity distribution is:

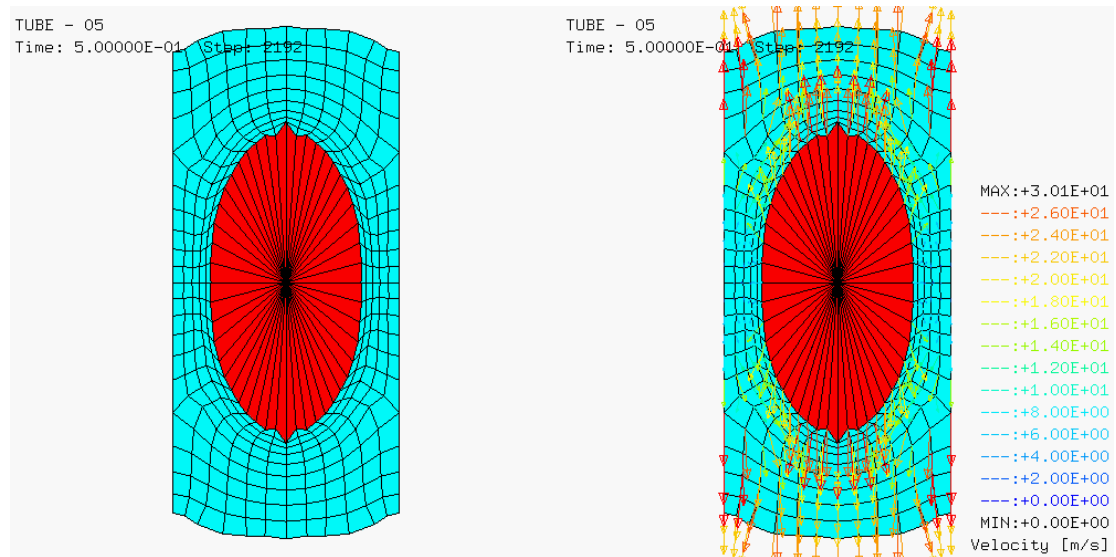


The computed vertical displacements of the upper right corner and of the upper centerpoint are shown hereafter:

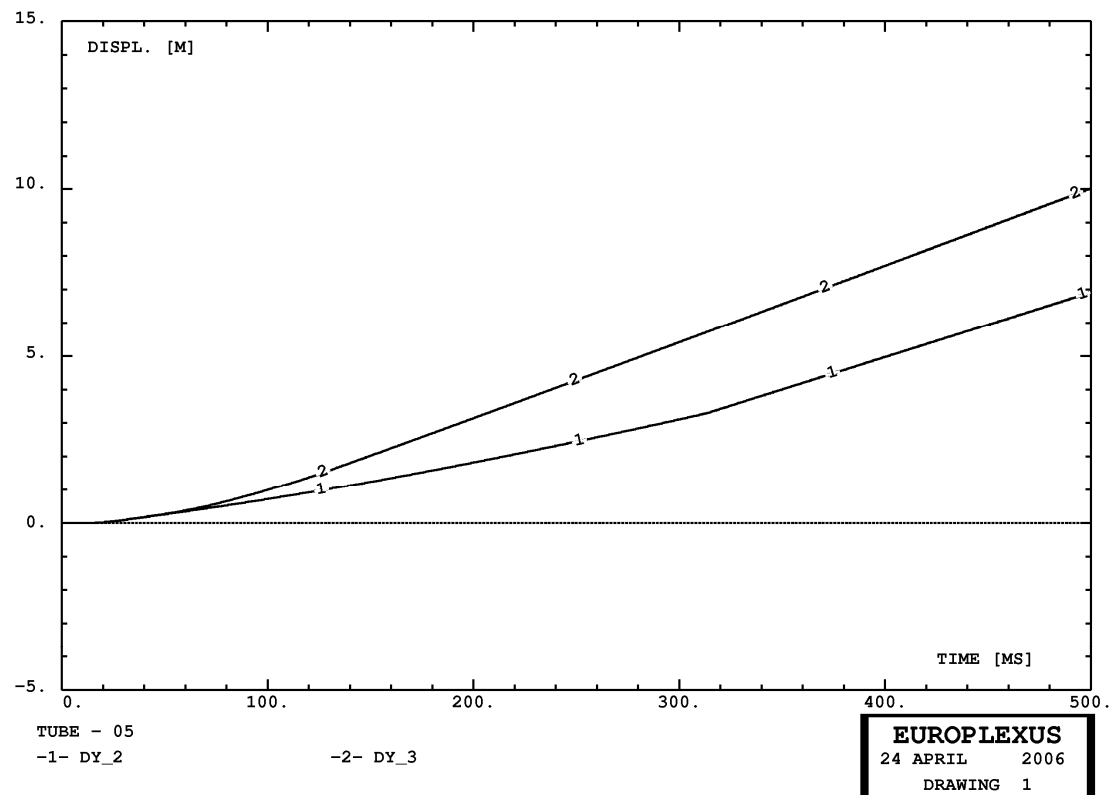


TUBE05

ALE solution with a single-component fluid material model: the whole mesh is ALE except the bubble interface that is Lagrangian. The final mesh and velocity is:

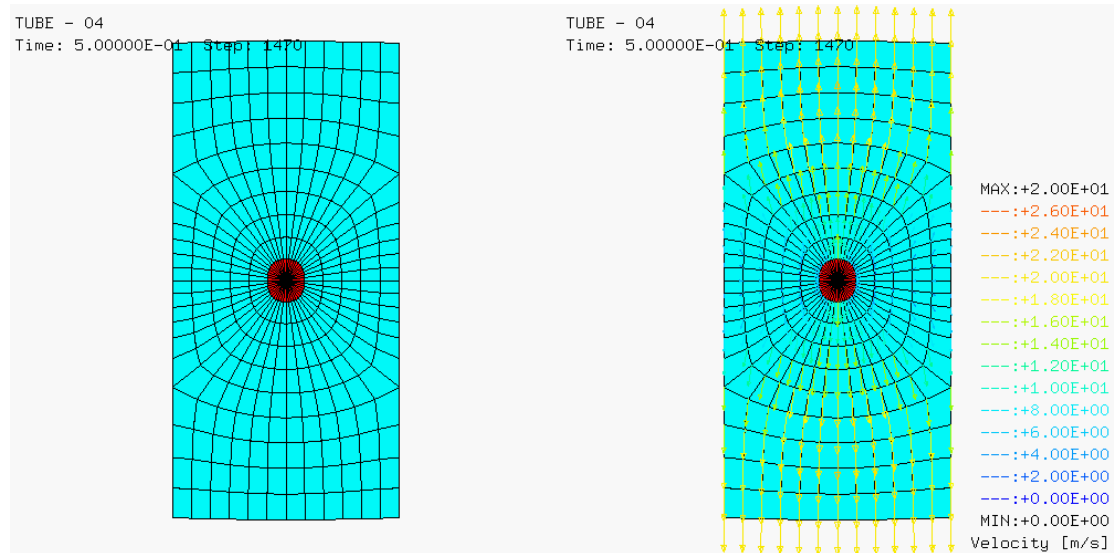


The computed displacements are:

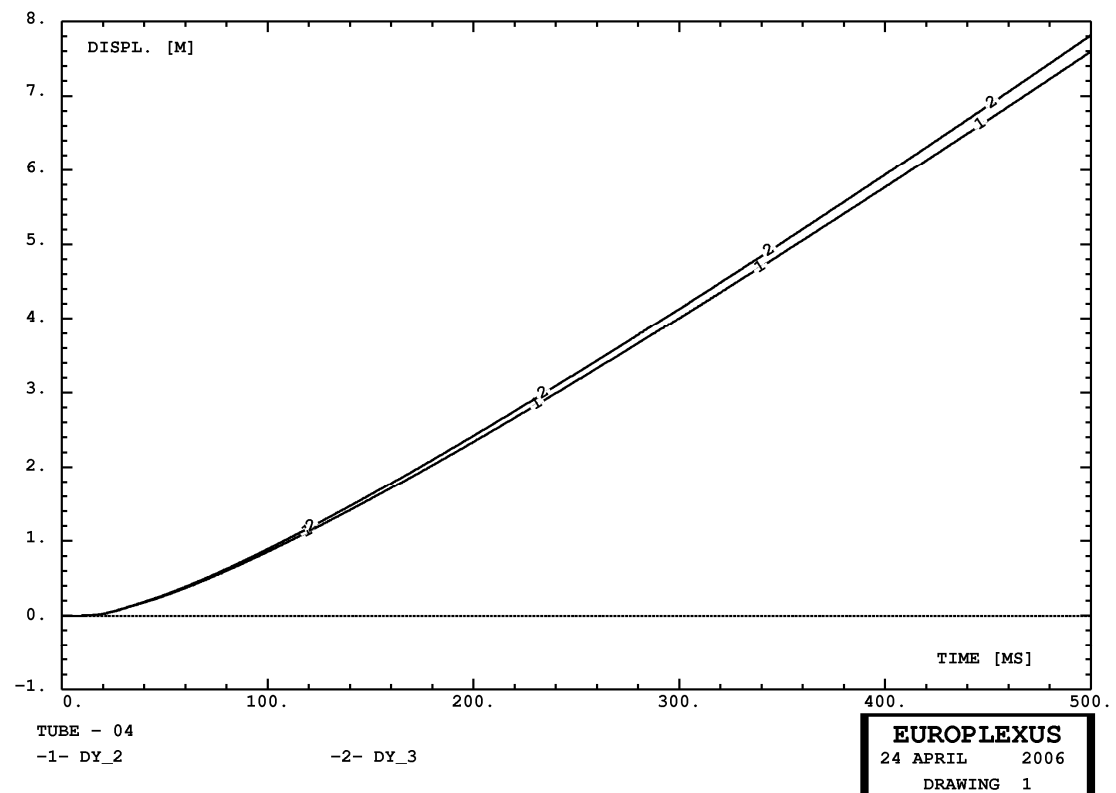


TUBE04

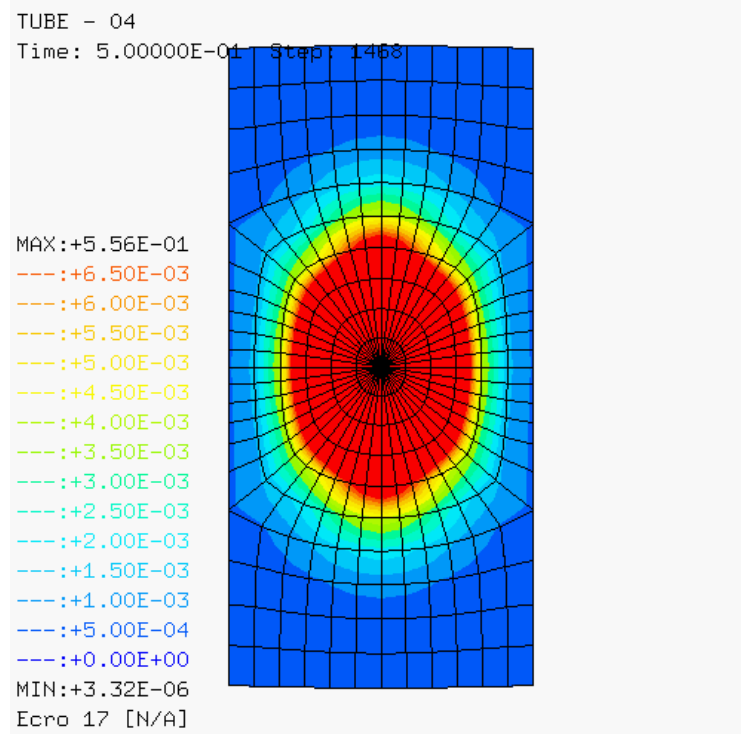
ALE solution with a multi-phase, multi-component fluid material model: the whole mesh is ALE including the bubble interface. The final mesh is (note that here colors do not represent materials!) and velocity is:



The computed displacements are:



To see the approximate position of the bubble interface, one may plot the mass fraction distribution of the bubble material component:



The input file for the test TUBE04 is:

```
TUBE - 04
*-----
ECHO
*CONV win
*-----Problem type
AXIS NOML ALE
*-----Dimensioning
DIME
FTZL 107 FL23 12 FL24 84 ZONE 2
NALE 1 NBLE 98
NREF 1020
ECRO 3264
TERM
*-----Geometry
GEOM LIBR POIN 107 FL23 12 FL24 84 TERM
0.0000E+00 0.0000E+00 3.14500E+00 0.0000E+00 3.11810E+00
4.10500E-01 3.03780E+00 8.13990E-01 2.90560E+00 1.20350E+00
2.72360E+00 1.57250E+00 2.49510E+00 1.91460E+00 2.22390E+00
2.22390E+00 1.91460E+00 2.49510E+00 1.57250E+00 2.72360E+00
1.20350E+00 2.90560E+00 8.13990E-01 3.03780E+00 4.10500E-01
3.11810E+00 0.0000E+00 3.14500E+00 5.15600E+00 0.0000E+00
5.09970E+00 7.30510E-01 5.00880E+00 1.45180E+00 4.86420E+00
2.15130E+00 4.64850E+00 2.81320E+00 4.34360E+00 3.41610E+00
3.93350E+00 3.93350E+00 3.41610E+00 4.34360E+00 2.81320E+00
4.64850E+00 2.15130E+00 4.86420E+00 1.45180E+00 5.00880E+00
7.30510E-01 5.09970E+00 0.0000E+00 5.15600E+00 7.16700E+00
0.0000E+00 7.11050E+00 1.06860E+00 7.02640E+00 2.12620E+00
6.88680E+00 3.15600E+00 6.65900E+00 4.13330E+00 6.30030E+00
5.02060E+00 5.76190E+00 5.76190E+00 5.02060E+00 6.30030E+00
4.13330E+00 6.65900E+00 3.15600E+00 6.88680E+00 2.12620E+00
7.02640E+00 1.06860E+00 7.11050E+00 0.0000E+00 7.16700E+00
9.17800E+00 0.0000E+00 9.13620E+00 1.42630E+00 9.07480E+00
2.84270E+00 8.96560E+00 4.23180E+00 8.76610E+00 5.56250E+00
8.40820E+00 6.78060E+00 7.78260E+00 7.78260E+00 6.78060E+00
8.40820E+00 5.56250E+00 8.76610E+00 4.23180E+00 8.96560E+00
2.84270E+00 9.07480E+00 1.42630E+00 9.13620E+00 0.0000E+00
9.17800E+00 1.11890E+01 0.0000E+00 1.11680E+01 1.80470E+00
4.13370E+01 3.60290E+00 1.10790E+01 5.38310E+00 2.09600E+01
7.11960E+00 1.07060E+01 8.75410E+00 1.01290E+01 1.01290E+01
8.75410E+00 1.07060E+01 7.11960E+00 1.09600E+01 5.38310E+00
1.10790E+01 3.60290E+00 1.11370E+01 1.80470E+00 1.11680E+01
0.0000E+00 1.11890E+01 1.32000E+01 0.0000E+00 1.32000E+01
2.20000E+00 1.32000E+01 4.40000E+00 1.32000E+01 6.60000E+00
1.32000E+01 8.80000E+00 1.32000E+01 1.10000E+01 1.32000E+01
1.32000E+01 1.10000E+01 1.32000E+01 8.80000E+00 1.32000E+01
6.60000E+00 1.32000E+01 4.40000E+00 1.32000E+01 2.20000E+00
1.32000E+01 6.29420E-06 1.32000E+01 1.32000E+01 1.49000E+01
1.10000E+01 1.49000E+01 8.80000E+00 1.49000E+01 6.60000E+00
1.49000E+01 4.40000E+00 1.49000E+01 2.20000E+00 1.49000E+01
6.29420E-06 1.49000E+01 1.32000E+01 1.66000E+01 1.10000E+01
1.66000E+01 8.80000E+00 1.66000E+01 6.60000E+00 1.66000E+01
4.40000E+00 1.66000E+01 2.20000E+00 1.66000E+01 6.29420E-06
1.66000E+01 1.32000E+01 1.83000E+01 1.10000E+01 1.83000E+01
8.80000E+00 1.83000E+01 6.60000E+00 1.83000E+01 4.40000E+00
1.83000E+01 2.20000E+00 1.83000E+01 6.29420E-06 1.83000E+01
1.32000E+01 2.00000E+01 1.10000E+01 2.00000E+01 8.80000E+00
2.00000E+01 6.60000E+00 2.00000E+01 4.40000E+00 2.00000E+01
2.20000E+00 2.00000E+01 6.29420E-06 2.00000E+01
2 3 5 6 3 4 1 7 4 5
1 6 1 6 1 7 1 9 10
7 8 1 8 9 1 9 10
1 10 11 1 11 12 1 2 15
12 13 1 13 14 1 2 15
16 3 3 16 17 4 4 17 18 5
5 18 19 6 6 19 20 7 7 20
21 8 8 21 22 9 9 22 23 10
10 23 11 11 24 25 12 12 25
26 13 13 26 27 14 15 28 29 16
16 29 30 17 17 30 31 18 18 31
32 19 19 32 33 20 20 33 34 21
21 34 35 22 22 35 36 23 23 36
37 24 24 37 38 25 25 38 39 26
26 39 40 27 28 41 42 29 29 42
43 30 30 43 44 31 31 44 45 32
32 45 46 33 33 46 47 34 34 47
48 35 35 48 49 36 36 49 50 37
37 50 51 38 38 51 52 39 39 52
53 40 41 54 55 42 42 55 56 43
43 56 57 44 44 57 58 45 45 58
59 46 46 59 60 47 47 60 61 48
48 61 62 49 49 62 63 50 50 63
64 51 51 64 65 52 52 65 66 53
54 67 68 55 55 68 69 56 56 69
70 57 57 70 71 58 58 71 72 59
59 72 73 60 60 73 74 61 61 74
75 62 62 75 76 63 63 76 77 64
64 77 78 65 65 78 79 66 73 80
81 74 74 81 82 75 75 82 83 76
76 83 84 77 77 84 85 78 78 85
86 79 80 87 88 81 81 88 89 82
```

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82 89 90 83 83 90 91 84 84 91
92 85 85 92 93 86 87 94 95 88
88 95 96 89 89 96 97 90 90 97
98 91 91 98 99 92 92 99 100 93
94 101 102 95 95 102 103 96 96 103
104 97 97 104 105 98 105 106 99
99 106 107 100
*-----Geometric Complements
COMP GROU 2 'expl' LECT 1 PAS 1 12 TERM
      'liq' LECT 13 PAS 1 96 TERM
      COUL rousg LECT expl TERM
      turq LECT liq TERM
*-----Grid Motion
GRIL LAGR LECT 1 67 101 PAS 1 107 TERM
ALE TOUT
AUTO AUTR
*-----Material data
MATE FIMP NLQ 1 NGAS 1
FLUT RO 1.E3 EINT 0 GAMM 2.E9 PB 0 ITER 1 ALFO 1 BETO 1 KINT 0
ANGF 0 CL 0.5 CQ 2.56 PMIN 0 NUM 9 LECT 13 PAS 1 96 TERM
FLUT RO 1.E2 EINT 2.5E5 GAMM 1.4 PB 0 ITER 1 ALFO 1 BETO 1 KINT 0
ANGF 0 CL 0.5 CQ 2.56 PMIN 0 NUM 1 LECT 1 PAS 1 12 TERM
*-----Boundary conditions
LINK COUP
BLOQ 1 LECT 1 67 68 PAS 1 73 80 PAS 7 101 14 PAS 13
      79 PAS 7 107 TERM
BLOQ 2 LECT 1 67 2 15 28 41 54 TERM
*-----Outputs
ECRI COOR DEPL VITE CONT ECRO TFRE 100.E-3
PICH ALIC TEMP FREQ 1
      BP PGIN LECT 101 107 TERM
      ELEM LECT 1 91 TERM
*-----Options
OPTI NOTE
      csta 0.5
      log 1
      rezo gam0 0.5
*-----Transient calculation
CALCUL TIME 0 TEND 500.E-3
*-----ANIMATION
PLAY
CAME 1 EYE 0.00000E+00 0.00000E+00 1.19817E+02
      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 3.00000E+01
scen geom navi free
      lvect scoc scal user prog 0.e0 pas 2.e0 2.6ei term
      ltext vscr
      iso fill fiel ecro 17 scal user prog 0.e0 pas 0.0005e0 0.0065 term
      text isca
      colo pape
freq 0 tfre 2.e-3
slcr caml 1 nfra 1
trac offs fich avi nocl nfto 251 fps 10 kfre 10 comp -1
      symx symy rend
gotr loop 249 offs fich avi cont nocl
      symx symy rend
go
trac offs fich avi cont
      symx symy rend
ENDPLAY
*-----POST-TREATMENT
SUIT
Post-treatment
ECRO
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1000.0 'Time [ms]'
*-----Curve definitions
COUR 1 'dy_2' DEPL COMP 2 NOEU LECT 101 TERM
COUR 2 'dy_3' DEPL COMP 2 NOEU LECT 107 TERM
COUR 3 'pr_1' ECRO COMP 1 ELEM LECT 1 TERM
COUR 4 'pr_2' ECRO COMP 1 ELEM LECT 91 TERM
*-----Plots
trac 1 2 axes 1.0 'DISPL. [M]' yzer
trac 3 4 axes 1.0 'PRESS. [PA]'
*-----Results qualification
QUAL DEPL COMP 2 LECT 101 TERM REFE 7.59570E+00 TOL 1.E-2
      DEPL COMP 2 LECT 107 TERM REFE 7.81536E+00 TOL 1.E-2
      ECRO COMP 1 LECT 1 TERM REFE 1.81508E+04 TOL 1.E-2
      ECRO COMP 1 LECT 91 TERM REFE 8.01899E+03 TOL 1.E-2
*-----
FIN
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