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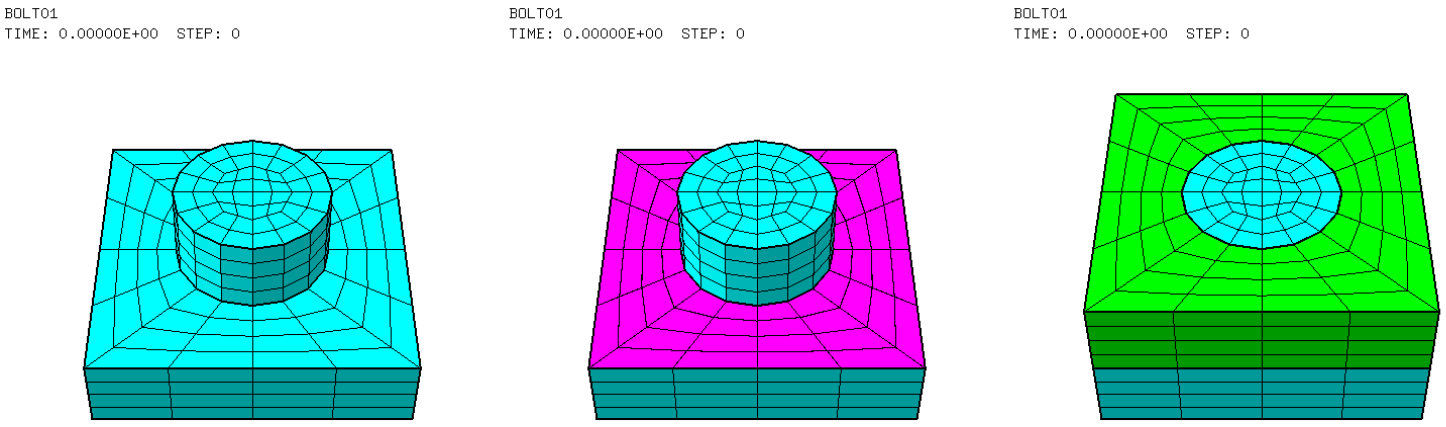

epx europlexus software

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Contents

List of Figures

List of Tables

1 Introduction

This document presents some numerical tests for the verification of the GLIS contact model available (among other contact models) in the EUROPLEXUS code (EPX).

EUROPLEXUS [1] is a computer code jointly developed by the French Commissariat á l'Energie Atomique (CEA DMT Saclay) and by EC-JRC. The code application domain is the numerical simulation of fast transient phenomena such as explosions, crashes and impacts in complex three-dimensional fluid-structure systems.

The Cast3m [2] software from CEA is used as a pre-processor to EPX when it is necessary to generate complex meshes.

2 The GLIS contact model

We briefly recall the characteristics of the `GLIS` contact model. This model implements the so-called "sliding surfaces" algorithm in 3D (or "siding lines" in 2D) and is based on the concept of *slave nodes* and *master surfaces*. Contact occurs when a slave node penetrates a master surface (element face).

As any contact algorithm, it consists of two parts:

1. A *contact detection* part which aims at detecting penetration of a body into another body.
2. A *contact enforcement* part which imposes suitable constraints to those parts of the model which would interpenetrate if left alone.

Contact enforcement can be obtained by two alternative types of approach:

- A *strong* (or coupled) approach, based upon kinematical constraints which are enforced implicitly by EPX's `LINK` model, making use of Lagrange multipliers.
- A *weak* (or decoupled) approach, based on a penalty method.

2.1 The test problem

The problem of interest here is the simulation of some plate blast experiments which are being conducted at NTNU Trondheim (Norway). A thin square aluminum plate is loaded by an explosive charge detonating at a short distance from the plate. The plate is mounted on a thick steel square frame which is attached to the plate by means of bolts along the perimeter of the plate (see Figure 36).

During preliminary experiments conducted it has been observed that, despite the fact that the frame bolts are being tightened by a relatively large torque, the plate tends to slip with respect to the frame, in the zones not directly in contact with the bolts, before eventually tearing apart under the action of the blast pressure (depending upon the charge mass and distance chosen for the experiment).

It seems therefore necessary to model the contact between the plate, the frame and the bolts, and to take into account the friction which occurs between the various parts (and the tightening couple on the bolts), in order to obtain an accurate numerical simulation of the experiment.

This report contains a series of preliminary numerical tests in a simplified geometrical set-up, in order to assess the `GLIS` contact model before using it in the realistic simulations of the experiments.

3 Numerical tests

We consider simplified versions (of gradually increasing complexity) of the problem of interest in order to check various aspects of the `GLIS` model that will likely be relevant in the realistic simulations to be performed.

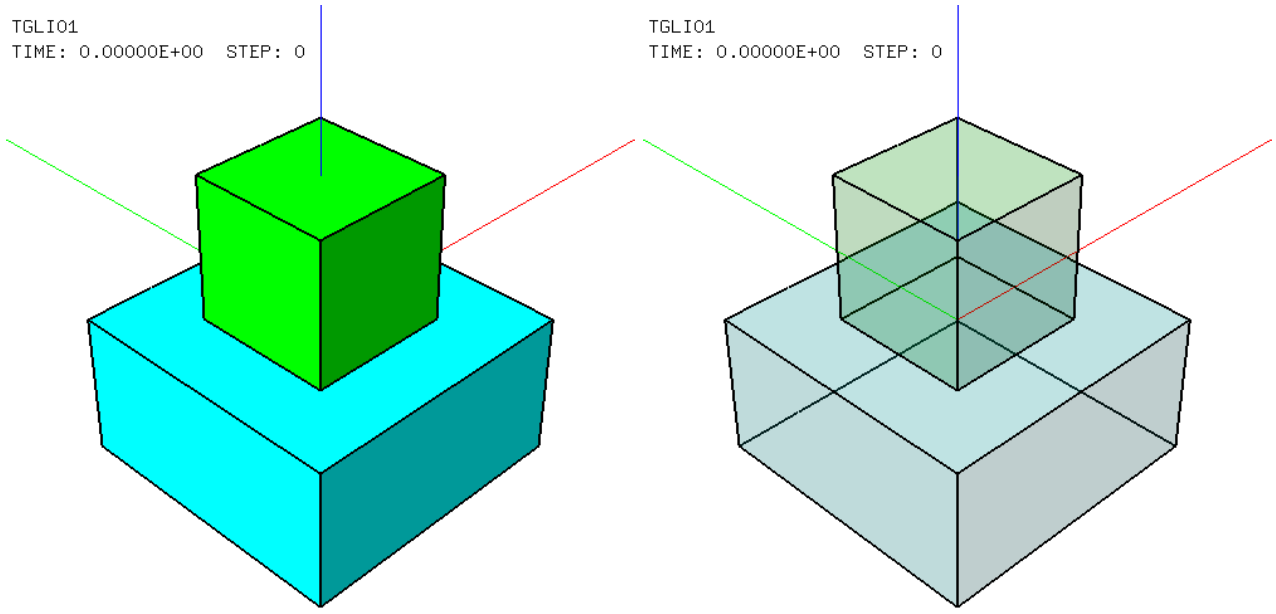
3.1 Test 1 – Contact between two blocks

The first problem considered is the contact beteen two solid blocks, discretized by continuum elements (cubes), see Figure 1 (a). The upper block (*punch*) measures $2 \times 2 \times 2$ units and has an initial velocity of 300 m/s in the negative vertical direction ($-Z$). The lower block (*die*) measures $4 \times 4 \times 2$ units and is completely blocked at its (lower) base. A small initial gap (0.01 units) exists between the two blocks.

The calculations done for this test case are summarized in Table 1.

Case	Mesh size	Description
TGLI01	1.00	Coarse mesh, option `GLIS NORM ELEM`
TGLI02	0.50	Medium mesh, option `GLIS NORM ELEM`
TGLI03	0.25	Fine mesh, option `GLIS NORM ELEM`
TGLI04	0.50	Medium mesh
TGLI05	0.50	Medium mesh, `LINK DECO GLIS`
TGLI06	1.00	Same as TGLI01 but with MAIT NODE
TGLI07	0.50	Same as TGLI02 but with MAIT NODE

Table 1: Calculations for the first test case.



(a) Geometry (b) Translucent geometry

Figure 1: Contact between two blocks.

3.1.1 TGLI01

The EPX input file for this first calculation is listed and shortly commented below.

```
TGLI01
ECHO
!CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die TERM
COMP NGRO 1 'bloc' LECT die TERM COND Z LT -1.99
     COUL VERT LECT punch TERM
          TURQ LECT die TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT punch TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT die TERM
```

The die is made of steel-like (rather hard) material, while the punch is made of aluminum-like (much softer) material. Both materials are modelled by means of the VPJC (Visco-Plastic Johnson-Cook) material law [3] recently implemented in EPX.

```
LINK COUP SPLT NONE
     GLIS 1 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            MAIT LECT die TERM
            ESCL LECT punch TERM
LINK DECO
     BLOQ 123 LECT bloc TERM
```

The boundary conditions are set as coupled (`LINK COUP`) for the contact (`GLIS`) and as decoupled (`LINK DECO`) for the blockages (`BLOQ`) at the base of the die. The reason for this choice is related to post-processing of results in this particular test. By separating the two types of boundary conditions one may in fact obtain and plot the coupled link forces (`FLIA`) due to contact, separately from the decoupled link forces (`FDEC`) due to the blockages.

One set of contacting surfaces is declared, subjected to friction (`FROT`) with a static coefficient $\mu_s = 0.3$ and a dynamic coefficient $\mu_d = 0.1$. The die is tentatively chosen as master (`MAIT`), while the punch plays the role of slave (`ESCL`). This choice is motivated by the fact that in this case the die is larger than the punch, so that the slave nodes will hopefully be facing a master face even after deformation. It will be interesting to see in a fortcoming test what happens if one exchanges the two roles.

```
INIT VITE 3 -300.0 LECT punch TERM
ECRI FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT DIAG DUMP VISU
CALC TINI 0.0 TEND 3.E-3 PASF 5.E-5 NMAX 60
```

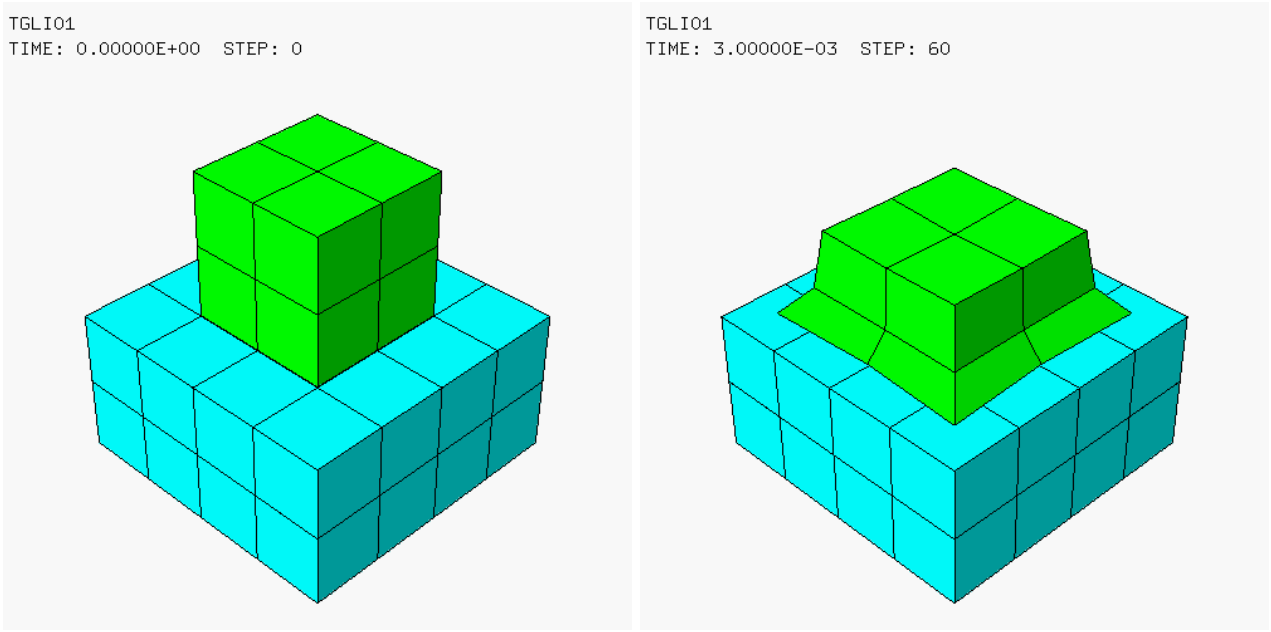
The following calculation options are set:

- `GLIS NORM ELEM`. This tells EPX to use "exact" facets normals instead of the normals obtained as average of the nodal normals (obtained themselves by averaging the normals of the surrounding facets.) The latter would be the default and, according to the Users' manual, it would tend to give a "smoother" variation of the normals (due to the repeated averaging process).

- `LNKS STAT DIAG DUMP VISU`. The first of these links-related options is used to print out in an ad-hoc file (.LKS) a summary of the links which are active step by step, while the next two produce additional printouts on the listing file (.LISTING). The last option activates the possibility of visualizing the links in the built-in graphical module. All these options should be used only for debugging purposes and in relatively small test cases, like the present one (else the output may become huge and the needed CPU time mey increase).

A constant user-imposed time step $\Delta t = 50\ \mu$s is chosen (the initial stability step is $\approx 80\ \mu$s). The final time is set to 3 ms for a total of 60 time steps.

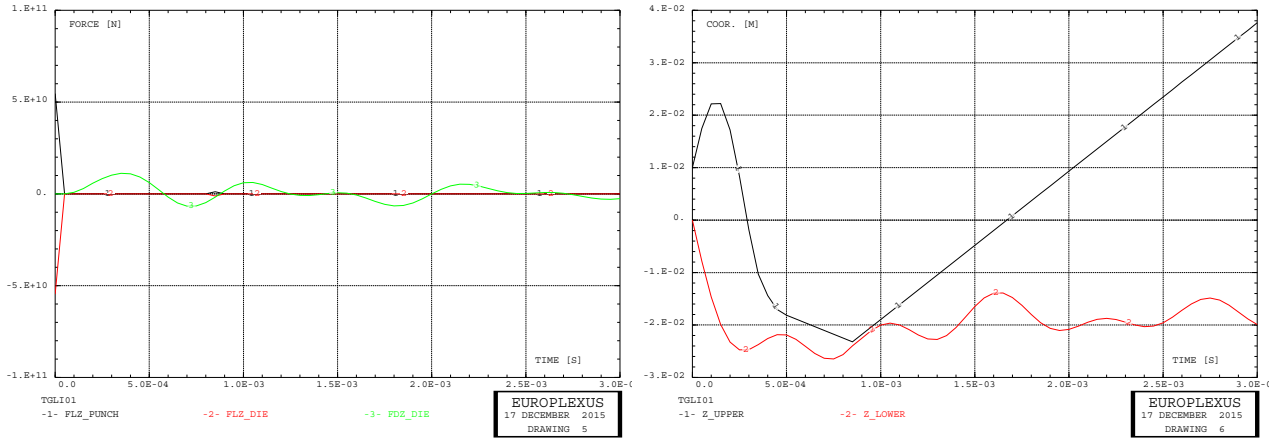
Some results are presented and discussed next. Figure 2 (a) shows the initial geometry while (b) shows the final geometry. The punch undergoes very large strains while the die stays almost undeformed. Overall, the solution looks at least qualitatively correct, especially if one takes into account the extremely coarse discretization assumed.



(a) Initial geometry (b) Final geometry

Figure 2: Some results of case TGLI01.

Next, in Figure 3 (a) we see the total contact force on the punch (black curve), the total contact force on the die (in red) and the total blockage force acting on the base of the die (in green). In (b) are shown the vertical positions (Z-coordinate) of the central points of the punch (in black) and of the die (in red). There is a gap of 0.01 units in the initial configuration, as imposed.



(a) Contact forces (b) Gap

Figure 3: Contact forces and gap in case TGLI01.

By inspecting the `TGLI01.LKS` file produced during the calculation:

```
STEP          T   N_GPS   N_LKS  N_PLKS N_NPLKS  N_OF_LINKS_BY_TYPE
   0 0.00000E+00       1      18       0      18  GLIS=       18
   1 5.00000E-05       0       0       0       0
   2 1.00000E-04       0       0       0       0
```

```
  3 1.50000E-04       0       0       0       0
  4 2.00000E-04       0       0       0       0
  5 2.50000E-04       0       0       0       0
  6 3.00000E-04       0       0       0       0
  7 3.50000E-04       0       0       0       0
  8 4.00000E-04       0       0       0       0
  9 4.50000E-04       0       0       0       0
 10 5.00000E-04       0       0       0       0
 11 5.50000E-04       0       0       0       0
 12 6.00000E-04       0       0       0       0
 13 6.50000E-04       0       0       0       0
 14 7.00000E-04       0       0       0       0
 15 7.50000E-04       0       0       0       0
 16 8.00000E-04       0       0       0       0
 17 8.50000E-04       1       2       0       2  GLIS=       2
 18 9.00000E-04       0       0       0       0
 19 9.50000E-04       0       0       0       0
 20 1.00000E-03       0       0       0       0
 21 1.05000E-03       1       8       0       8  GLIS=       8
 22 1.10000E-03       1       8       0       8  GLIS=       8
 23 1.15000E-03       1       8       0       8  GLIS=       8
 24 1.20000E-03       1       8       0       8  GLIS=       8
 25 1.25000E-03       1       8       0       8  GLIS=       8
 26 1.30000E-03       1       8       0       8  GLIS=       8
 27 1.35000E-03       1       8       0       8  GLIS=       8
 28 1.40000E-03       1       8       0       8  GLIS=       8
 29 1.45000E-03       1       8       0       8  GLIS=       8
 30 1.50000E-03       1       8       0       8  GLIS=       8
 31 1.55000E-03       1       8       0       8  GLIS=       8
 32 1.60000E-03       1       8       0       8  GLIS=       8
 33 1.65000E-03       1       8       0       8  GLIS=       8
 34 1.70000E-03       1       8       0       8  GLIS=       8
 35 1.75000E-03       1       8       0       8  GLIS=       8
 36 1.80000E-03       1       8       0       8  GLIS=       8
 37 1.85000E-03       1       8       0       8  GLIS=       8
 38 1.90000E-03       1       8       0       8  GLIS=       8
 39 1.95000E-03       1       8       0       8  GLIS=       8
 40 2.00000E-03       1      12       0      12  GLIS=      12
 41 2.05000E-03       1      12       0      12  GLIS=      12
 42 2.10000E-03       1      16       0      16  GLIS=      16
 43 2.15000E-03       1      16       0      16  GLIS=      16
 44 2.20000E-03       1      16       0      16  GLIS=      16
 45 2.25000E-03       1      16       0      16  GLIS=      16
 46 2.30000E-03       1      16       0      16  GLIS=      16
 47 2.35000E-03       1      16       0      16  GLIS=      16
 48 2.40000E-03       1      16       0      16  GLIS=      16
 49 2.45000E-03       1      16       0      16  GLIS=      16
 50 2.50000E-03       1      16       0      16  GLIS=      16
 51 2.55000E-03       1      16       0      16  GLIS=      16
 52 2.60000E-03       1      16       0      16  GLIS=      16
 53 2.65000E-03       1      16       0      16  GLIS=      16
 54 2.70000E-03       1      16       0      16  GLIS=      16
 55 2.75000E-03       1      16       0      16  GLIS=      16
 56 2.80000E-03       1      16       0      16  GLIS=      16
 57 2.85000E-03       1      16       0      16  GLIS=      16
 58 2.90000E-03       1      16       0      16  GLIS=      16
 59 2.95000E-03       1      16       0      16  GLIS=      16
 60 3.00000E-03       1      16       0      16  GLIS=      16
```

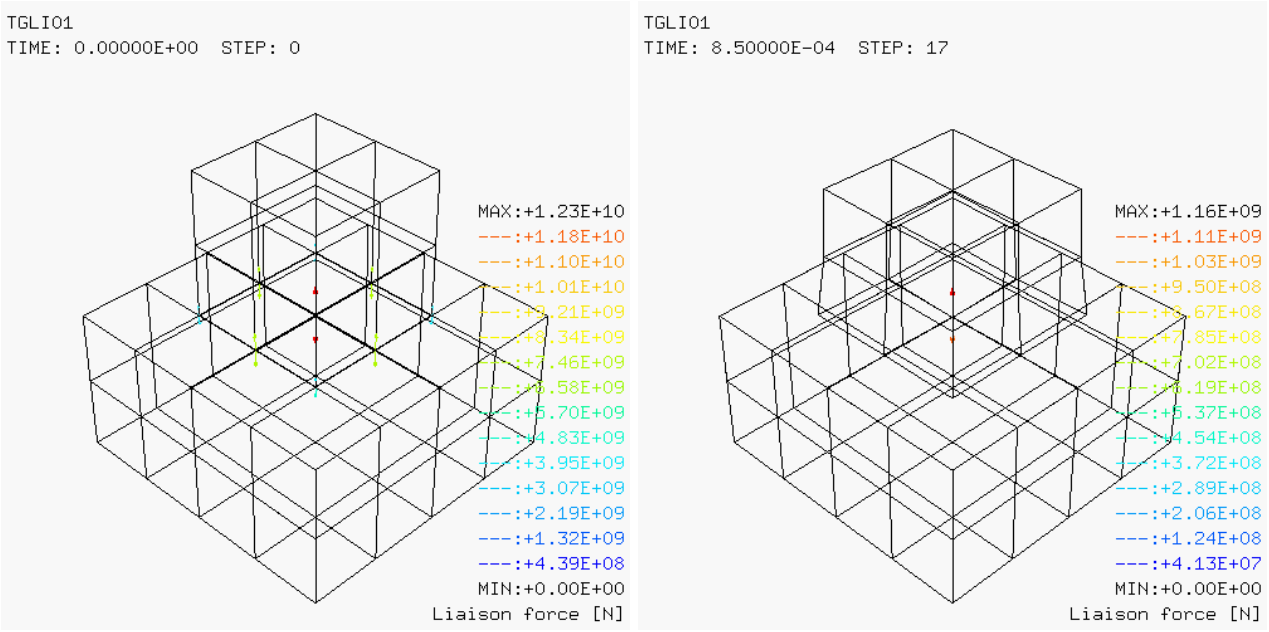
one sees that the only links present are the `GLIS` links, since the blockages have been imposed by a decoupled method. However, contact is intermittent: it is present at step 0, then at step 17, and finally from step 21 onwards until the end of the simulation (step 60).

By looking in detail at the (global) contact force curves in Figure 3 (a) we see that a (comparatively very high) contact force occurs at step 0, then the force is zero until $t = 0.85$ ms (step 17), where it assumes a small (non-zero) value, and finally it remains zero until the end of the test.

The global contact force on the punch (respectively on the die) is obtained by adding up all link forces (`FLIA`) acting on the punch (respectively die) nodes. In principle, the fact that the sum is zero does not necessarily imply that the force is zero at all nodes (although this is highly probable). However, either by inspecting the listing, or by looking at an animation of pressure forces, one sees that indeed all link forces are zero except at steps 0 and 17 (see Figure 3 (a)).

The contact force vectors at steps 0 and 17 are shown in Figure 4 (a) and (b), respectively.

Recently the possibility of visualizing the (coupled) links has been added in the EPX built-in graphical module. This new feature is still under development and details on it will be given at a later stage in a separate report ([4]). However, the result obtained in the present test case can already be shown, see Figure 5. Basically, one or more (unit) vectors are drawn at each node subjected to a coupled link. The length of the vector has no meaning, but its direction is the direction of the normal used to build up the constraint. In the present case, this basically means that one normal (along the detected penetration direction) is drawn at each slave node, and one (opposite) normal is drawn at each of the nodes of the corresponding master face. Since in general a master node belongs to more than one master face, more than one normal vector is drawn at a master node belonging to more than one penetrated master face.



(a) Step 0 (b) Step 17

Figure 4: Contact forces in case TGLI01.

In Figure 5 a picture is drawn each time the number of (`GLIS`) links changes, i.e. at steps 0, 17, 21, 40, 42 (plus at the final time, step 60). No links are present at steps 1 to 16 included and at steps 18 to 20 included, as already noted.

The links at steps 0 and 17 are directed along the vertical (Z) axis, as it would be expected in this "vertical" impact problem.

However, starting at step 21, the links are exclusively "horizontal", i.e. they lie in the XY plane, which is roughly parallel to the contact surface between the two bodies. This might indicate that these links concern the friction between the two bodies, thus explaining why the vertical contact forces are zero at these instants (note that also the net horizontal contact forces, due to friction, should be zero because of symmetry).

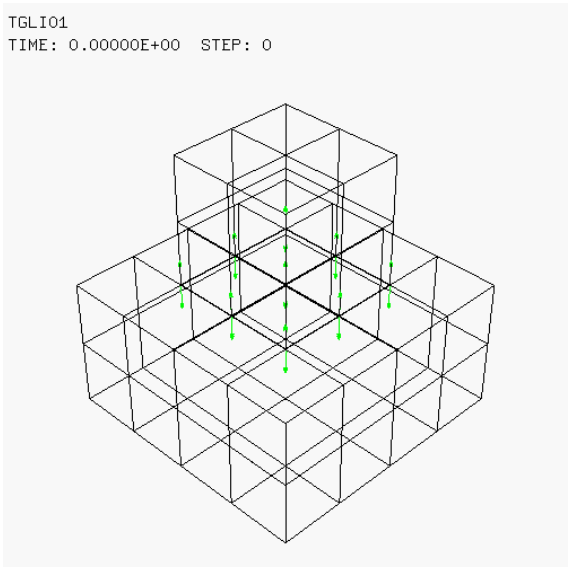
It is strange to see that starting at step 21 some links affect also nodes located on the vertical walls of the die. This fact is highlighted in Figure 6, where the link "joints" are drawn in addition to the link directions. A red line joins each couple of nodes which are linked together in a link constraint. Maybe these links are formally present but are discarded after solution of the linear system because the corresponding Lagrange multiplier is positive, indicating an attractive (rather than repulsive) contact force. Indeed, one possible technique (*a posteriori* strategy) for dealing with rebound is to set to 0 all contact-related Lagrange multipliers which are positive from the solution of the links system. In this way the corresponding link forces become zero. Although it is not easy to check whether this is the case in the present solution, it is remarkable that the link forces are zero at all steps after step 17.

Another very strange thing is to see that the punch deforms during the entire period from step 1 to step 16, without being subjected to any external or link forces.

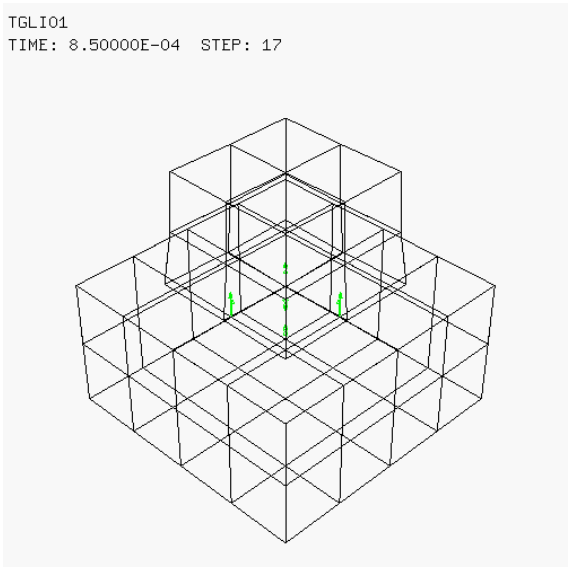
Finally, it is worthwhile noting that the contact algorithm seems to modify the initial velocities of the problem, contrary to the normal time integration scheme used by EPX. This can be observed in Figure 7 where at step 0 the bottom nodes of the punch have a lower velocity than the one (300 m/s) imposed by the user and some nodes on the top of the die have a non-zero initial velocity.

3.1.2 TGLI02

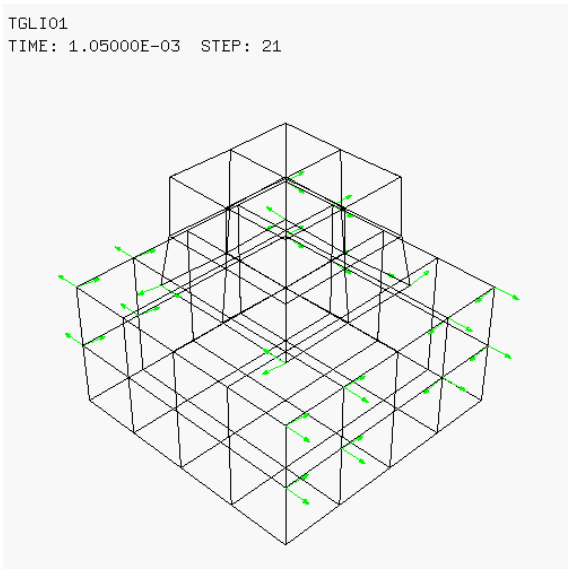
This test is similar to case TGLI01 but uses a twice finer mesh both in the punch and in the die. The initial and final mesh are shown in Figure 8. The model captures the physical fact that, due to friction, the maximum "swelling" of the punch does not occur on its face in contact with the die, but



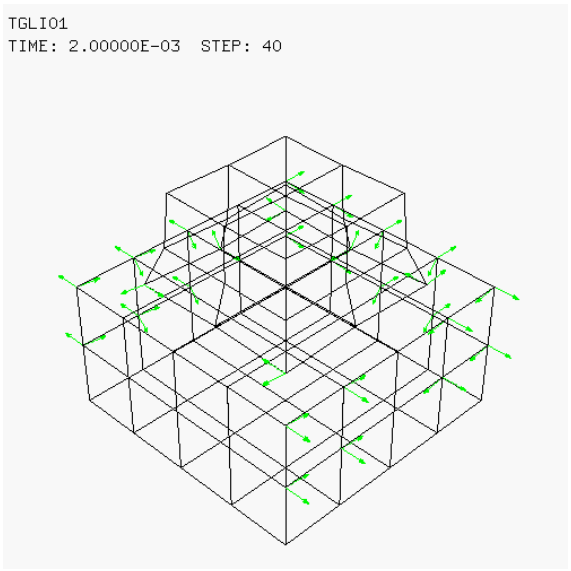
(a) Step 0



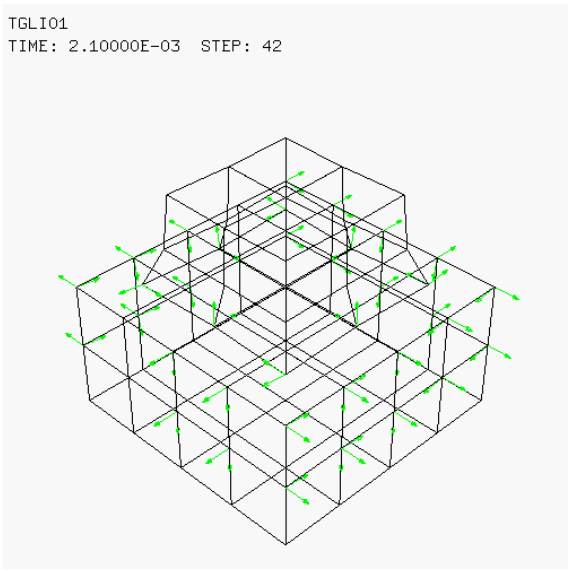
(b) Step 17



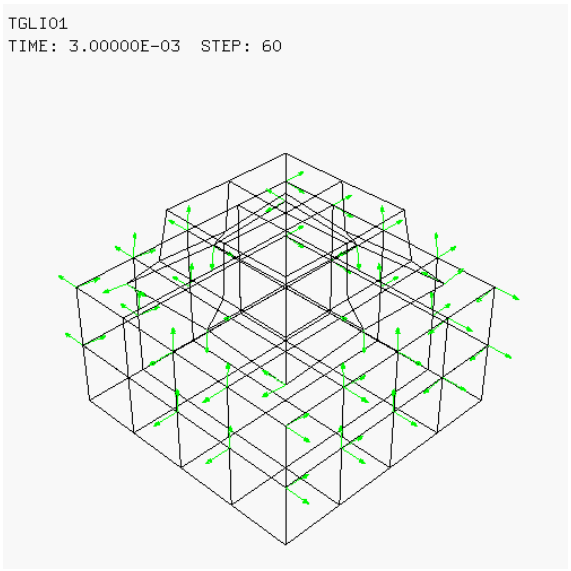
(c) Step 21



(d) Step 40

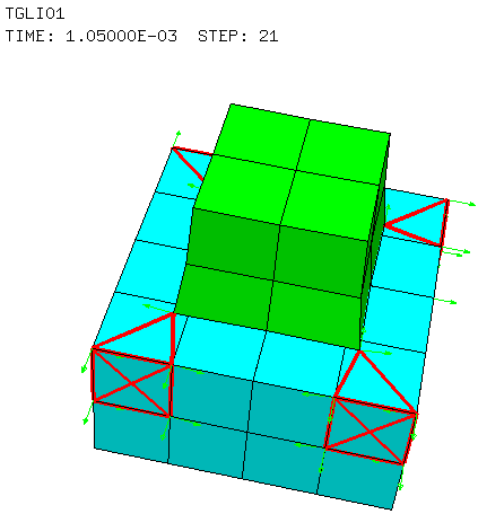


(e) Step 42

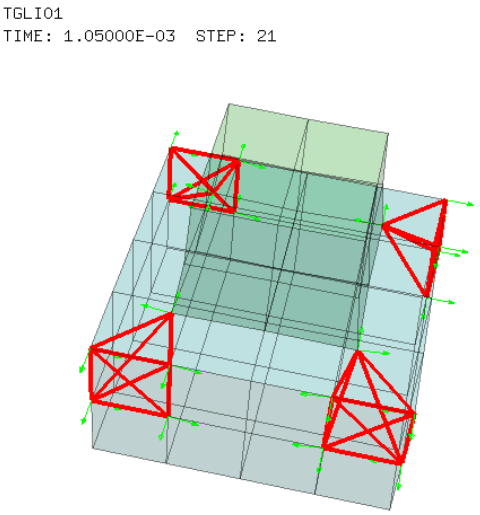


(f) Step 60

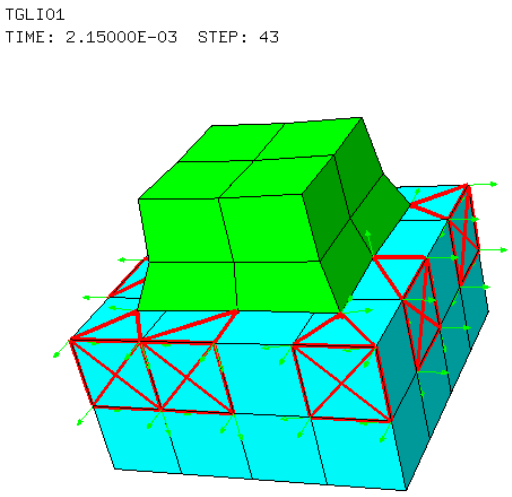
Figure 5: Visualization of the coupled links in case TGLI01.



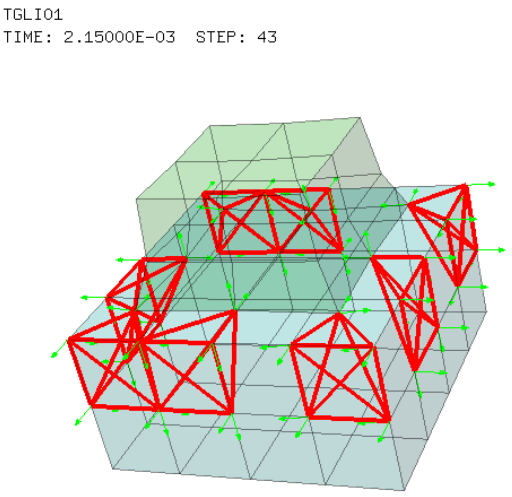
(a) Step 21, solid



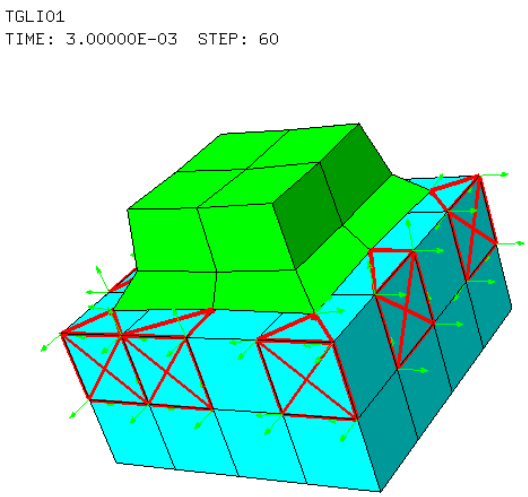
(b) Step 21, translucid



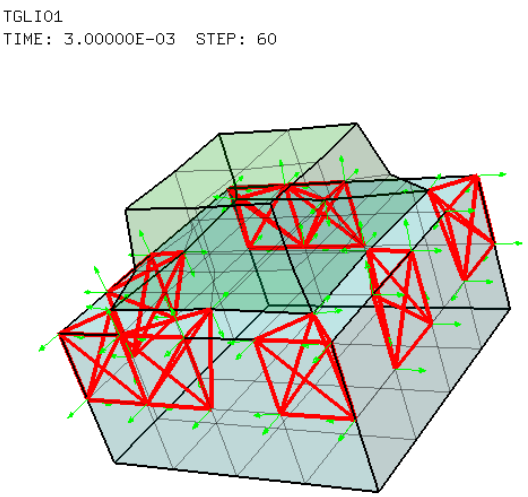
(c) Step 43, solid



(d) Step 43, translucid

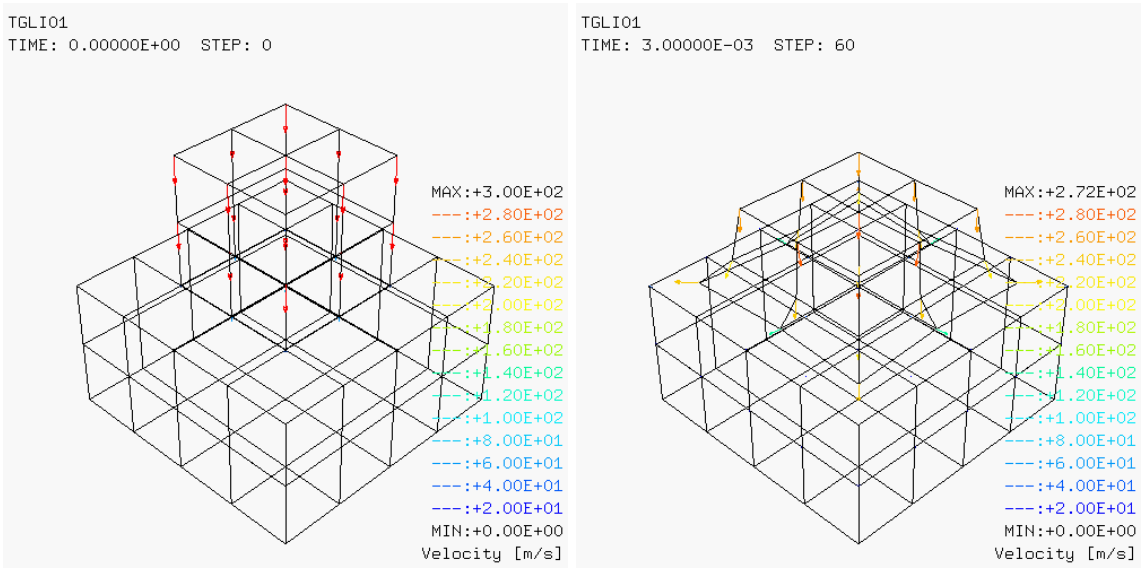


(e) Step 60, solid



(f) Step 60, translucid

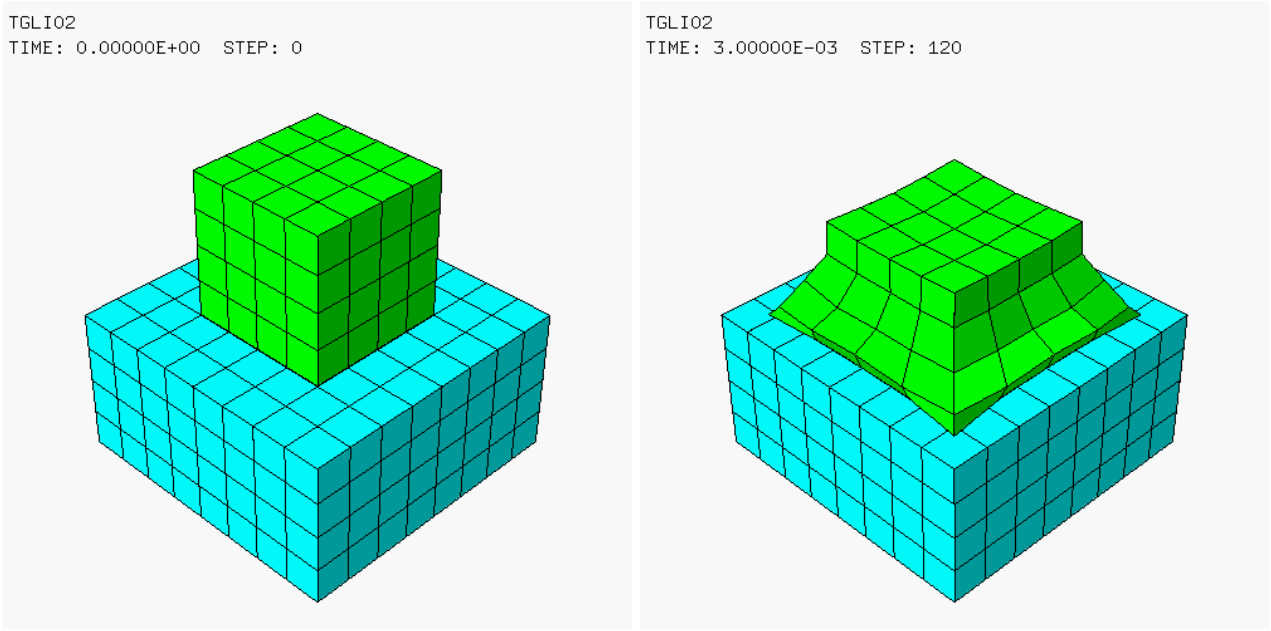
Figure 6: Coupled links with joints in case TGLI01.



(a) Step 0 (b) Step 60

Figure 7: Initial and final velocities in case TGLI01.

at a certain distance from it.

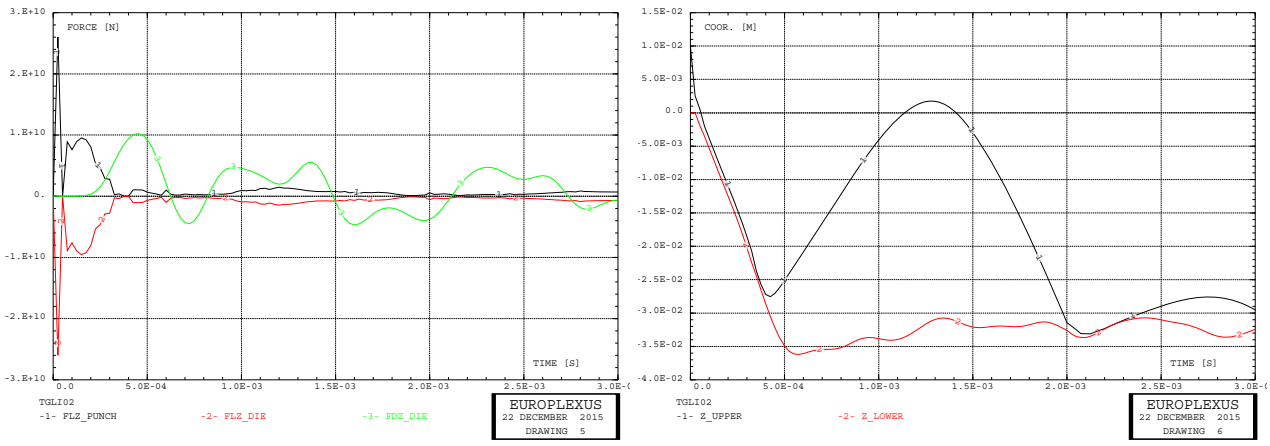


(a) Initial geometry (b) Final geometry

Figure 8: Some results of case TGLI02.

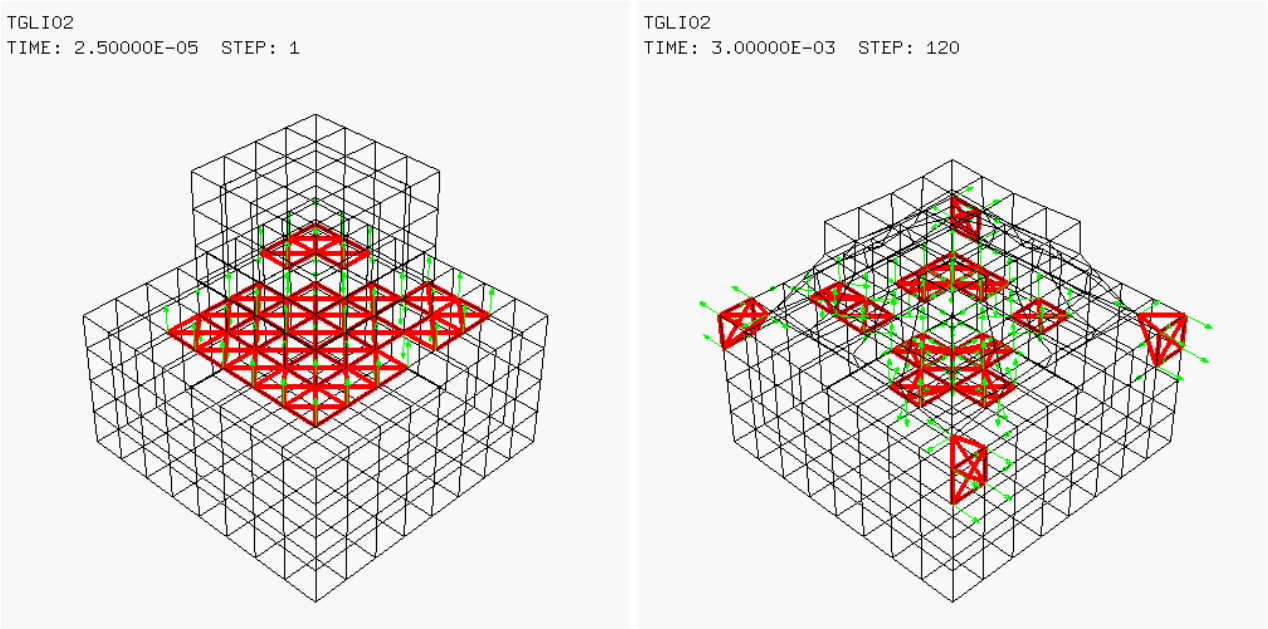
In Figure 9 (a) we see the total contact force on the punch (black curve), the total contact force on the die (in red) and the total blockage force acting on the base of the die (in green). In (b) are shown the vertical positions (Z-coordinate) of the central points of the punch (in black) and of the die (in red).

In this solution no contact is detected at step 0. Contact first occurs at step 1, and it is lost again at step 2. However, from step 3 onwards until the final time of 3 ms (step 120) some `GLIS` links are always present in the solution. Near the end of the solution, some strange contacts involving the lateral walls of the die are detected, like in case TGLI01, see Figure 10.



(a) Contact forces (b) Gap

Figure 9: Contact forces and gap in case TGLI02.



(a) Step 1 (b) Step 120

Figure 10: Coupled links with joints in case TGLI02.

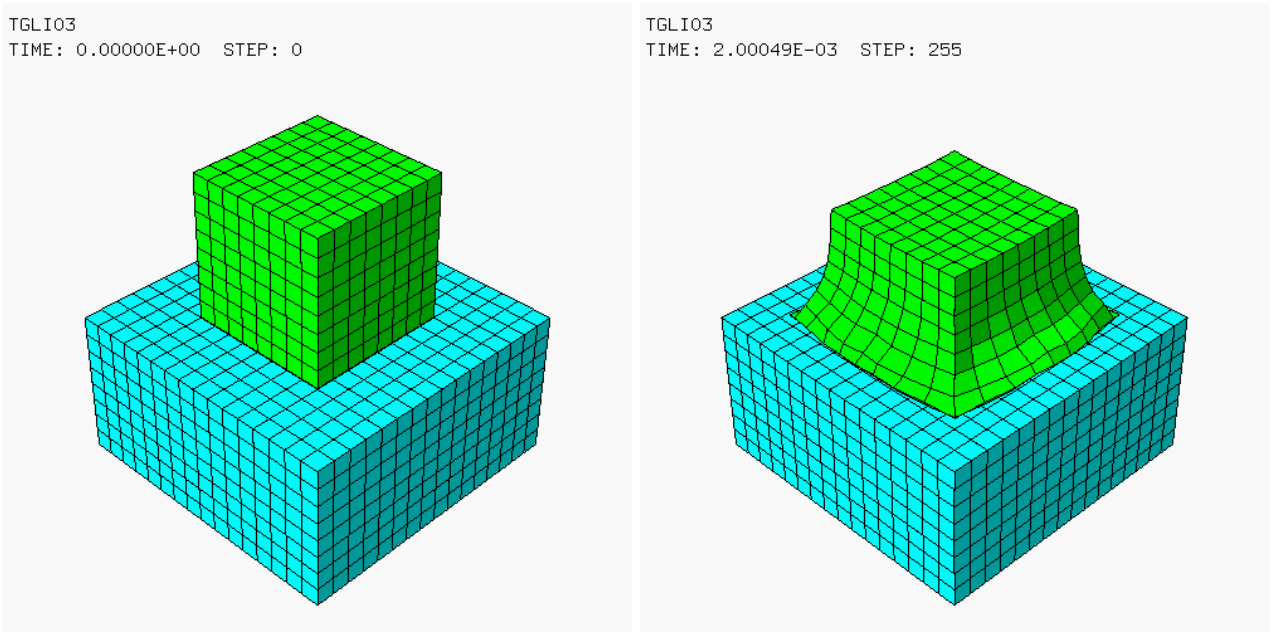
3.1.3 TGLI03

This test is similar to case TGLI01 but uses a four times finer mesh both in the punch and in the die. The initial and final mesh are shown in Figure 11. In this case the calculation is stopped at 2 ms instead of 3 ms and an automatic time step rather than a constant time step is used. At larger times the calculation would fail due to huge deformation of the first layer of punch elements in contact with the die (however, this is a problem of the element and not of the contact algorithm.)

In Figure 12 (a) we see the total contact force on the punch (black curve), the total contact force on the die (in red) and the total blockage force acting on the base of the die (in green). In (b) are shown the vertical positions (Z-coordinate) of the central points of the punch (in black) and of the die (in red).

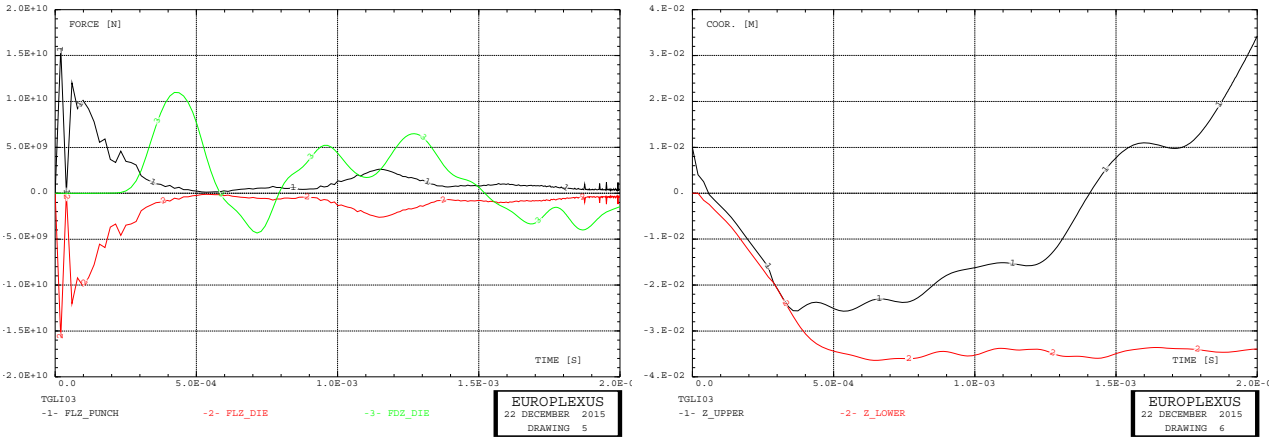
3.1.4 TGLI04

This test is similar to case TGLI02 (medium mesh) but we remove the option `GLIS NORM ELEM`. Therefore, nodally averaged normals are used rather than element (face) normals. The main results



(a) Initial geometry (b) Final geometry

Figure 11: Some results of case TGLI03.



(a) Contact forces (b) Gap

Figure 12: Contact forces and gap in case TGLI03.

(contact forces, gap, general deformation) are very similar to those of the case TGLI02 and are not presented for brevity.

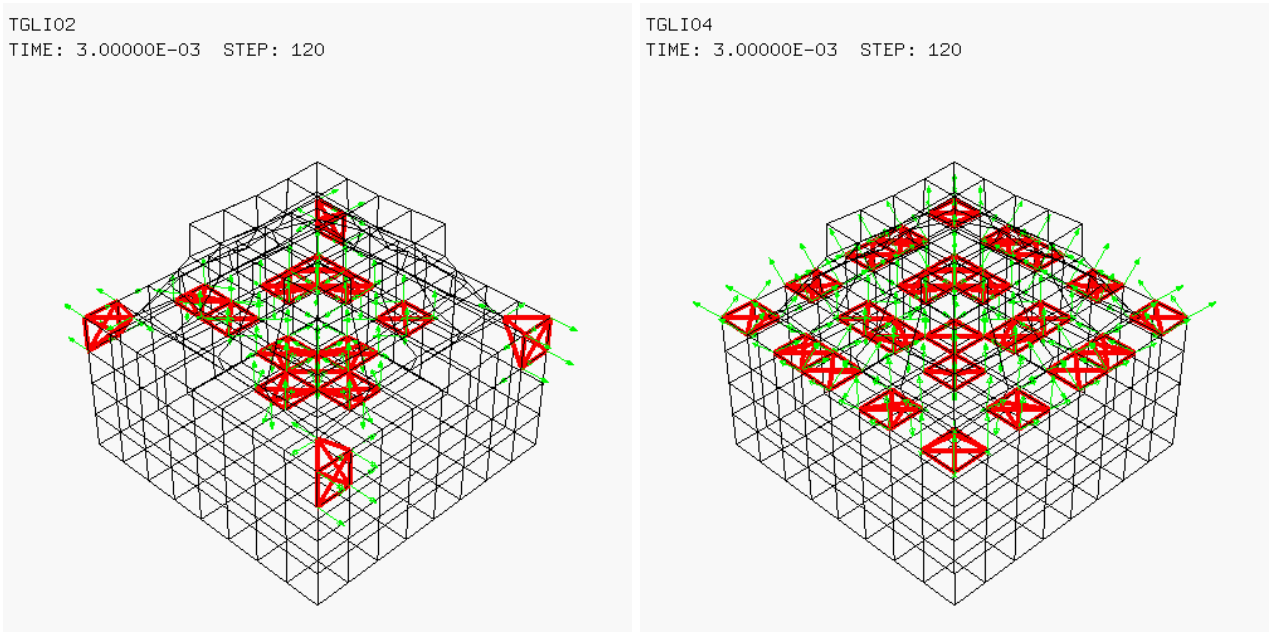
However, a notable difference is the fact that now the links involve only nodes of the upper surface of the die, while in the previous case also some nodes on the lateral walls of the die were involved during the latest stages of the deformation, see Figure 13.

The fact that the normal-related option changes the nodes involved in the links (and not only the direction of the normals) is somewhat surprising and should be better understood.

3.1.5 TGLI05

This test is similar to case TGLI04 (medium mesh) but the decoupled version (`LINK DECO GLIS`) of the contact model is used instead of the coupled version (`LINK COUP GLIS`). Since the blockages at the base of the die were already imposed in a decoupled manner in all previous test cases, it turns out that all constraints are decoupled in this test problem.

The User's Manual is quite obscure about this, but it is believed that using `LINK DECO GLIS`

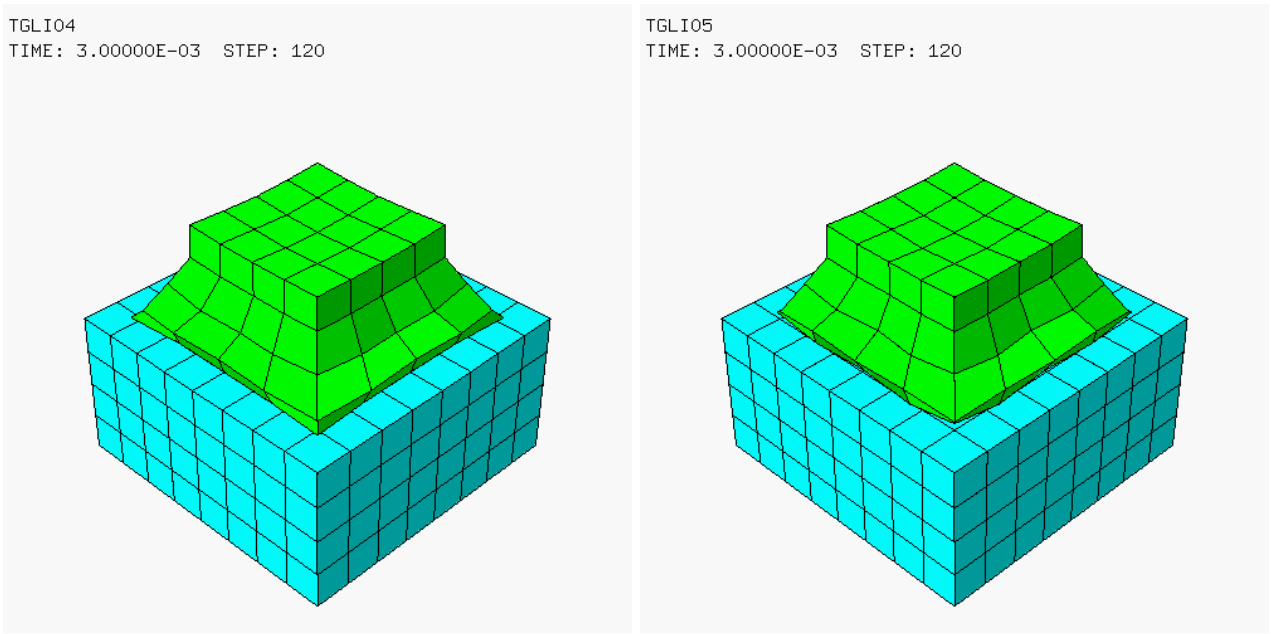


(a) Case TGLI02 (b) Case TGLI04

Figure 13: Coupled links with joints in cases TGLI02 and TGLI04.

without activating the `PENA` keyword chooses a Lagrange multiplier method for each contact constraint separately (or perhaps for the `GLIS` constraints alone), in any case *without* coupling these constraints with any other constraints imposed by the user via `LINK COUP`. If the `PENA` keyword would be added (which is not the case here), then a penalty method (uncoupled) would be used instead of a Lagrange multiplier method, to impose the contact constraints.

This calculation works well and the final deformed shape of the model is very similar to the previous solution, see Figure 14.

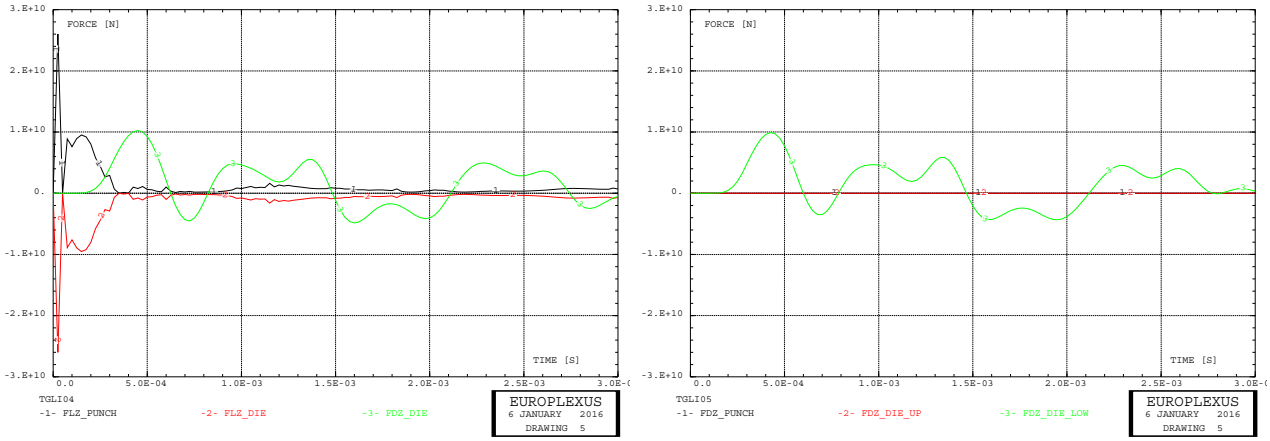


(a) Case TGLI04 (b) Case TGLI05

Figure 14: Final shape in cases TGLI04 and TGLI05.

The forces are compared in Figure 15 with those obtained in case TGLI04. It can be seen that the blocking forces at the base of the die (green curves) are quite similar. However, surprisingly at first, in case TGLI05 both the total punch contact force and the total die contact force are zero.

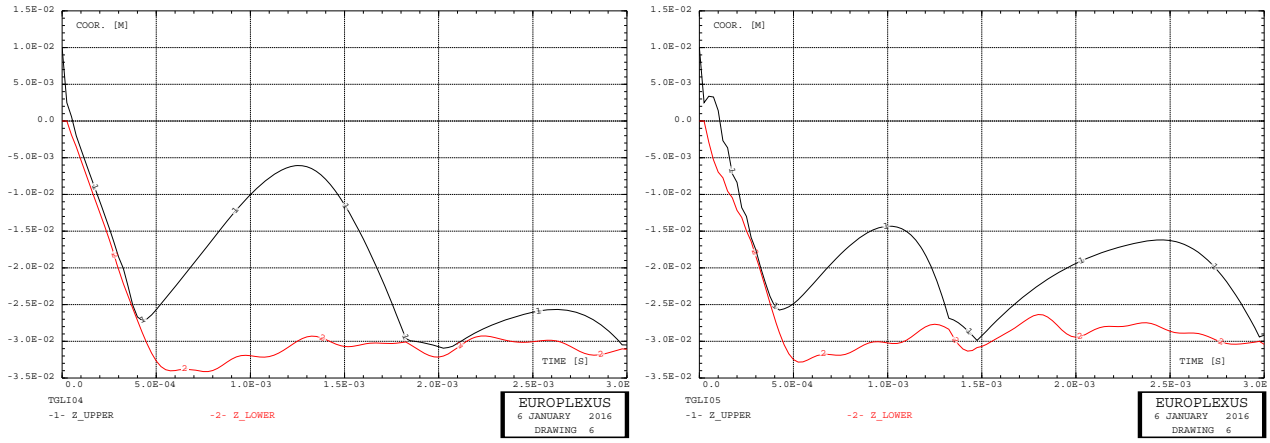
After some inspection, it seems that this is due to a post-processing bug in the code: while the decoupled blockage forces (`LINK DECO BLOQ`) are stored in the `FDEC` array for post-processing purposes, the decoupled contact forces (`LINK DECO GLIS`) are (probably) not, so the corresponding entries in `FDEC` remain at zero. Thus, in the present case the `FDEC` values at both the punch nodes and at the die (upper surface) nodes are zero.



(a) Case TGLI04 (b) Case TGLI05

Figure 15: Total forces in cases TGLI04 and TGLI05.

The displacements (gap) are compared in Figure 16 with those obtained in case TGLI04 and show relatively good agreement.



(a) Case TGLI04 (b) Case TGLI05

Figure 16: Gap in cases TGLI04 and TGLI05.

3.1.6 TGLI06

This test is similar to case TGLI01 (coarse mesh) but the `GLIS MAIT NODE` form of the sliding directive is used in order to define the master surface, instead of the `GLIS MAIT` form. In this way, the *nodes* of the master surface are declared, instead of the elements forming it.

The scope is to see whether the apparently spurious contacts between some punch nodes and "lateral" faces of the die (which, however, have been seen to produce no forces in case TGLI01 and so are probably harmless) will be avoided by declaring directly which are the nodes forming the master faces.

The results of this calculation are identical to those of case TGLI01 for all quantities except the number of GLIS links detected, which here is zero at all times except steps 0 and 17. The "spurious"

contacts involving the lateral walls of the die do disappear completely, as it was hoped.

3.1.7 TGLI07

This test is similar to case TGLI02 (medium mesh) but the `GLIS MAIT NODE` form of the sliding directive is used in order to define the master surface, instead of the `GLIS MAIT` form. In this way, the *nodes* of the master surface are declared, instead of the elements forming it.

The results of this calculation are very similar to those of case TGLI02 for all quantities except the number of GLIS links detected, which here is smaller at the later time steps. Any "spurious" contacts involving the lateral walls of the die do disappear completely, as it was hoped.

3.2 Test 2 – Contact between two blocks and a plate

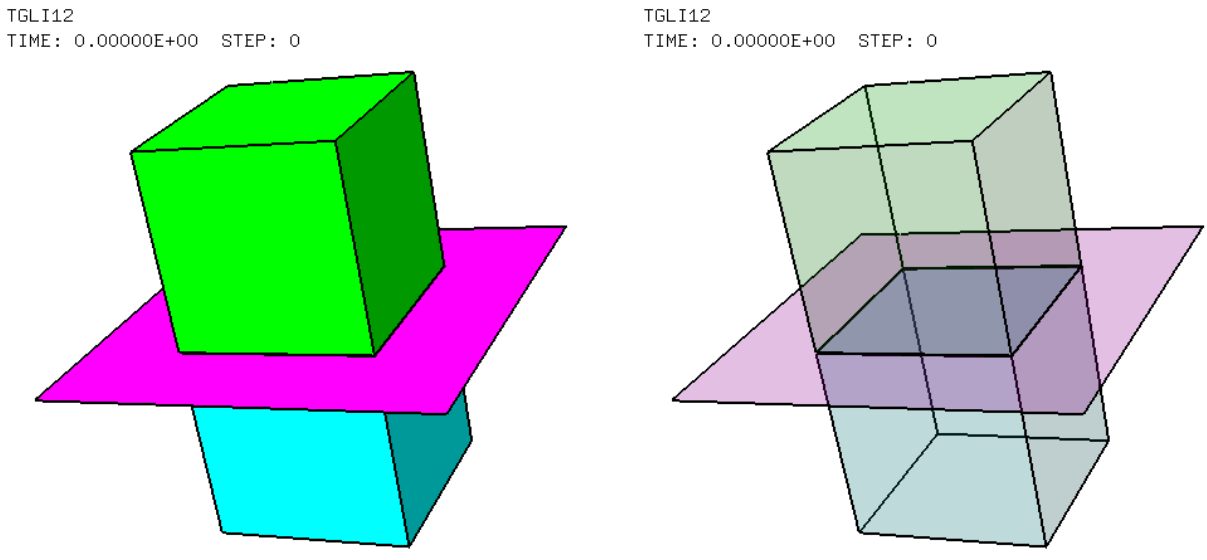
The second test problem is similar to the first one, but a thin plate (meshed by shell elements) is present in the initial gap between the two blocks, i.e. the punch and the die. The die is taken of the same dimensions as the punch while the plate is taken larger in order to avoid potential contact problems along the borders (if the correct contact model parameters are chosen.)

The problem geometry is shown in Figure 17. The upper block (*punch*) measures $2 \times 2 \times 2$ units and has an initial velocity of 300 m/s in the negative vertical direction ($-Z$). The lower block (*die*) measures $2 \times 2 \times 2$ units and is completely blocked at its (lower) base. The plate (*plate*) measures 4×4 units and is initially at rest. A small initial gap (0.01 units) exists between the two blocks. The plate lies in the middle of the initial gap, and has a thickness equal to the gap itself.

The calculations done for this test case are summarized in Table 2.

Case	Mesh size	Description
TGLI12	0.50	Medium mesh, `PGAP 0.005`, option `GLIS NORM ELEM`
TGLI14	0.50	Medium mesh
TGLI13	0.50	Medium mesh, `PGAP 0.003`, option `GLIS NORM ELEM`
TGLI11	0.50	Same as TGLI12 but larger initial physical gap (0.05 units)

Table 2: Calculations for the second test case.



(a) Geometry (b) Translucent geometry

Figure 17: Contact between two blocks and a plate.

3.2.1 TGLI12

The EPX input file for this first calculation is listed and shortly commented below.

```
TGLI12
ECHO
 CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die Q4GS plate TERM
COMP EPAI 0.01 LECT plate TERM
     NGRO 1 'bloc' LECT die TERM COND Z LT -1.99
     COUL VERT LECT punch TERM
          TURQ LECT die   TERM
          ROSE LECT plate TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT punch die TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT plate TERM
```

The punch and the die are meshed with CUB8 hexahedra, while the plate is meshed by Q4GS shells. The material for the punch and the die is a comparatively softer metal, while for the plate a comparatively harder metal material is used. One would expect that both the punch and the die deform quite a lot, in a way similar to the punch in the previous test case, while the plate should remain almost flat. The problem is geometrically symmetric but the initial and boundary conditions are not symmetric, so the solution might be slightly unsymmetric.

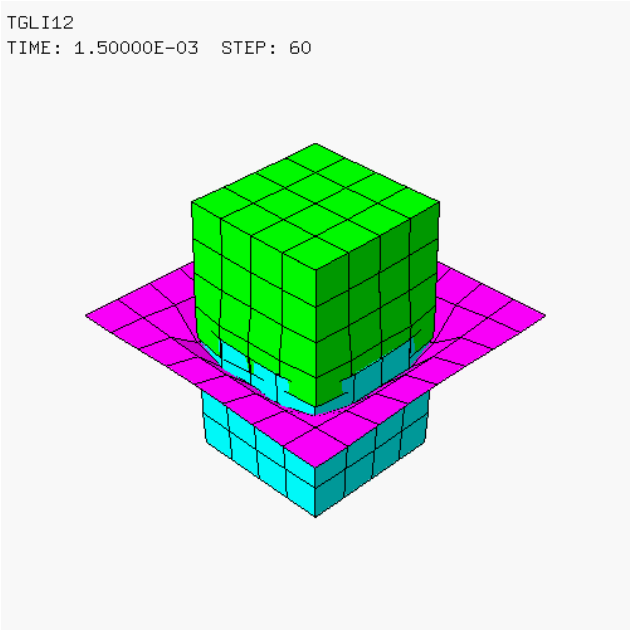
```
LINK COUP SPLT NONE
     GLIS 2 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            PGAP 0.005
            MAIT LECT punch TERM
            PESC LECT plate TERM
            FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #2
            PGAP 0.005
            MAIT LECT die   TERM
            PESC LECT plate TERM
LINK DECO
     BLOQ 123 LECT bloc TERM
INIT VITE 3 -300.0 LECT punch TERM
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 3.E-3 PASF 2.5E-5 NMAX 120
fin
```

As concerns contact, two sliding surfaces (`GLIS`) are tentatively set up by the `LINK COUP` directive. The first one designates the punch as master surface (`MAIT`), and the plate *nodes* as slave nodes (`PESC`). The second sliding surface designates the die as master surface (`MAIT`), and again the plate *nodes* as slave nodes (`PESC`). This choice will prove not particularly successful, see below. For both surfaces, a gap of 0.005 units (i.e., half of the physical thickness of the plate) is set (`PGAP`). Friction is activated with the same characteristics along both surfaces. The blockage of the lower surface of the die is set by the `LINK DECO BLOQ` directive, like in the first test case.

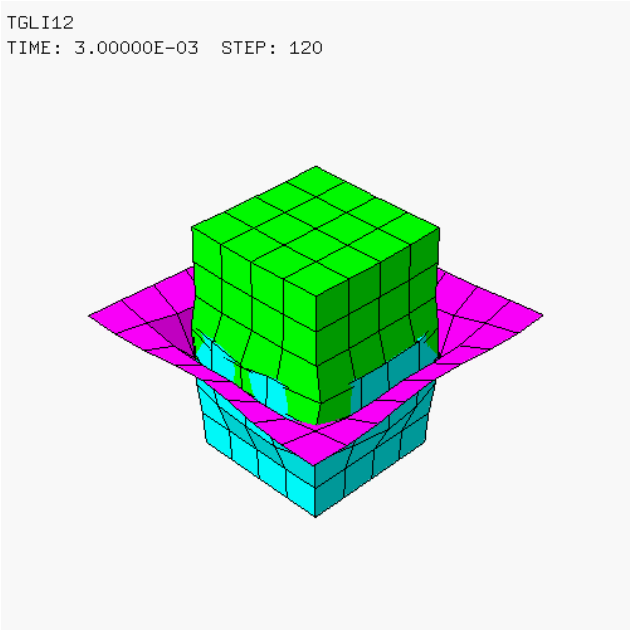
The problem solutions at an intermediate and at the final time are shown in Figure 18. The plate seems to "feel" the contact only (or mainly) with the punch, it moves downwards as it deforms and large interpenetration occurs between the punch and the die (which are not set directly into contact with each other in this case), except perhaps at the central node of each contacting surface. Contact between the plate and the die's "upper" set of nodes seems to be undetected (except perhaps for the central node), but some contact seems to occur between the plate and the "second row" of nodes of the die (those laying one element "below" the upper die surface), which looks very strange indeed.

Figure 19 illustrates more clearly these results at the final time, showing a lower view of the punch and plate (without the die) and an upper view of the plate and the die (without the punch) at the final time.

Further post-processing of this solution's results (forces etc.) is not performed, due to the evident problems in this solution.

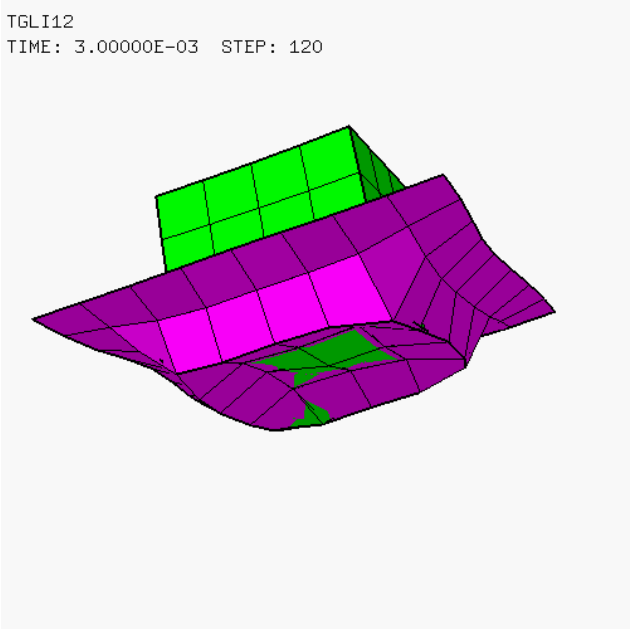


(a) Step 60

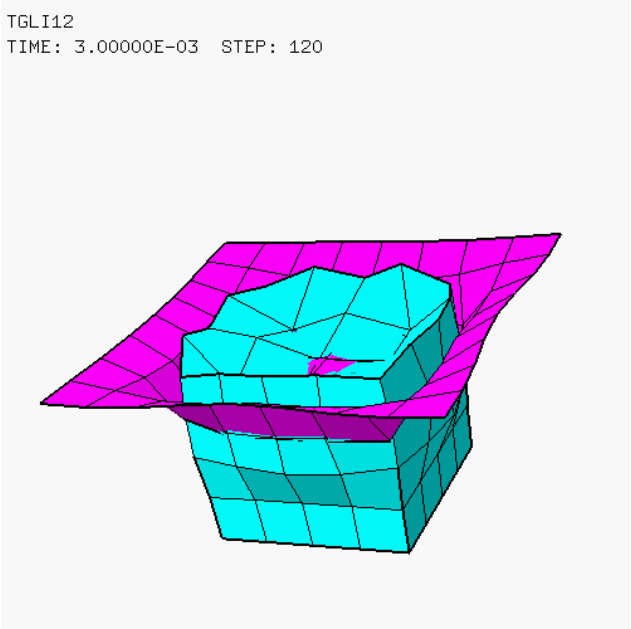


(b) Step 120

Figure 18: Results of test TGLI12.



(a) Punch and plate



(b) Plate and die

Figure 19: Punch/plate and die/plate contacts in case TGLI12.

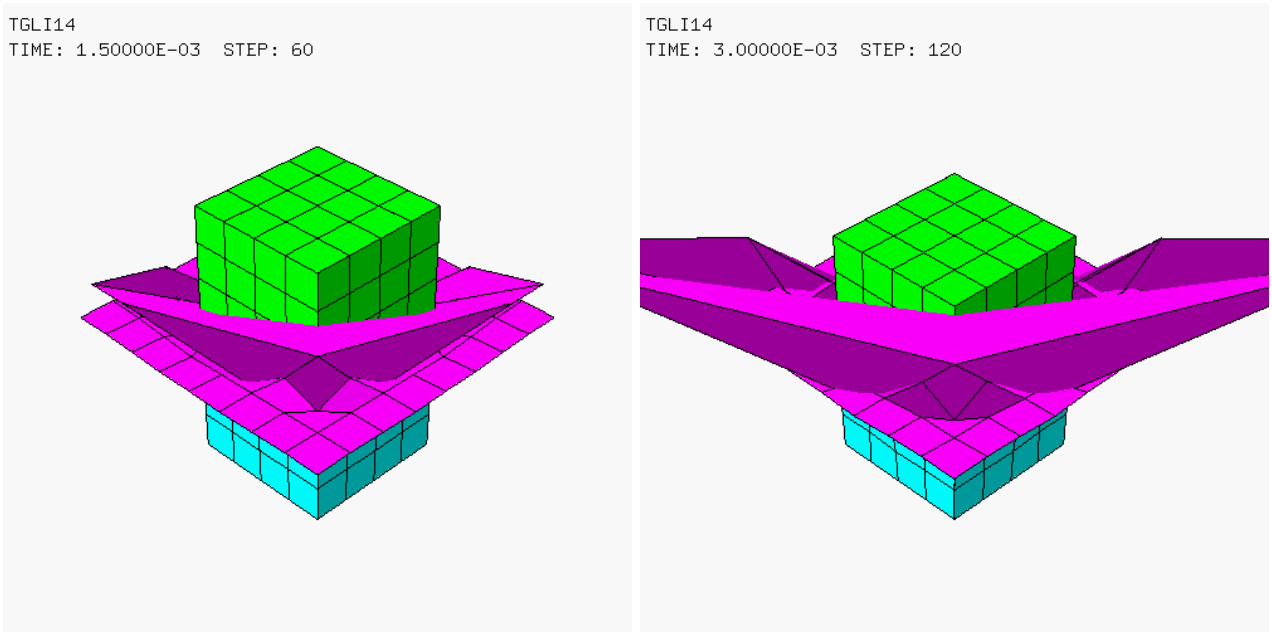
3.2.2 TGLI14

This solution is similar to the previous one but the option `OPTI GLIS NORM ELEM` is removed. In the first test problem, this option seemed to have little effect (compare cases TGLI02 and TGLI04).

In the present case, however, the consequences on the solution are dramatic. The plate undergoes some extreme and quite strange deformations, as shown in Figure 20.

3.2.3 TGLI13

This solution is similar to case TGLI12 but the logical gap is reduced to 0.003 units instead of 0.005 units for both sliding surfaces. The intent is to see whether the lack of contact between plate and

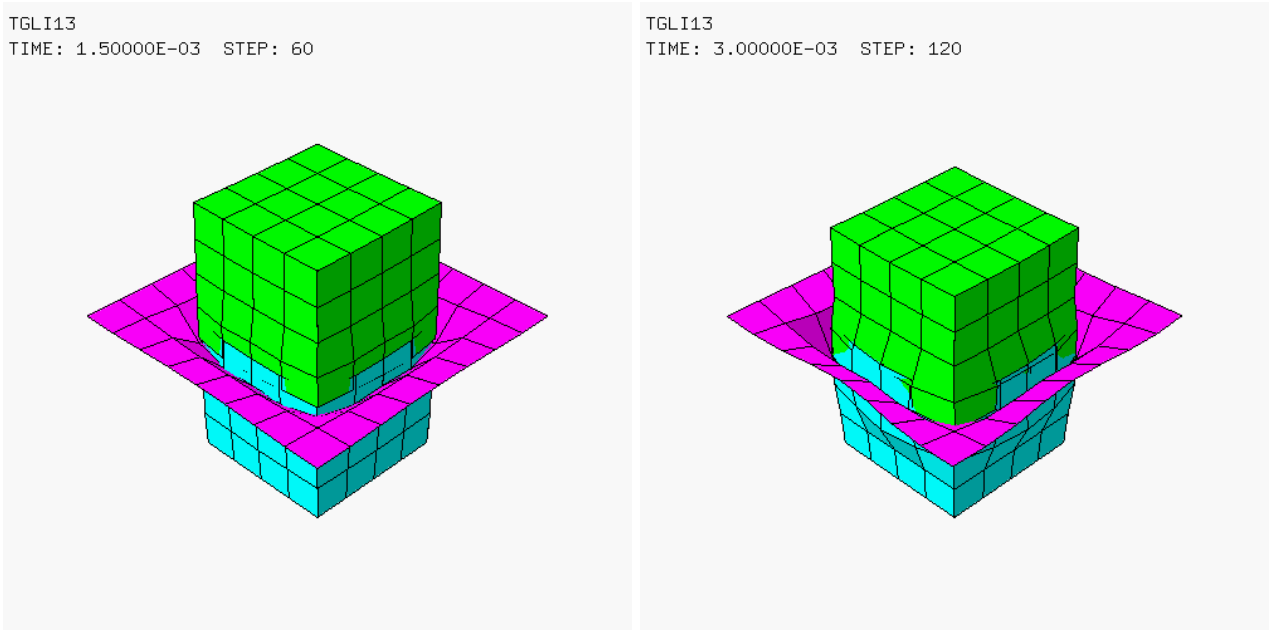


(a) Step 60 (b) Step 120

Figure 20: Results of test TGLI14.

die is due to the fact that the plate nodes might initially lie already slightly "inside" the plate. The "physical" gap between the punch and the die is not modified in this test, and remains set to 0.01 units.

The result of this calculation is quite similar to test case TGLI12, see Figure 21. Large interpenetrations between punch and die and between plate and die continue to occur.



(a) Step 60 (b) Step 120

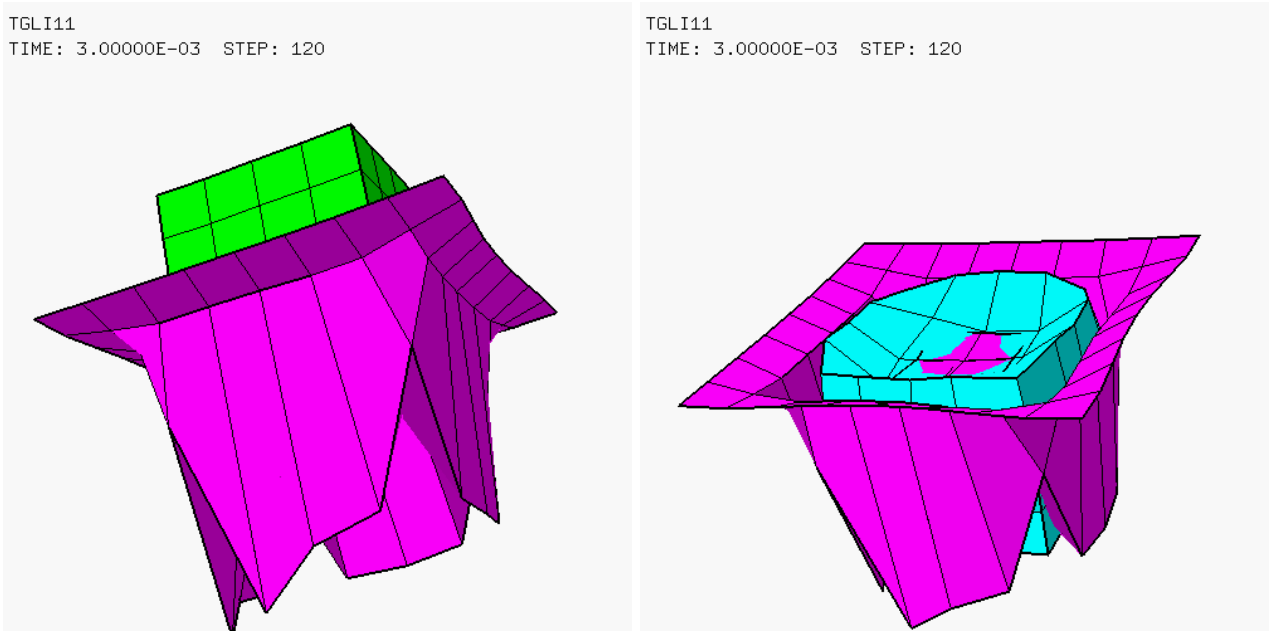
Figure 21: Results of test TGLI13.

3.2.4 TGLI11

This solution is identical to case TGLI12 but the physical gap between the punch and the die is augmented to 0.05 instead of 0.01 units for both sliding surfaces. The plate is initially located in the

middle of this gap. The intent is to see whether the lack of contact between plate and die is due to the fact that the plate nodes might initially lie already slightly "inside" the plate. The "logical" gap between the punch and the die is not modified in this test, and remains set to 0.05 units (`PGAP 0.05`).

The result of this calculation is even worse than that of test case TGLI12, see Figure 22. Large interpenetrations occur (in fact, even larger than before) between punch and die and between plate and die.



(a) Step 60 (b) Step 120

Figure 22: Results of test TGLI11.

A very strange fact is that at the initial time (step 0) there are as many as 32 links of GLIS type detected in this calculation, despite the physical gap between punch and plate (respectively die and plate) being now much larger than the plate (half) thickness.

3.3 Some consistency checks

This Section is devoted to performing some consistency checks in order to hopefully help clarifying the origin of some of the strange behaviours observed in tests 1 and 2.

The calculations done are summarized in Table 3.

Case	Mesh size	Description
TGLI22	0.50	Similar to TGLI12 but no punch, die has upward velocity
TGLI20	0.50	Similar to TGLI12 but invert orientation of the plate

Table 3: Calculations for consistency checks.

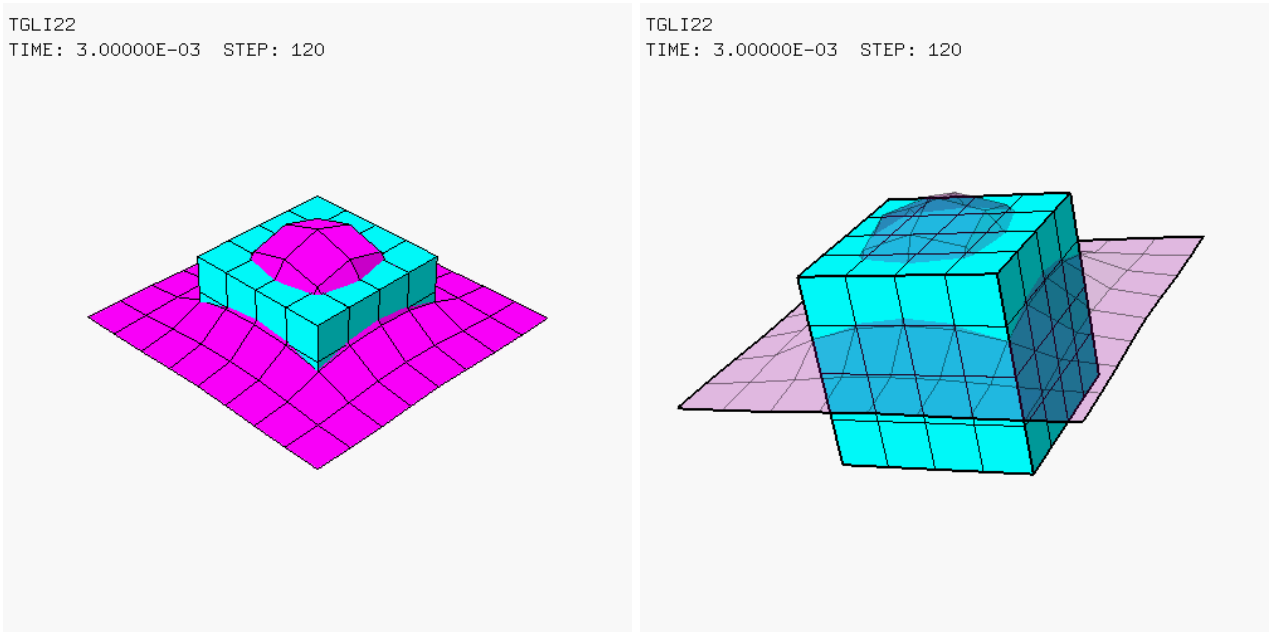
3.3.1 TGLI22

This test is similar to case TGLI12 but the punch is removed from the model and the die is given an initial upwards velocity of 300 m/s, so that it hits the plate from below.

The results of this calculation are shown in Figure 23. The fact that no contact seems to take place at the center of the plate may be due to the plate bending deformation which creates a large central gap between the plate and the die.

It seems that contact is missed all along the edge of the upper face of the die, while it is detected at some distance from it. This might be a consequence of the choice of using the plate (nodes) as slave (nodes). In fact, the plate nodes where contact is missed lie just "on the edge" of a die facet, so

it is perhaps not surprising that contact might be detected or missed depending on small geometrical imperfections, or even round-off errors.



(a) Solid view (b) Translucent view

Figure 23: Results of test TGLI22.

3.3.2 TGLI20

This test is similar to case TGLI12 but the orientation of the plate is inverted (directly in EPX) by means of directive `COMP ORIE INVE`. This modification should have no effect on results if, as expected, only the nodes (and not the faces) of the plate are involved in the contact model (since we have used the `PESC` directive to define the slave nodes, and not the `ESCL` directive).

Results, shown in Figure 24, look quite similar to those of test TGLI12 (by taking into account the coarseness of the discretization). This is re-assuring as concerns the influence of the plate orientation.

3.4 Further calculations of Test 2

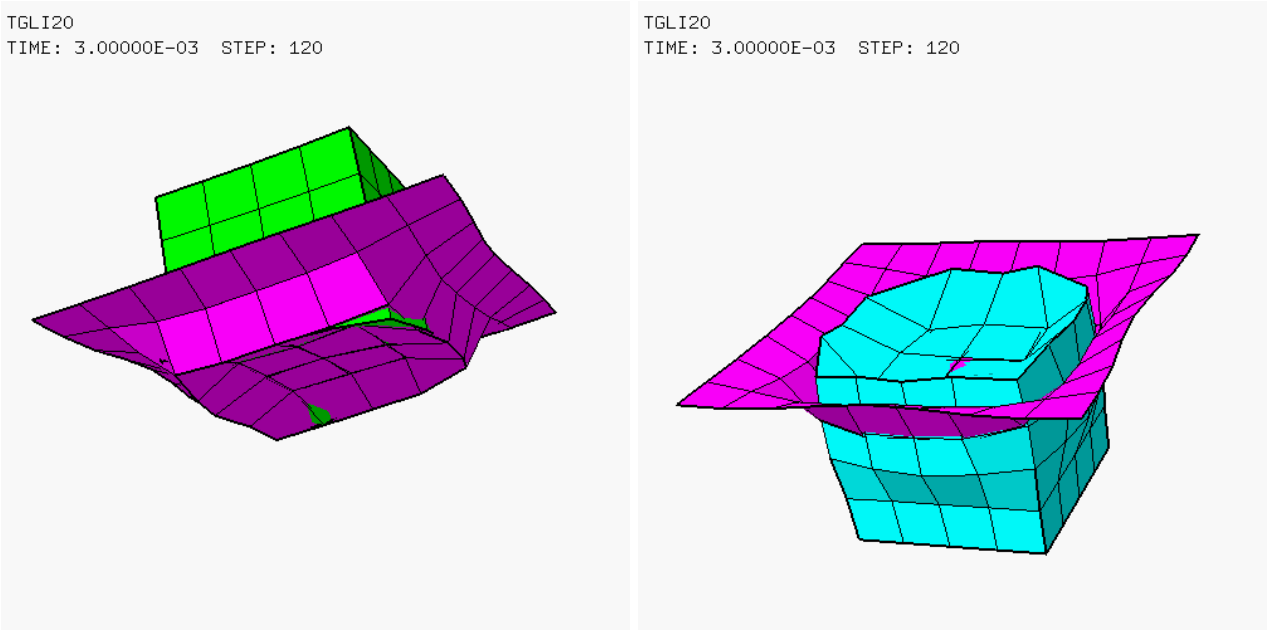
In the light of the consistency tests performed in the previous Section, we now do some further simulations of Test 2. The major problem with the previous simulations seemed to be that many contacts were not detected, due to the fact that some slave nodes were just along an edge of master (element) facets.

An attempt is therefore made to ameliorate the results by inverting the role of master and slave in the problem. The plate becomes the master, while the punch and respectively the die become the slaves. This makes sense, because slave nodes will then always find a "facing" master (face) since the plate extends beyond the contact surfaces of the punch and of the die.

The calculations done are summarized in Table 4.

Case	Mesh size	Description
TGLI32	0.50	Similar to TGLI12 but master/slave roles inverted
TGLI30	0.50	Similar to TGLI32 but fully symmetric problem
TGLI31	0.50	Similar to TGLI30 but without friction

Table 4: Further calculations of the second test case.



(a) Punch and plate (b) Die and plate

Figure 24: Results of test TGLI20.

3.4.1 TGLI32

in order to swap the roles of master and slave with respect to test case TGLI12, we first identify the nodes on the expected contacting surfaces of the punch (*pun_low*) and of the die (*die_top*), respectively:

```
COMP EPAI 0.01 LECT plate TERM
     NGRO 5 'bloc' LECT die TERM COND Z LT -1.99
            'pun_low' LECT punch TERM COND Z LT  2.E-2
            'die_top' LECT die   TERM COND Z GT -1.E-2
            'pun_cen' LECT punch TERM COND NEAR POIN 0 0 0
            'die_cen' LECT die   TERM COND NEAR POIN 0 0 0
```

Then, the input directives for the contact become:

```
LINK COUP SPLT NONE
     GLIS 2 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            PGAP 0.005
            CMAI LECT plate TERM EXTE LECT pun_cen TERM
            PESC LECT pun_low TERM
            FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #2
            PGAP 0.005
            CMAI LECT plate TERM EXTE LECT die_cen TERM
            PESC LECT die_top TERM
LINK DECO
     BLOQ 123 LECT bloc TERM
```

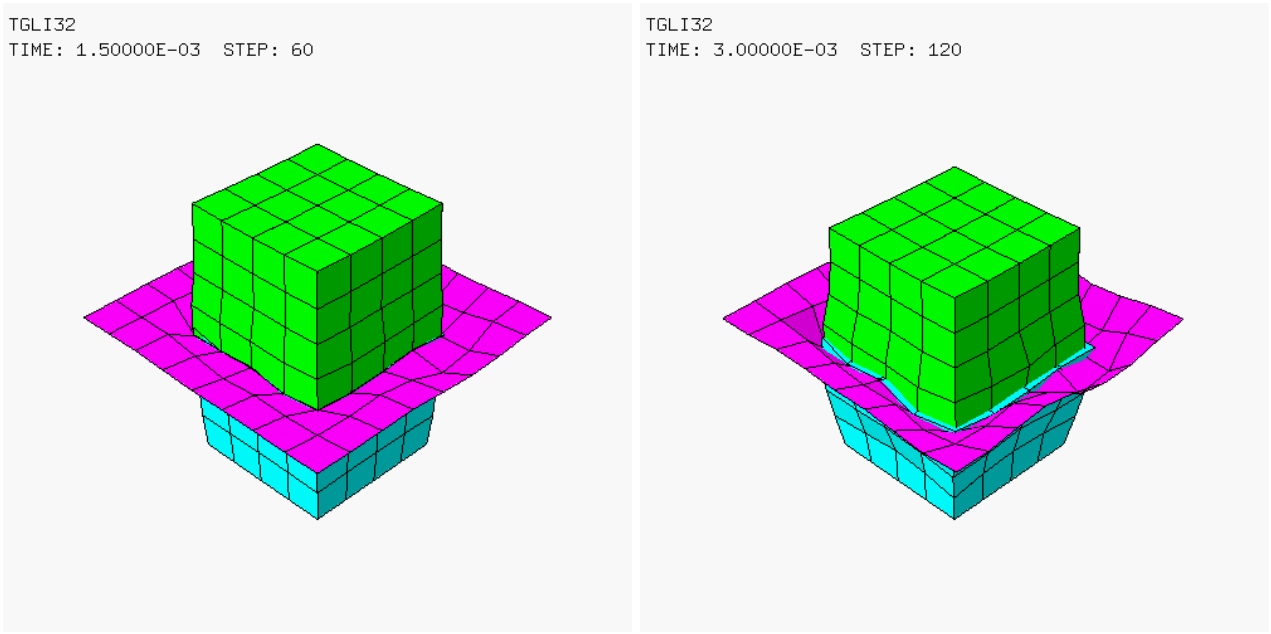
The plate is declared as a master made of shell elements (`CMAI`) in both sliding surface definitions. Because of their shell nature, the master surfaces need the definition of either the "exterior" or the "interior" of the shell. To this end, the positions of the central nodes of the punch and die contacting surfaces (*pun_cen* and *die_cen*, respectively) are used. The nodes of the contacting surfaces of the punch and of the die are declared as slave nodes via the `PESC` directive ("slave points").

The results of this calculation are shown in Figure 25. The solution looks very good, if one considers the extremely coarse discretization. In comparison with the previous solutions, one might say that (almost) no interpenetrations take place and the result looks quite physical.

In Figure 26 one can observe more in detail the results because either the punch or the die are removed from the visualization. Altogether, these results are quite convincing.

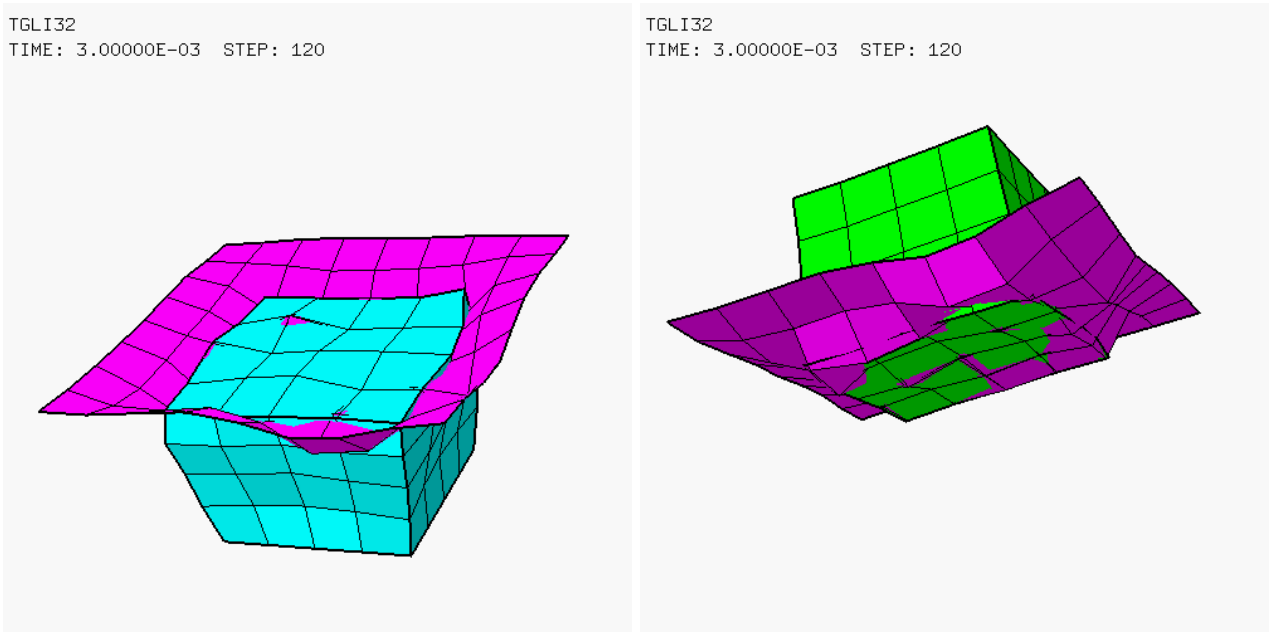
3.4.2 TGLI30

This test is similar to case TGLI32 but the problem is made entirely symmetric with respect to the plate. Both the punch and the die have initial velocities (in opposite directions, pointing towards



(a) Step 60 (b) Step 120

Figure 25: Results of test TGLI32.

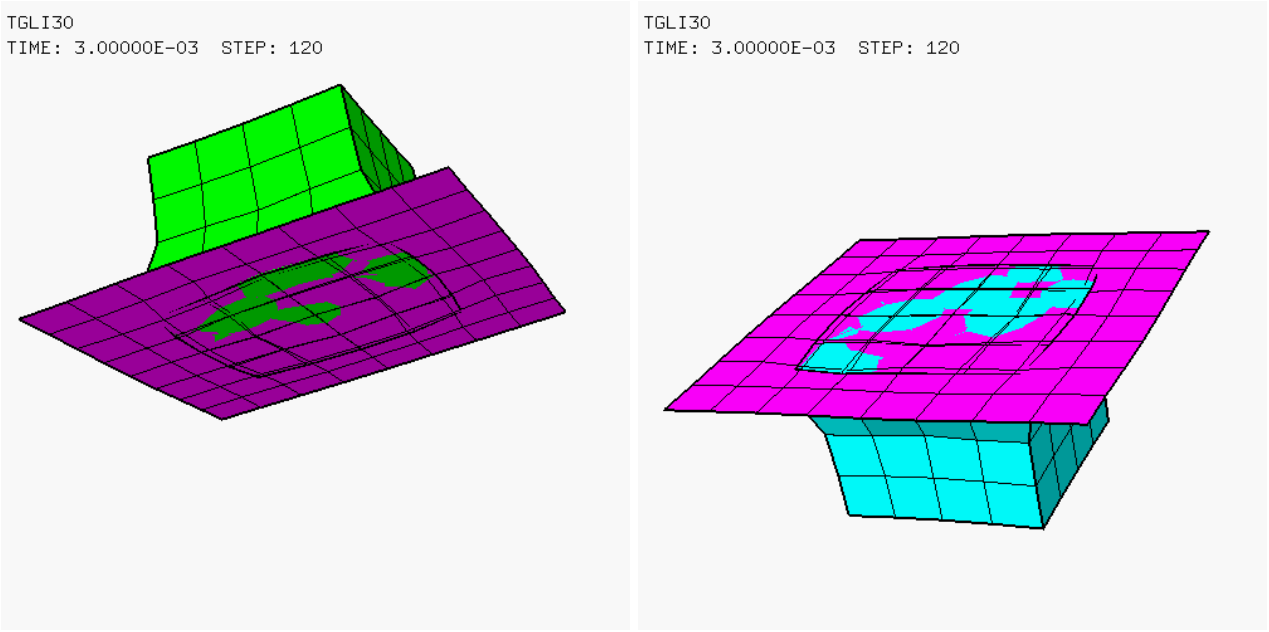


(a) Punch and plate (b) Die and plate

Figure 26: More detailed results of test TGLI32.

the plate) of 150 m/s instead of giving a velocity of 300 m/s to the punch only. No blockages are imposed so the problem is symmetric as concerns both the geometry and the boundary conditions. The expected solution is that the plate remains plane.

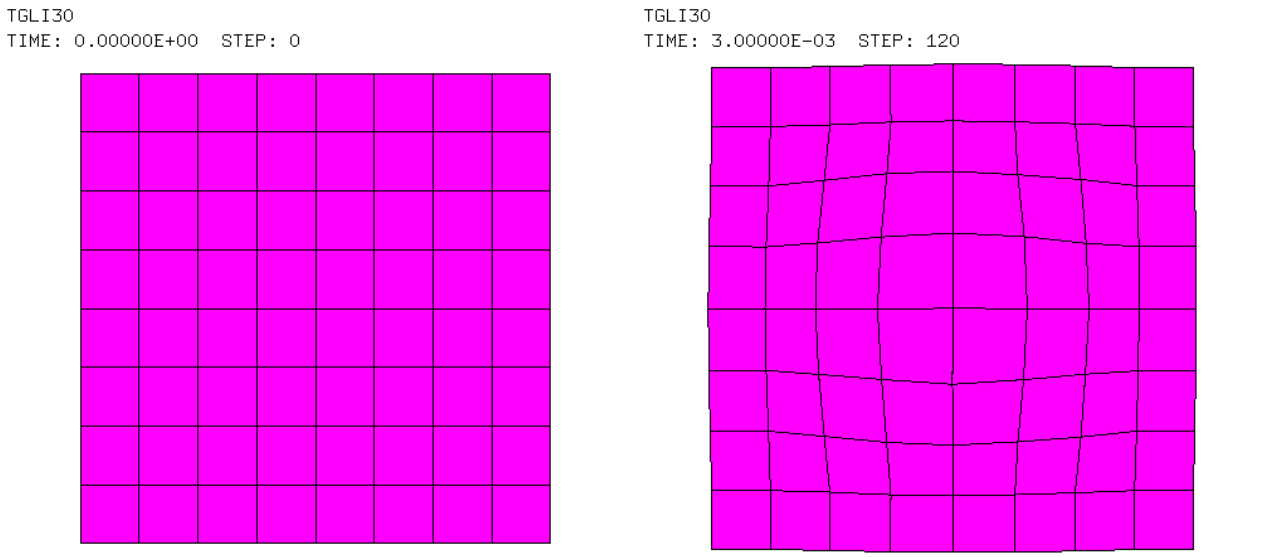
The results of this calculation are shown in Figure 27. The solution looks extremely good. Not only does the plate remain practically flat, but one can also observe a nice (also symmetric) deformation of the plate in its own plane due to friction (see Figure 28). The final shapes of the punch and of the die are also symmetric.



(a) Punch and plate

(b) Die and plate

Figure 27: Results of test TGLI30.



(a) Step 0

(b) Step 120

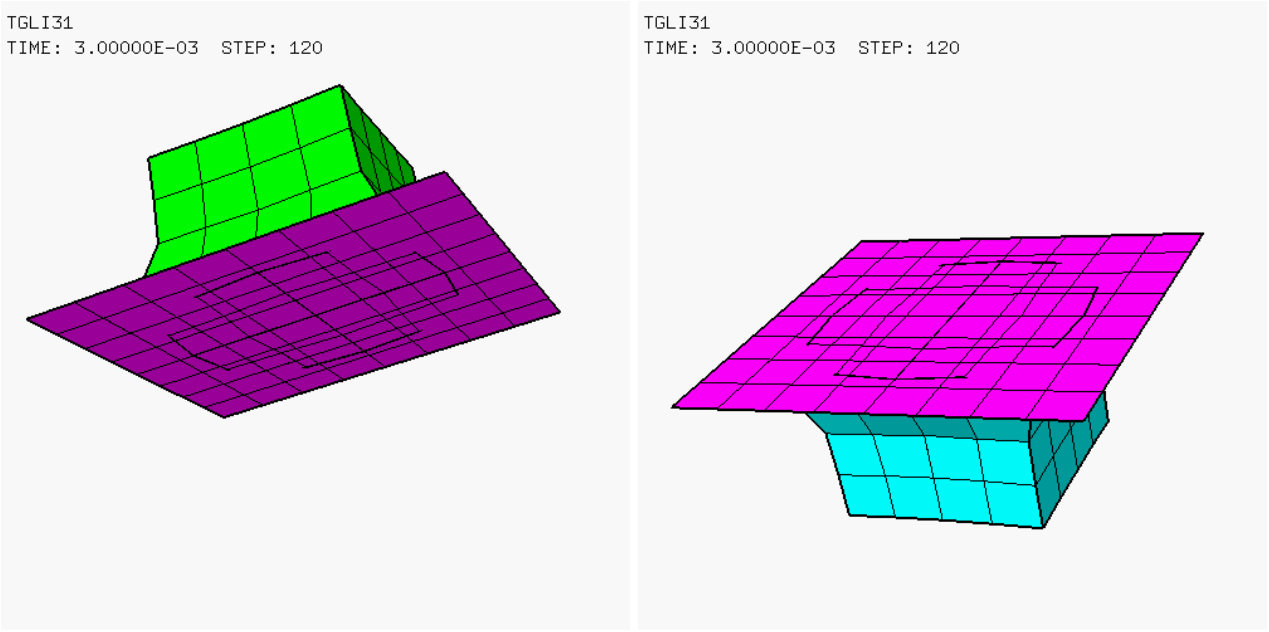
Figure 28: Plate deformation in test TGLI30.

3.4.3 TGLI31

As a final test, we do a calculation similar to case TGLI32 but without any friction. We expect the plate to remain flat and undeformed, in particular there should be no deformations in the plane of the plate. Of course, the punch and the die should still deform symmetrically.

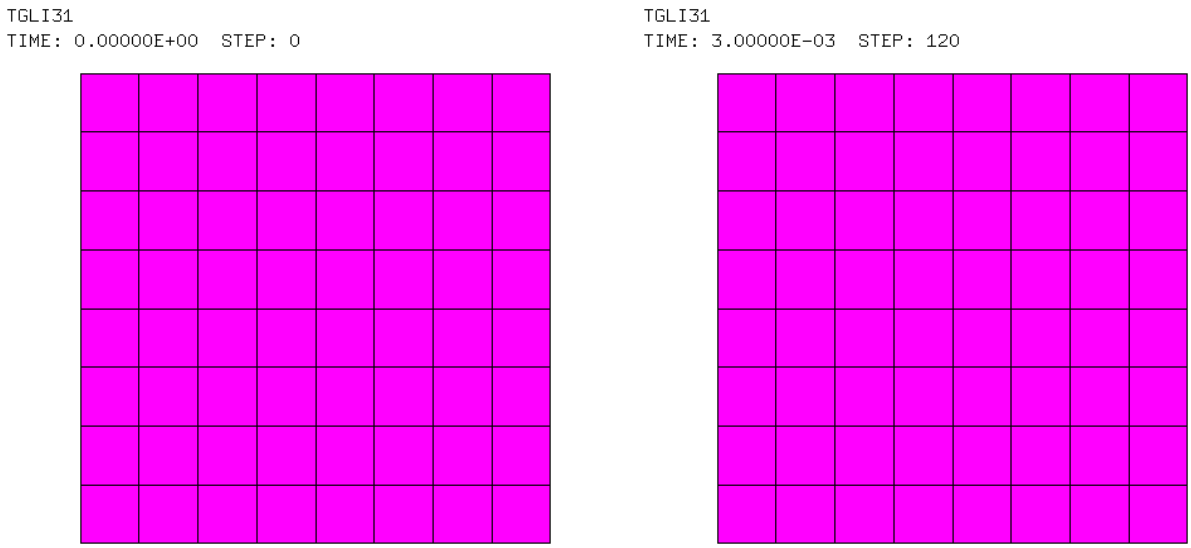
In ths problem, the plate acts simply as a means of transmitting the contact forces between the punch and the die, wich are not directly in contact with each other.

The results of this calculation are shown in Figures 29 and 30 and fully confirm the expectations.



(a) Punch and plate (b) Die and plate

Figure 29: Results of test TGLI31.



(a) Step 0 (b) Step 120

Figure 30: Plate deformation in test TGLI31.

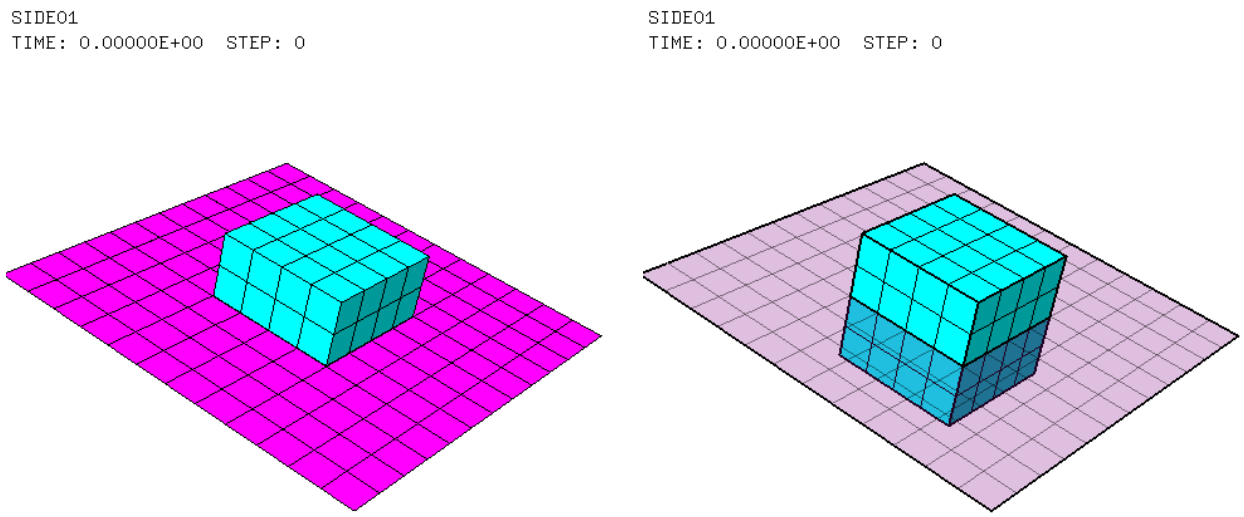
3.5 Test 3 – Edge contact of a plate on a block

This test examines another critical aspect of some contact problems, the case of a plate or other thin structure modelled by shells which contacts a solid continuum body "along an edge". Think e.g. of a plate with a hole in it, and a bolt which passes through the hole.

A simplified set-up of this problem is shown in Figure 31. The block (*die*) measures $2 \times 2 \times 2$ units. The plate measures 6×6 units by a thickness of 0.1 units, and has a central square "hole" sufficient to accommodate the block with a small gap of 0.01 units all around. The die has an initial horizontal velocity of 300 m/s and so it impacts the plate along an (internal) edge of the plate hole. No blockage conditions are imposed, so the plate is free to deform and move around.

The block and plate materials are like in the previos examples, so the block is much "softer" than

the plate and is expected to deform quite a bit.



(a) Solid view (b) Translucent view

Figure 31: Edge contact plate/block.

The calculations performed are summarized in Table 5.

Case	Mesh size	Description
SIDE01	0.50	Die is the master, plate is the slave
SIDE02	0.50	Plate is the master, die is the slave

Table 5: Calculations for the third test case.

3.5.1 SIDE01

The input file for the first calculation (SIDE01) is shortly commented below.

```
SIDE01
ECHO
 CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 die Q4GS plate TERM
COMP EPAI 0.1 LECT plate TERM
     NGRO 1 'pl_hole' LECT plate TERM COND BOX X0 -1.1 Y0 -1.1 Z0 -1
                                          DX  2.2 DY  2.2 DZ  2
     COUL TURQ LECT die   TERM
          ROSE LECT plate TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT die TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT plate TERM
```

The plate nodes along the inner perimeter of the plate (i.e. along the square "hole") are identified (*pl_hole*) by the `NGRO` directive using a `BOX` condition.

```
LINK COUP SPLT NONE
     GLIS 1 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            MAIT LECT die   TERM
            PESC LECT plate TERM
INIT VITE 2 -300.0 LECT die TERM
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
```

```
    CSTA 0.5
    GLIS NORM ELEM
    LOG 1
    LNKS STAT VISU
CALC TINI 0.0 TEND 3.E-3 PASF 2.5E-5 NMAX 120
FIN
```

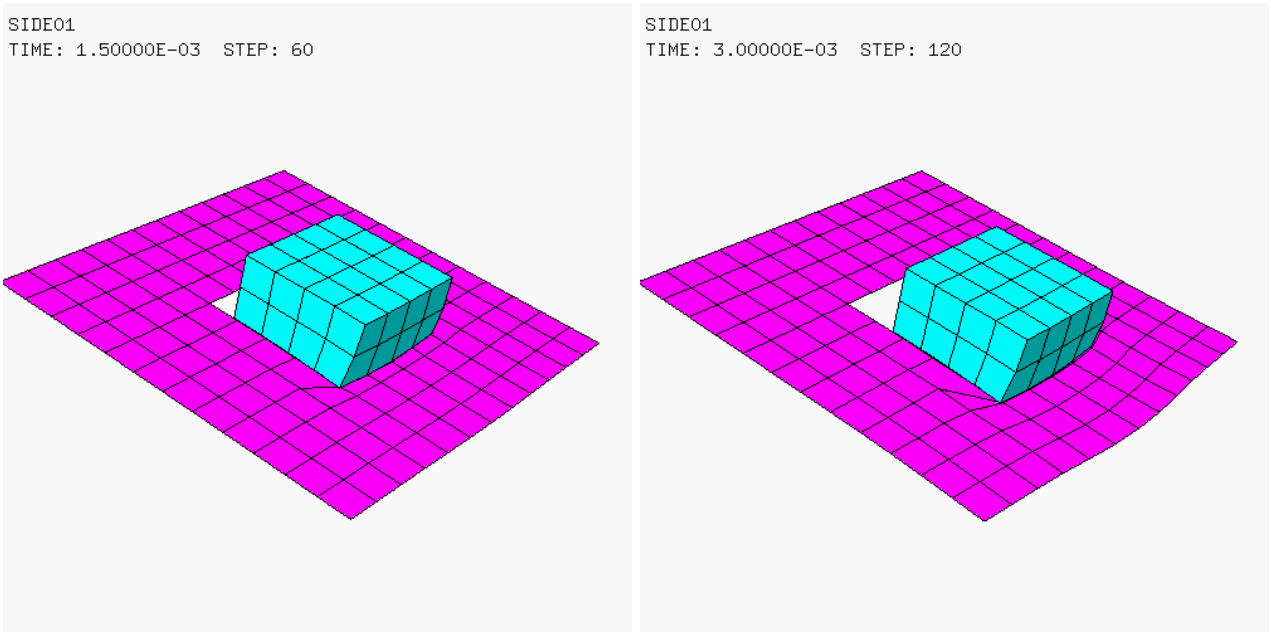
Contact is enforced by a single `GLIS` surface. Since the plate lays "perpendicular" to the contacting surfaces of the die, it seems mandatory to define the plate (nodes) as slaves, and the die (faces) as masters. Otherwise, the algorithm would probably fail in detecting penetration between die nodes and plate facets (but this will have to be checked later).

Like in previous examples, we tentatively use the `PESC` directive for the plate slave nodes. Friction is defined as usual. We also (tentatively) do *not* prescribe a gap (`PGAP`) since anyway the contact is "sideways" and not normal to the plate.

The results of this calculation are shown in Figure 32. The solution looks good as far as contact is concerned. Excessive deformation of the shell elements directly hit by the die occurs towards the final time, and these elements almost vanish, but this seems to be a problem of the Q4GS shell element, and not of the contact algorithm.

By the way, it is almost a miracle that the calculation goes on so nicely without becoming unstable, since the size of the distorted elements tends to 0 and this calculation is piloted by a fixed (user-imposed) time step of 25 μs, which is clearly far too big near the end of the computed transient.

We recall from another ongoing validation activity that, at the moment of this writing, CEA's shell elements (among which most notably Q4GS) do *not* update the element thickness as large membrane strains are produced. This may perhaps explain why in the present test the impacted elements deform so much without being able to transmit enough (membrane) load to their neighbors.



(a) Step 60 (b) Step 120

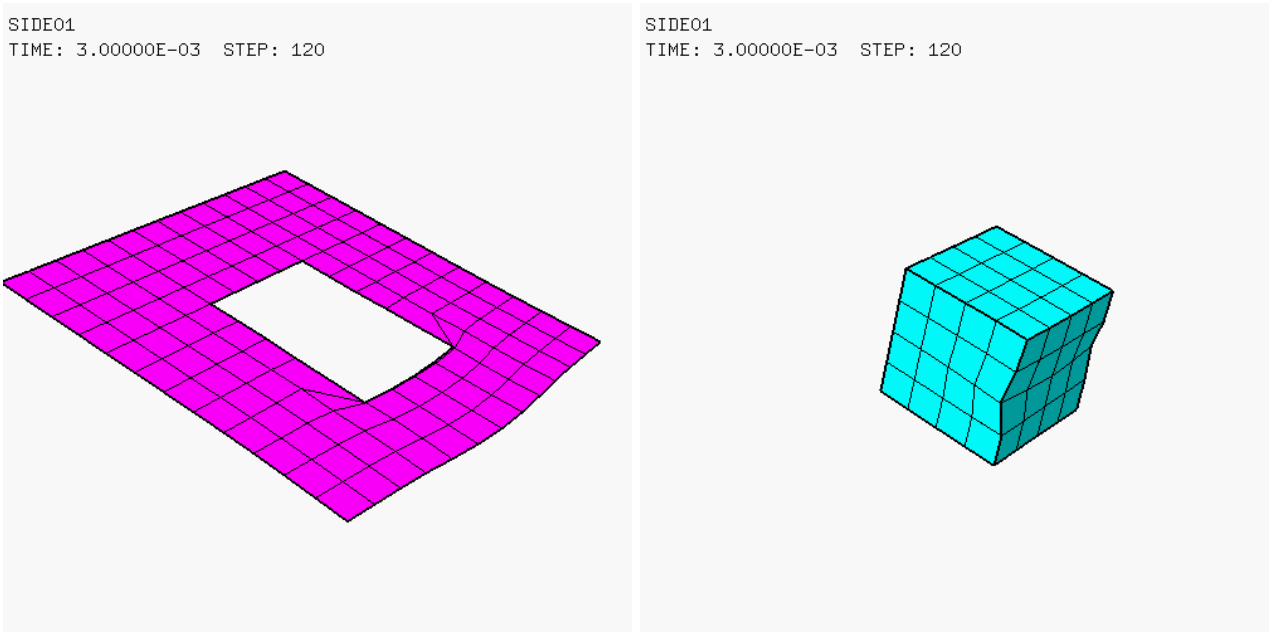
Figure 32: Some results of test SIDE01.

Figure 33 gives separate views of the plate and of the die at the final step to help appreciate the respective deformations.

3.5.2 SIDE02

In this calculation we swap the roles of master and slave with respect to the previous calculation. The plate (facets) becomes the master while the die (nodes) becomes the slave. As already mentioned above, this calculation is expected to fail in detecting the contact, but a try is made anyway.

The contact directive now reads:



(a) Plate (b) Die

Figure 33: Plate and die final shapes in test SIDE01.

```
LINK COUP SPLT NONE
     GLIS 1 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            PGAP 0.05
            CMAI LECT plate    TERM EXTE LECT die_c_top TERM
            PESC LECT die_enve TERM
```

where *die_c_top* is the center-top node of the die, used to (tentatively) define the "external" direction to the plate. Defining either an external on an internal direction is now mandatory because the plate uses the `CMAI` (not the `MAIT`) directive, which is the appropriate one for a shell master.

The *die_enve* object contains the nodes located on the envelope of the die (this object is constructed in the Cast3m pre-processor). A logical gap is tentatively defined by `PGAP 0.05` equal to half thickness of the plate, but this has no effect on the present calculation (the test has been run both with and without it).

The results of this calculation are shown in Figure 34. As expected, no (effective) contact is detected and the die "passes through" the plate undisturbed. As shown in Figure 35, some links of type GLIS are indeed present in the calculation, but they produce no contact forces, probably because the motion of the die is "parallel" to the plate surface and not perpendicular to it.

4 Applications

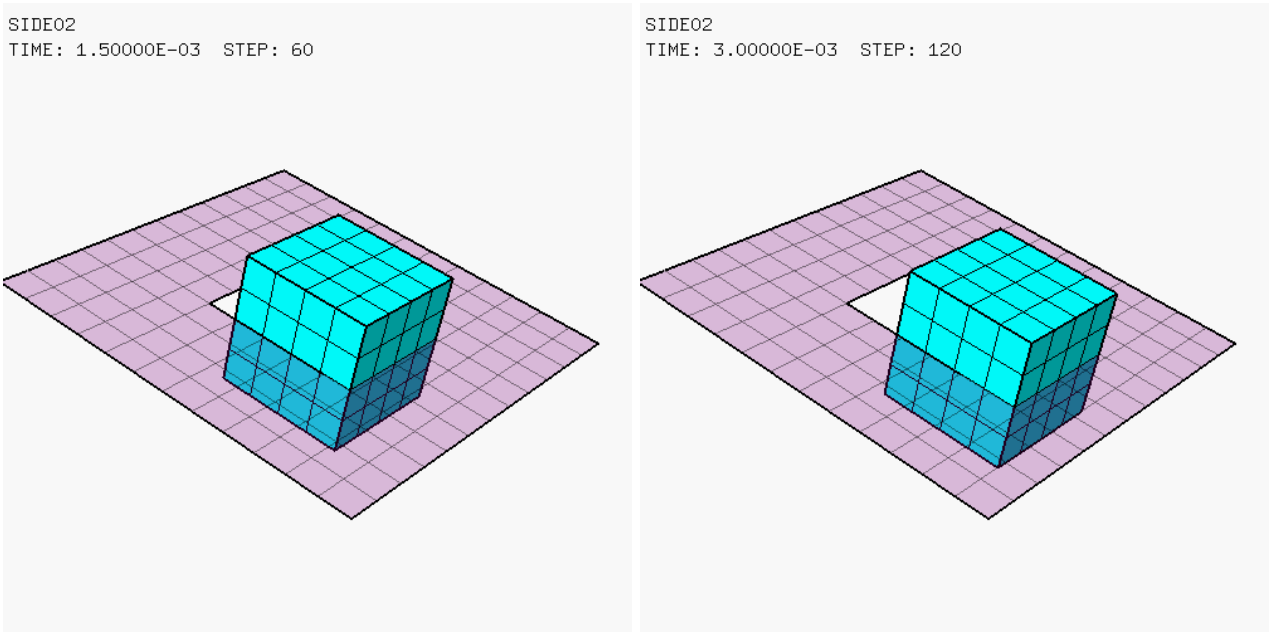
After having considered some simplified numerical tests in the previous Section, we now pass to some more realistic applications.

4.1 Plate/bolt contact under pre-stress

The application of interest here is the study of a square thin plate clamped between two relatively thick frames along its border, see Figure 36. The two frame parts are connected by bolts passing through the plate and subjected to an initial torque which exerts a given pressure on the frame in the vicinity of the bolt head and of the nut. Note that as a first approximation the nut is not included in the model and the bolt is stress-free since the clamping effect is generated by an applied pressure.

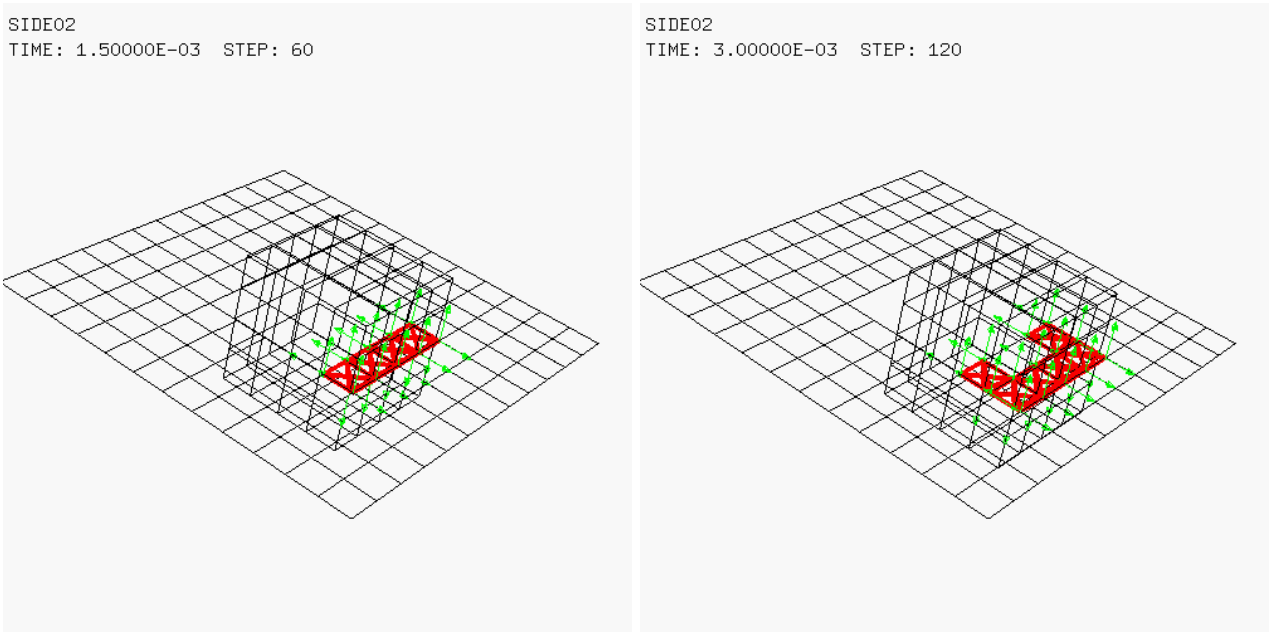
The plate is subjected to a force acting in the plate plane, which tries to pull it out of the frame. A certain friction exists between the plate and the frame.

For simplicity, here me model only one of the bolts and a small portion of the surrounding frame and plate, as shown in Figure 37. The components of the numerical model are the *plate* (shown in



(a) Step 60 (b) Step 120

Figure 34: Results of test SIDE02.



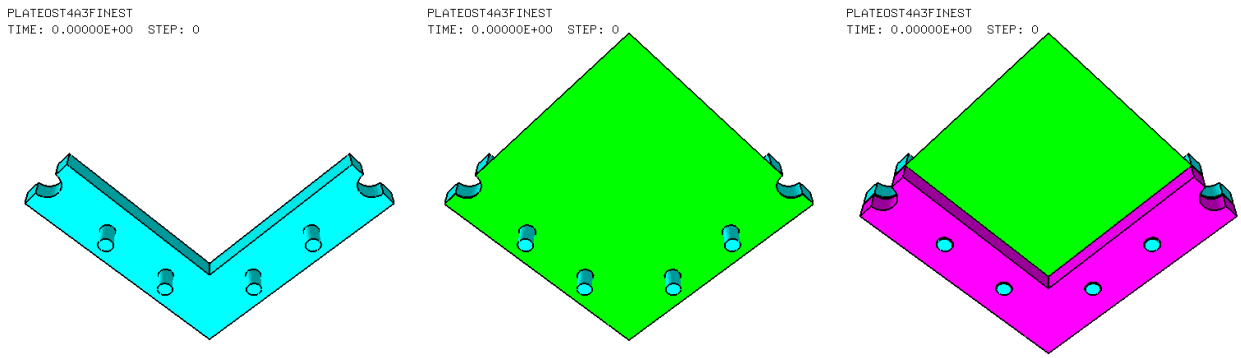
(a) Step 60 (b) Step 120

Figure 35: GLIS links (ineffective) in test SIDE02.

magenta), the *die*, which consists of the bolt and of one half of the frame modelled as a single piece (in cyan), and the *punch* which consists of the second half of the frame (in green).

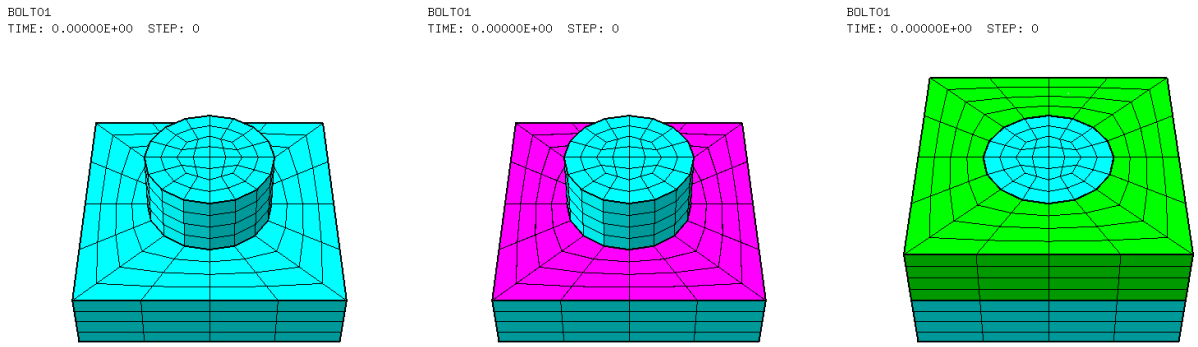
As boundary conditions, we assume that the lower surface of the die is completely blocked, and a pressure is applied to the upper surface of the punch. In addition, contact occurs between the punch and the plate, and between the die and the plate. The latter occurs along the flat upper surface of the die and the lower face of the plate, but also between the lateral cylindrical surface of the bolt and the inner (circular) perimeter of the plate (hole drilled in the plate to let the bolt pass through).

The calculations performed are summarized in Table 6.



(a) Upper frame (b) Upper frame and plate (c) Complete assembly

Figure 36: Application of interest.



(a) Die (b) Die and plate (c) Complete assembly

Figure 37: Simplified application set-up.

Case	Description
BOLT01	Pressure $p = 10$ bar on (whole) punch upper face, no traction on plate
BOLT02	Same as BOLT01 but "extended" punch and die to ameliorate contact detection
BOLT03	Same as BOLT02 but $p = 1$ bar and add horizontal force on plate edge nodes
BOLT04	Same as BOLT03 but impose horizontal velocity to plate edge nodes (fails)
BOLT05	Same as BOLT04 but add plate extension to impose velocity on
BOLT06	Same as BOLT05 but without friction
BOLT07	Same as BOLT05 but apply pressure only near the bolt

Table 6: Calculations for the simplified application test.

4.1.1 BOLT01

In this first simulation of the test problem, a pressure $p = 10$ bar is uniformly applied on the upper surface of the punch, in order to simulate the clamping effect due to the bolt torque.

The initial gap between the punch and the die is 0.01 units. The plate is located in the middle of this gap and has a logical thickness (`EPAI`) of 0.01 units. A circular gap of 0.01 units exists also between the bolt and the (hole perimeter of the) plate.

The EPX input file for this test is shortly commented.

```
BOLT01
ECHO
 CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die Q4GS plate CL3D surpre TERM
COMP EPAI 0.01 LECT plate  TERM
     COUL VERT LECT punch  TERM
          TURQ LECT die    TERM
          ROSE LECT plate  TERM
```

```
          JAUN LECT surpre TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT plate TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT punch die TERM
     IMPE PIMP RO 7850.0 PRES 10.E5 PREF 0.0
          LECT surpre TERM
```

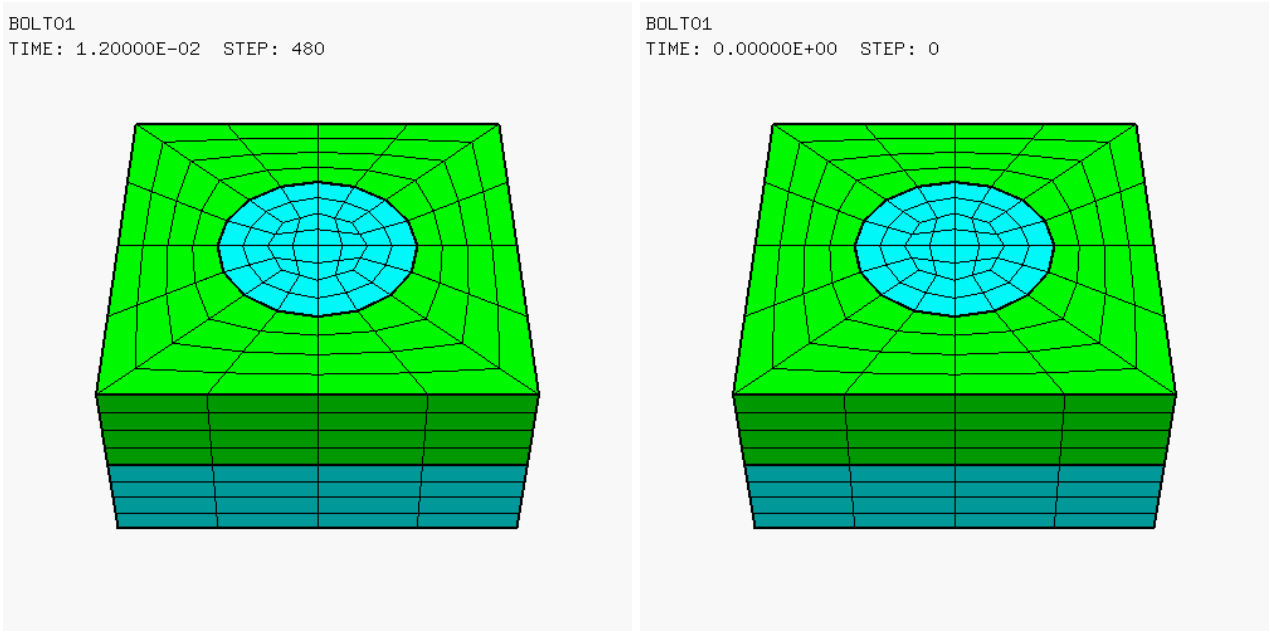
The material of the plate is aluminium-like (softer) while the material of the die and punch is steel-like (stiffer).

```
LINK COUP SPLT NONE
     GLIS 2 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            PGAP 0.005
            MAIT LECT punch TERM
            PESC LECT plate TERM
            FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #2
            PGAP 0.005
            MAIT LECT die   TERM
            PESC LECT plate TERM
LINK DECO
     BLOQ 123 LECT basdie TERM
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 12.E-3 PASF 2.5E-5 NMAX 120
FIN
```

The (coupled) boundary conditions (`LINK COUP`) are set as follows. Two sliding (contact) surfaces are declared. The first one uses the punch as master (`MAIT`) and the plate nodes as slave (`PESC`). The second one uses the die as master (`MAIT`) and, again, the plate nodes as slave (`PESC`). In both cases, a gap equal to one half of the plate thickness is declared (`PGAP 0.005`). Friction is activated for both surfaces with $\mu_s = 0.3$, $\mu_d = 0.1$. The option `GLIS NORM ELEM` is activated.

Uncoupled blockages (`LINK DECO`) are declared at the base of the die.

Some results of this calculation are shown in Figure 38. As it could be expected, the plate remains (almost) flat as it is pressed between the punch and the die. Only very small motions (hardly visible) occur, due to elastic deformations in the punch and in the die induced by the applied pressure.

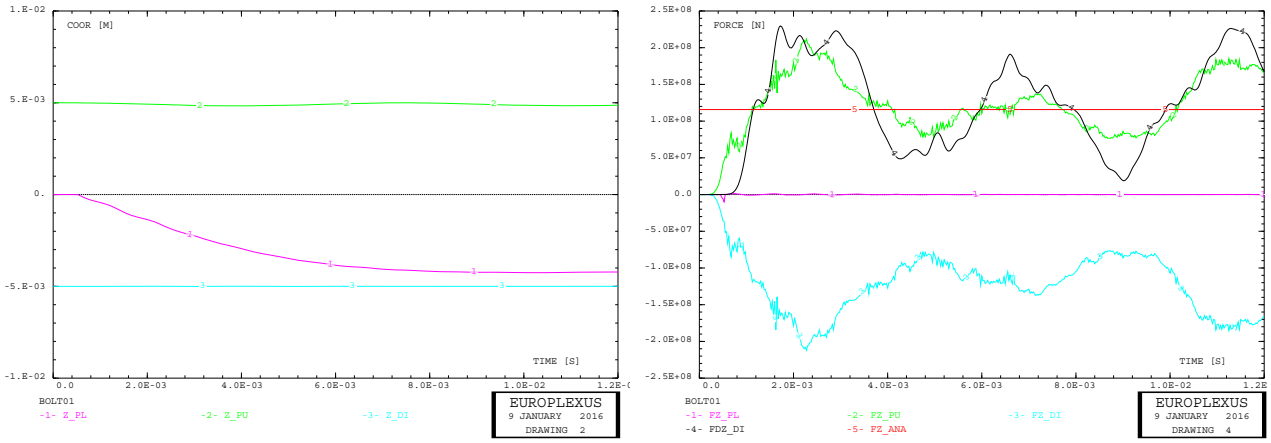


(a) Step 0 (b) Step 480

Figure 38: Deformed mesh in test BOLT01.

Figure 39 shows that, at a closer inspection, some (small) motions do occur at nodes located along the external perimeter of the plate. In (a) one sees that a plate corner node (magenta curve) moves slightly downwards, by a greater amount than the vertical motion of the corresponding punch node (green curve). The corresponding die node (cyan curve) hardly moves. This is thought to be due to the fact that contact detection along the perimeter of the plate could be problematic because of numerical tolerances (the extent of the plate is exactly the same as that of the plate and die.) Anyway, the plate node constantly remains within the "gap" formed by the physical thickness of the plate between the die and the punch. In (b) we look at (total) forces. The red curve shows the total force exerted on the punch by the applied pressure (which is constant in time). This force can be computed as follows: $F = pA$ where p is the applied pressure ($p = 10$ bar here) and A is the area of the upper surface of the punch ($A \approx 12^2 - \pi 3^2 = 115.73$ m^2), so that $F \approx 1.167 \times 10^8$ N.

The green and cyan curves are the total (coupled) vertical link forces (`FLIA`) acting on the punch and on the die, respectively. They are symmetric, as expected. Finally, the black curve is the total (uncoupled) vertical blockage force (`FDEC`) acting on the base of the die.



(a) Positions

(b) Forces

Figure 39: Motions and forces in test BOLT01.

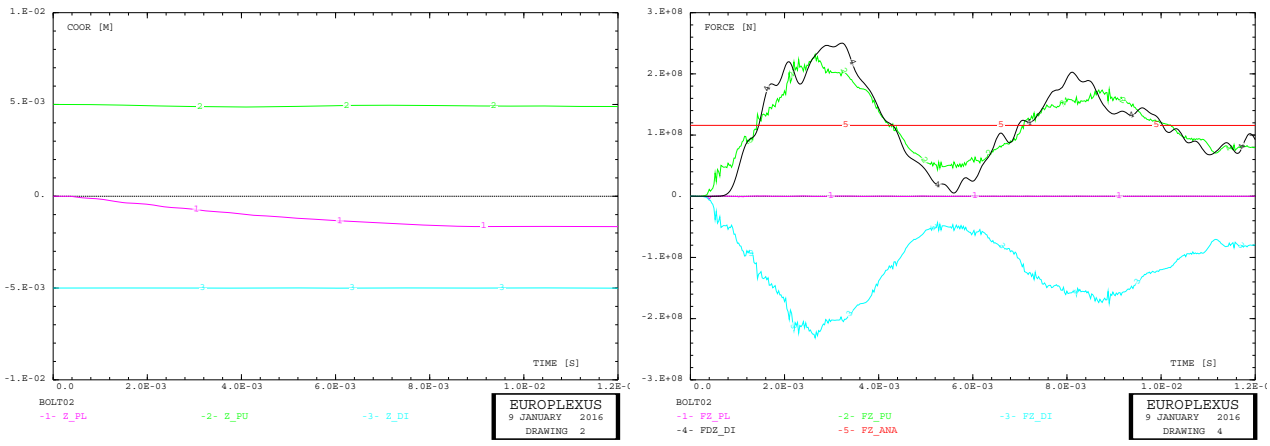
4.1.2 BOLT02

In the second solution an attempt is made to eliminiate the spurious motions of nodes along the perimeter of the plate. The punch and die models are "extended" by a small amount (0.01 units, which is hardly visible on pictures) beyond the outer perimeter of the plate, hoping that in this way contact between the slave plate nodes and the master punch and die surfaces is always detected.

The motions and forces obtained are shown in Figure 40 which should be compared with Figure 39 of the previous solution. Indeed, plate corner motion is smaller than before and also the effect on total forces is noticeable.

4.1.3 BOLT03

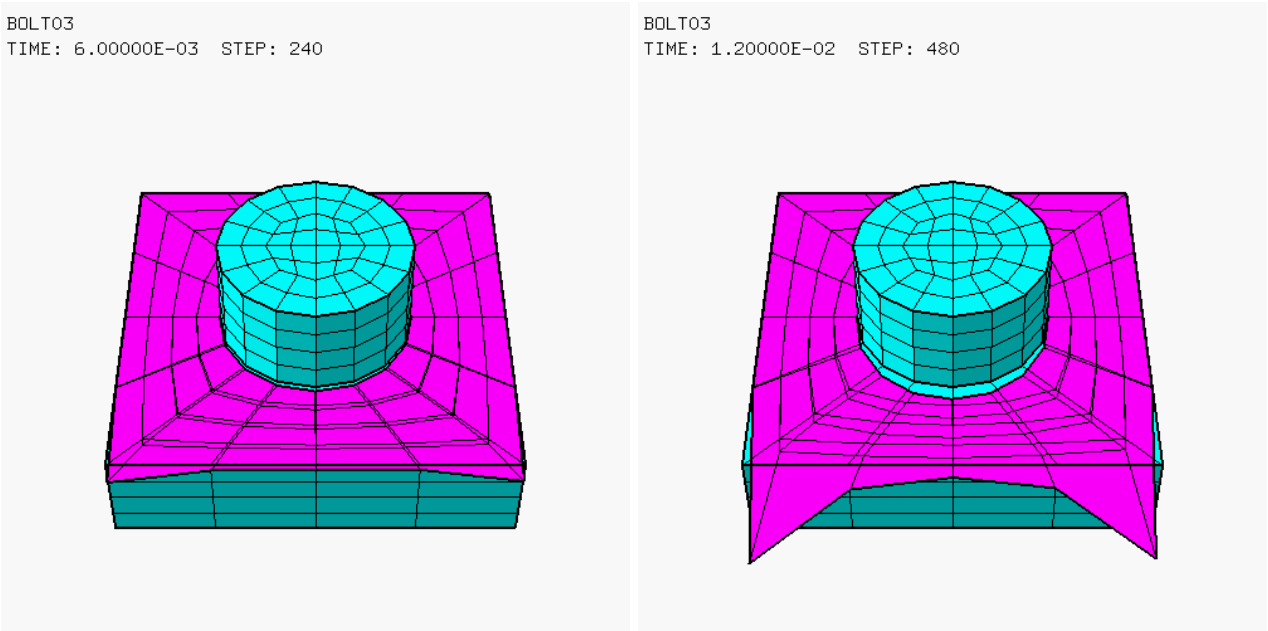
In this solution we add a horizontal force $F_y = -4.0$ MN (constant in time) to each node of the plate located along the $y = -6$ quarter-perimeter of the plate. These forces tend to pull the plate out of the clamp, but some resistance is expected to be raised by friction and also by contact between the inner perimeter (circle) of the plate and of the bolt. Note that such applied forces are only a crude approximation to a uniform membrane traction in the plate. In fact, in the case of uniform traction the (assembled) forces should not be equal at all nodes, but should rather stay in the ratio of nodal masses (i.e. the "corner" node forces should be one half of the "inner" node forces). The clamping pressure acting on the upper part of the punch is reduced to $p = 1$ bar instead of $p = 10$ bar, in order to leave the plate free to slide a bit out of the clamp without immediately tearing off in the extension zone.



(a) Positions (b) Forces

Figure 40: Motions and forces in test BOLT02.

Figure 41 shows the deformed mesh. The punch has been removed to highlight the deformation of the plate. The interaction of the plate with the bolt looks qualitatively correct: contact between the two parts is detected and the expected ovalization of the plate hole is achieved. The uneven displacement of the pulled plate edge is due to the fact that corner forces are roughly twice the value they should have in iniform membrane strain, as already noticed.



(a) Step 240 (b) Step 480

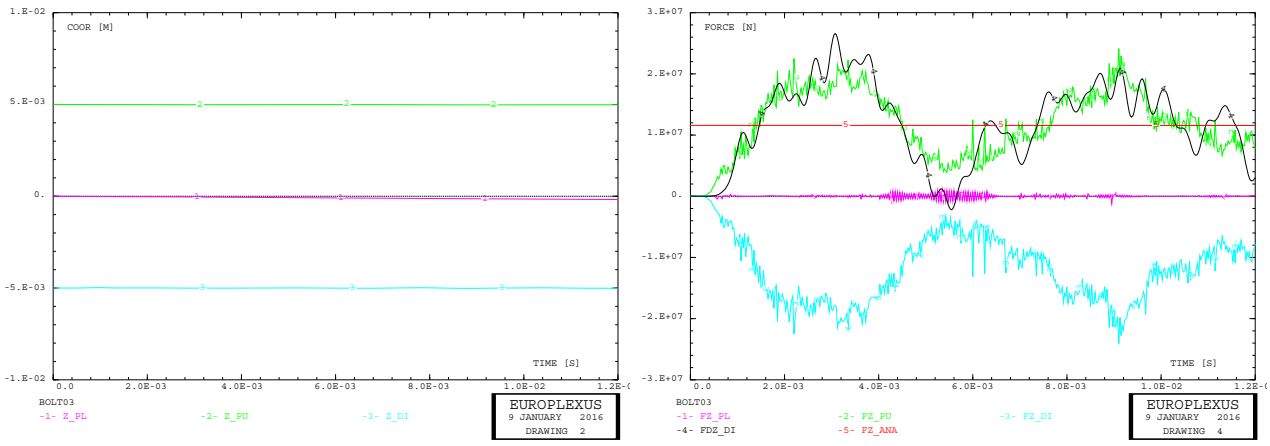
Figure 41: Defomation in test BOLT03.

Figure 42 shows the vertical positions and the vertical forces for the various components. The applied force (red curve) is now $F \approx 1.167 \times 10^7$ N, since the clamping pressure has been reduced from 10 bar to 1 bar.

4.1.4 BOLT04

In the next solution the applied force is replaced by an imposed horizontal velocity $v_y = -100$ m/s at the nodes of the concerned plate edge. This is perhaps more representative of an (almost) uniform membrane pull-out stress in the plate than applying localized forces.

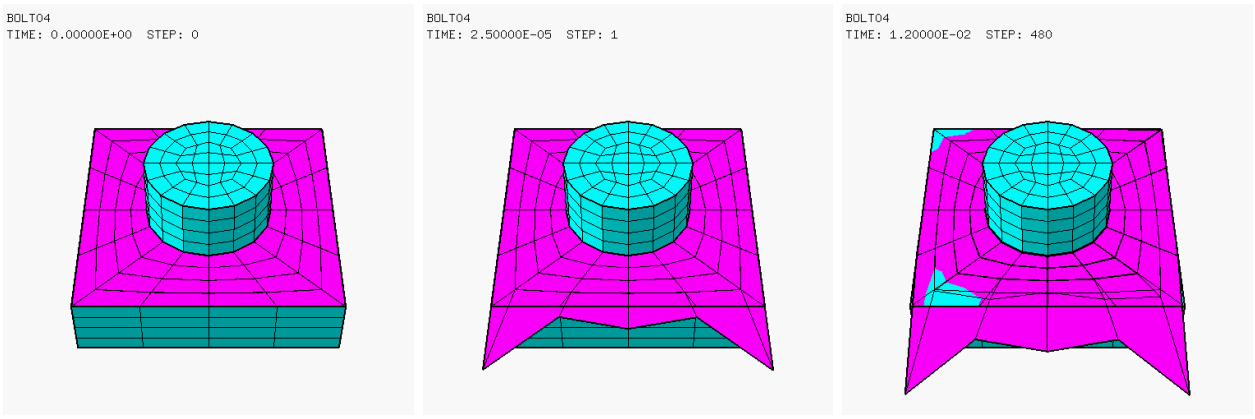
Unexpectedly, a strange behaviour is observed, see Figure 43:



(a) Positions (b) Forces

Figure 42: Motions and forces in test BOLT03.

- At step 0 (i.e. at the initial time) the (imposed) initial velocity of some nodes is modified, presumably by the `GLIS` algorithm, and raises up to some 60,000 m/s from the 100 m/s imposed.
- Consequently, already at step 1 the plate assumes the strange deformed shape of Figure 43 (b).
- Therefater, the simulation proceeds with the imposed velocity of 100 m/s until the final time, see Figure 43 (c).



(a) Step 0 (b) Step 1 (c) Step 480

Figure 43: Deformations in case BOLT04 (with imposed velocities).

The fact that the contact algorithm modifies the initial velocity is somewhat disturbing. As noted in some past publications, the time integration algorithm of EPX is such that the meaningful velocities are those at half-step. The contact (or any other) algorithm is authorized modify the mid-step velocities, but not the full-step (in particular the initial) ones.

The problem here might arise from the fact that in this test case the plate nodes on which an initial velocity is imposed are at the same time subjected to contact with the die and the punch.

An attempt has been made to circumvent the problem by imposing a linear in time displacement, rather than a constant velocity (which should be equivalent, in principle). However, the solution gets even worse.

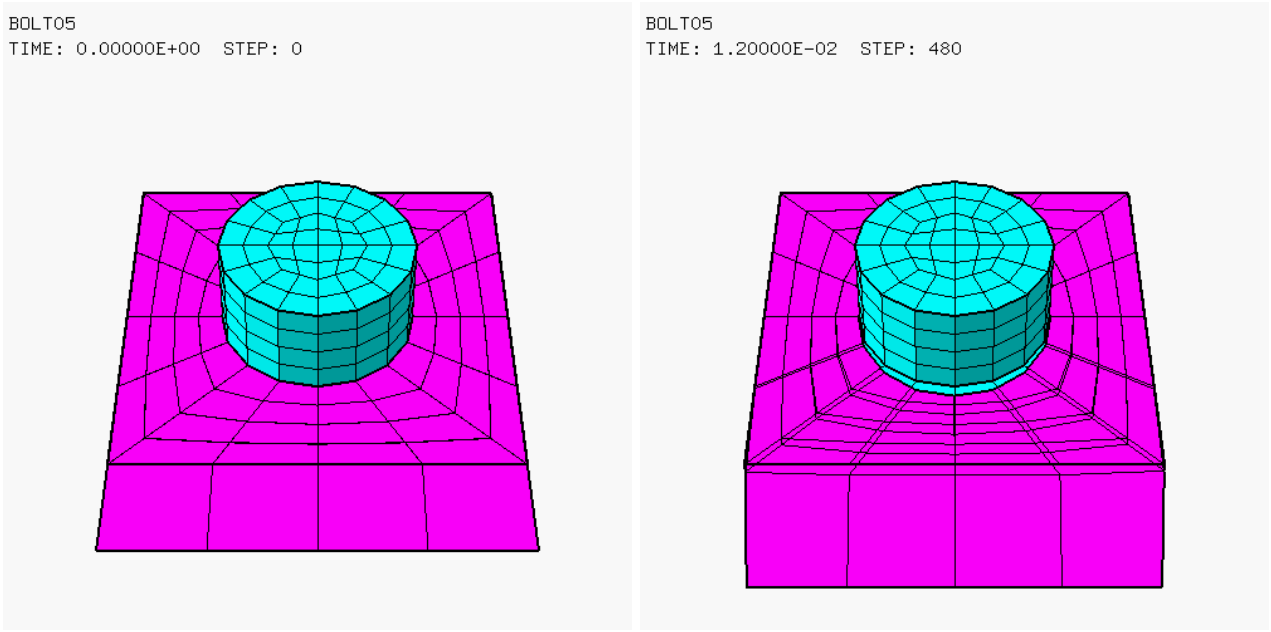
4.1.5 BOLT05

In order to avoid the numerical problems observed in the previous solution, an “extension” (ore row of elements) is added to the plate edge where the imposed velocity has to pe prescribed, so that the

nodes with the concerned velocities are not at the same time subjected to contact, see Figure 44 (a).

A displacement $d_y = -100$ m is imposed at 1 s with a linear law in time, which corresponds to an imposed velocity $v_y = -100$ m/s. An initial velocity $v_{y0} = -100$ m/s is also assigned, in order to avoid any initial "shock" in the boundary conditions.

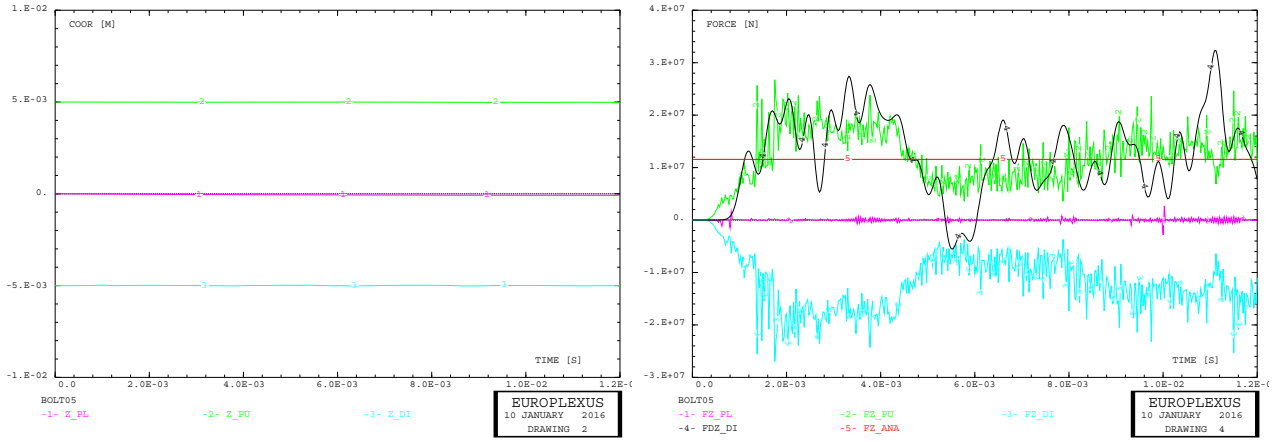
The computed deformations are shown in Figure 44 (b), and are now smooth and conforming to the expectations.



(a) Step 0 (b) Step 480

Figure 44: Defomation in test BOLT05.

Figure 45 shows the vertical positions and the vertical forces for the various components.

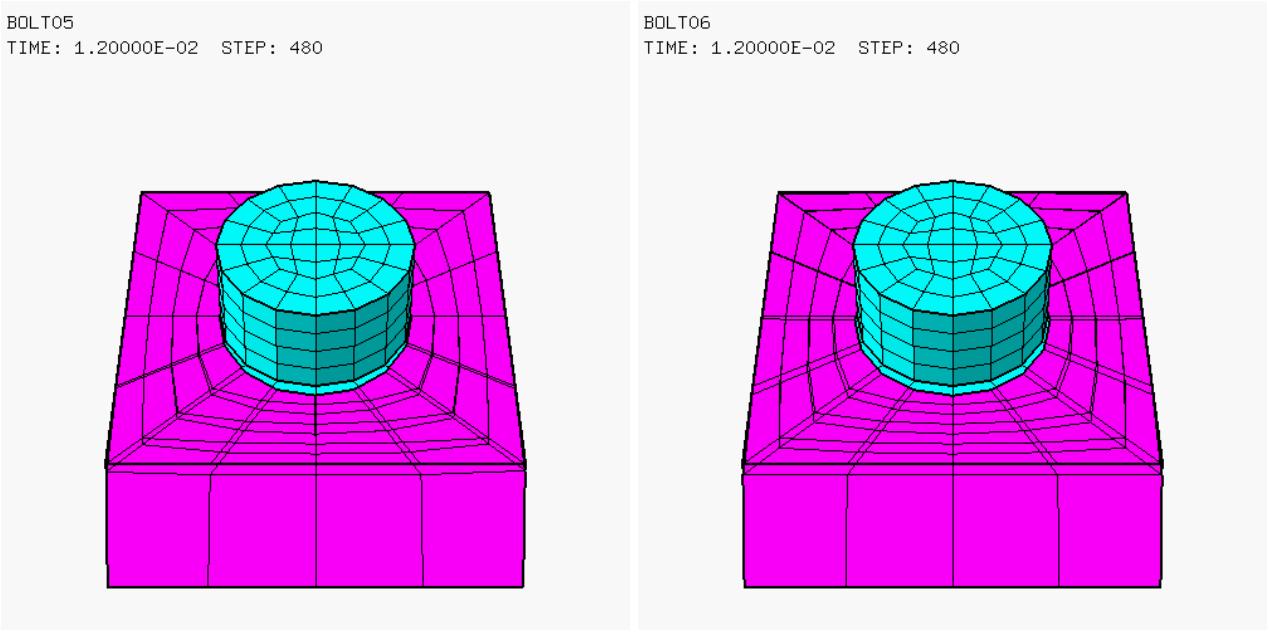


(a) Positions (b) Forces

Figure 45: Motions and forces in test BOLT05.

4.1.6 BOLT06

This calculation is a repetition of test case BOLT05 but the friction is removed, in order to check its influence on the solution. Figure 46 compares the final deformed meshes for the solutions with and without friction, showing small differences in the final shape of the deformed plate (see also the final comparison at the end of next Section).

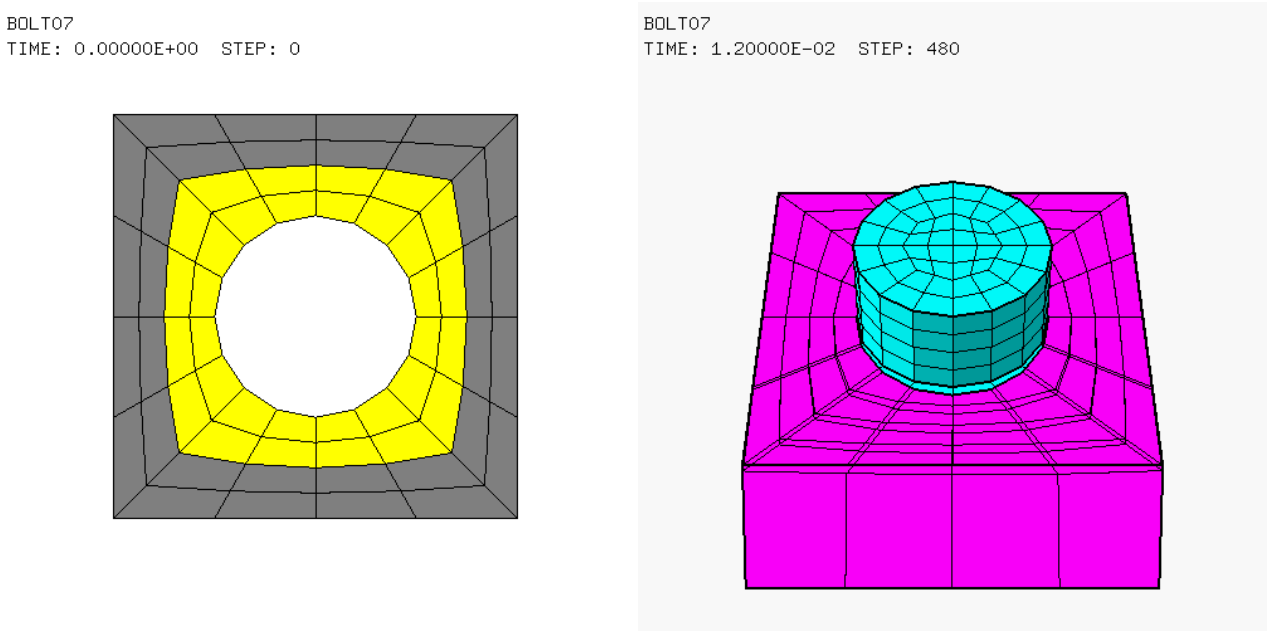


(a) Friction (b) No friction

Figure 46: Comparison of solutions BOLT05 and BOLT06.

4.1.7 BOLT07

This final calculation is a repetition of test case BOLT05 (with friction) but a (uniform) clamping pressure is applied only in the zone of the punch close to the bolt head (yellow zone in Figure 47 (a)), and not on the entire upper surface of the punch. This is thought to be more representative of the real situation.

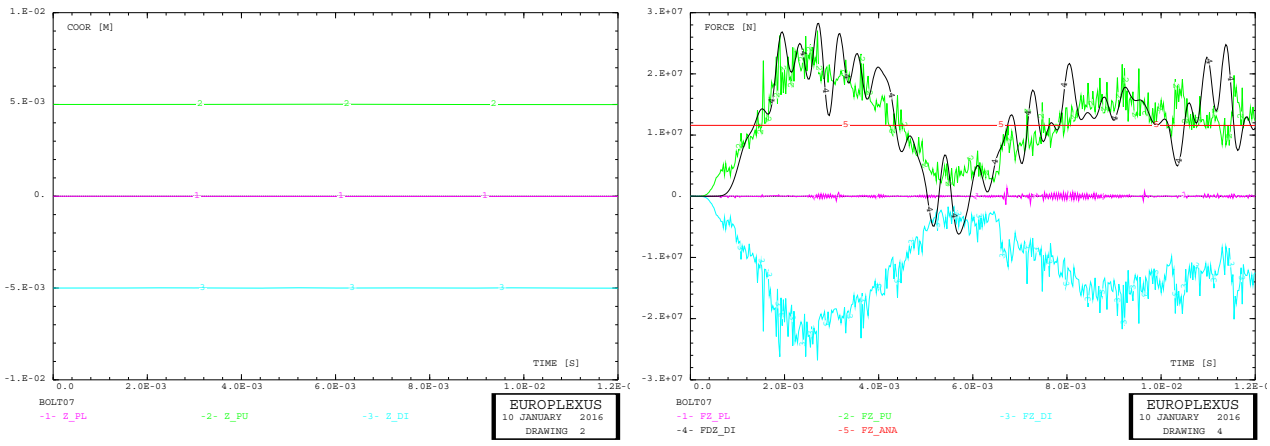


(a) Pressurized zone (yellow) (b) Step 480

Figure 47: Case BOLT07.

The value of the imposed pressure is scaled accordingly, resulting in 2.46 bar istead of 1.00 bar, so that the total applied force remains the same.

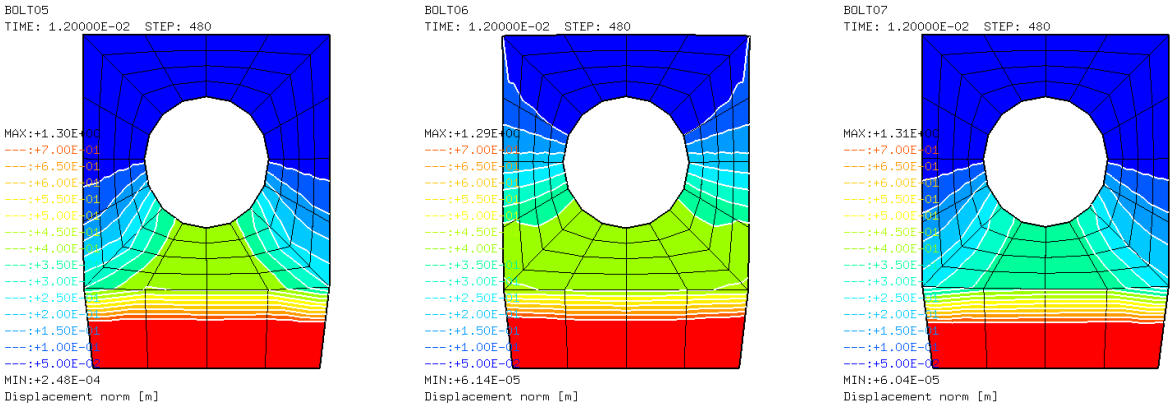
Figure 47 (b) shows the final deformed shape of the plate and Figure 48 shows the computed motions and total forces.



(a) Positions (b) Forces

Figure 48: Motions and forces in test BOLT07.

A final comparison between the solutions BOLT05 (friction, uniform pressure on the punch), BOLT06 (no friction, uniform pressure) and BOLT07 (friction, localized pressure) is shown in Figures 49 and 50.



(a) BOLT05 (b) BOLT06 (c) BOLT07

Figure 49: Plate displacement fields in cases BOLT05, BOLT06 and BOLT07.

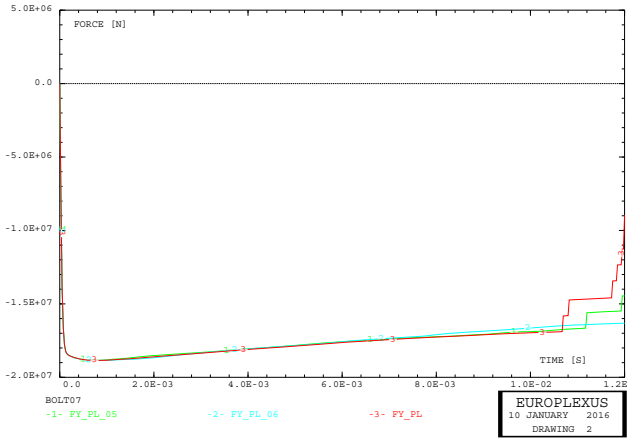


Figure 50: Comparison of pulling forces in cases BOLT05, BOLT06 and BOLT07.

The first Figure shows the displacement field in the plate at the final time. The influence of friction

is evident by comparing pictures (a) and (b). The influence of pressure distribution (in the presence of friction) is smaller but visible, see pictures (a) and (c).

The last Figure compares the total pulling forces which have to be applied to the plate edge in order to obtain the desired uniform velocity. Here the differences are less pronounced.

References

[1] EUROPLEXUS User's Manual, on-line version: http://europlexus.jrc.ec.europa.eu.

[2] Cast3m Software: http://www-cast3m.cea.fr/.

[3] V. Aune, F. Casadei and G. Valsamos. *Formulation and Implementation of a Viscoplastic Material Model in ABAQUS/Explicit and EUROPLEXUS. Application of the Cutting Plane Algorithm to Determine the Structural Response in Fast Transient Dynamics.* NTNU/JRC Report (2015), in publication.

[4] F. Casadei, G. Valsamos, M. Larcher. *Visualization of links in EUROPLEXUS* Technical Note, in publication.

Appendix A — Input files

All the input files used in the previous Sections are listed below.

bolt01.dgibi

```
*$$$$ PX4CIR3D
*
* Pour generer le maillage 3D (plan) d'un quart de cercle
* avec seulement des quadrilateres a 4 noeuds.
* Le quart de cercle est defini par les deux extremes
* d'un arc (de 90 degrees), par le centre du cercle
* et par un autre point qui definit l'axe de rotation
* (axe perpendiculaire au plan du cercle, passant pour son centre).
*
* Input:
* =====
* P1 = premiere extremite de l'arc
* P2 = deuxieme extremite de l'arc
* PC = centre de l'arc
* PZ = autre point de l'axe
* N  = nombre de mailles a generer sur chaque cote (doit etre pair)
* TOL= tolerance pour l'elimination des noeuds doubles
*
* Output:
* ======
* SUR = objet MAILLAGE d'elements de type QUA4
* IER = 0: pas d'erreur, .NE.0: erreur dans la generation de SUR
*
'DEBPROC' PX4CIR3D P1*'POINT' P2*'POINT' PC*'POINT' PZ*'POINT'
                   N*'ENTIER' TOL*'FLOTTANT';
*------------------------------------------------------------------
*
ier=0;
n2 = n / 2;
p0 = 0 0 0;
pm1 = p1 plus p0;
depl pm1 tour 45 pc pz;
pm2 = 0.5*(pc plus p2);
pm3 = 0.5*(pc plus p1);
pm = 0.5*(pc plus pm1);
c1a = cerc n2 p1 pc pm1;
c1b = cerc n2 pm1 pc p2;
c2a = droi n2 p2 pm2;
c2b = droi n2 pm2 pc;
c3a = droi n2 pc pm3;
c3b = droi n2 pm3 p1;
c4a = droi n2 pm pm1;
c4b = droi n2 pm pm2;
c4c = droi n2 pm pm3;
sur1 = dall plan c4c c3b c1a (inve c4a);
sur2 = dall plan c4a c1b c2a (inve c4b);
sur3 = dall plan c2b c3a (inve c4c) c4b;
sur = sur1 et sur2 et sur3;
*
elim tol sur;
*
'FINPROC' sur ier;
*------------------------------------------------------------------
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'bolt01.msh';
opti trac psc ftra 'bolt01_mesh.ps';
r = 3.0;
h = 3.0;
gap = 0.01;
gap2 = 0.5*gap;
pc = 0 0 0;
p1 = r 0 0;
p2 = 0 r 0;
pz = pc plus (0 0 1);
n = 4;
tol = 0.1*gap;
bol1 ier = px4cir3d p1 p2 pc pz n tol;
*
p3 = (r + gap) 0 0;
p4 = (r + r) 0 0;
p5 = (r + r) (r + r) 0;
p6 = p3 tour 45 pc pz;
c1 = p3 d n p4;
c2 = p4 d (n / 2) p5;
c3 = p5 d n p6;
c4 = c (n / 2) p6 pc p3;
sur2 = dall c1 c2 c3 c4 plan;
sur3 = orie (sur2 syme plan p6 p5 pz) dire pz;
pla1 = elim tol (sur2 et sur3);
pla2 = pla1 tour 90 pc pz;
pla3 = pla2 tour 90 pc pz;
pla4 = pla3 tour 90 pc pz;
plate = pla1 et pla2 et pla3 et pla4;
elim tol plate;
*
bol2 = bol1 tour 90 pc pz;
bol3 = bol2 tour 90 pc pz;
bol4 = bol3 tour 90 pc pz;
basbol = bol1 et bol2 et bol3 et bol4;
elim tol basbol;
basblow = basbol plus (0 0 (0 - h));
*
plc = pc plus (0 0 (0 - h));
pl3 = r 0 (0 - h);
pl4 = (r + r) 0 (0 - h);
pl5 = (r + r) (r + r) (0 - h);
pl6 = pl3 tour 45 plc pz;
cl1 = pl3 d n pl4;
cl2 = pl4 d (n / 2) pl5;
cl3 = pl5 d n pl6;
cl4 = c (n / 2) pl6 plc pl3;
surl2 = dall cl1 cl2 cl3 cl4 plan;
surl3 = orie (surl2 syme plan pl6 pl5 pz) dire pz;
plal1 = elim tol (surl2 et surl3);
plal2 = plal1 tour 90 plc pz;
plal3 = plal2 tour 90 plc pz;
plal4 = plal3 tour 90 plc pz;
platel = plal1 et plal2 et plal3 et plal4;
basdie = platel et basblow;
orie basdie dire pz;
elim tol basdie;
lowdie = basdie volu n tran (0 0 (h - gap2));
*
depl basbol plus (0 0 (0 - gap2));
bolt = basbol volu n tran (0 0 (h + gap2));
die = lowdie et bolt;
elim tol die;
*
baspun = plate plus (0 0 gap2);
punch = baspun volu n tran (0 0 (h - gap2));
surpre = baspun plus (0 0 (h - gap2));
elim tol (surpre et punch);
*
mesh = plate et die et punch et surpre;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

bolt01.epx

```
BOLT01
ECHO
 CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die Q4GS plate CL3D surpre TERM
COMP EPAI 0.01 LECT plate  TERM
     NGRO 3 'c1_pl' LECT plate TERM COND NEAR POIN -6 -6 0
            'c1_pu' LECT punch TERM COND NEAR POIN -6 -6 0
            'c1_di' LECT die   TERM COND NEAR POIN -6 -6 0
     COUL VERT LECT punch  TERM
          TURQ LECT die    TERM
          ROSE LECT plate  TERM
          JAUN LECT surpre TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT plate TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT punch die TERM
     IMPE PIMP RO 7850.0 PRES 10.E5 PREF 0.0
          LECT surpre TERM
LINK COUP SPLT NONE
     GLIS 2 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            PGAP 0.005
            MAIT LECT punch TERM
            PESC LECT plate TERM
            FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #2
            PGAP 0.005
            MAIT LECT die   TERM
            PESC LECT plate TERM
LINK DECO
     BLOQ 123 LECT basdie TERM
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 12.E-3 PASF 2.5E-5 NMAX 480
*=================================================================
PLAY
CAME   1 EYE   0.00000E+00 -3.18198E+01  3.18198E+01
!        Q     9.23880E-01  3.82683E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  7.07107E-01 -7.07107E-01
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  7.07107E-01  7.07107E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
```

```
!CENTER :  0.00000E+00  0.00000E+00  0.00000E+00
!RSPHERE:  9.00000E+00
!RADIUS :  4.50000E+01
!ASPECT :  1.00000E+00
!NEAR   :  3.51000E+01
!FAR    :  6.30000E+01
SCEN GEOM NAVI FREE
          LINE SSHA SFRE
!    ISO  FILL FIEL VITE SCAL USER PROG 0.1 PAS 0.1 1.4 TERM
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 481 FPS 15 KFRE 10 COMP -1
     OBJE LECT plate punch die TERM REND
!    OBJE LECT plate TERM REND
GOTR LOOP 479 OFFS FICH AVI CONT NOCL
     OBJE LECT plate punch die TERM REND
!    OBJE LECT plate TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT plate punch die TERM REND
!    OBJE LECT plate TERM REND
ENDPLAY
*=====================================================================
SUIT
Post-processing
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_pl' DEPL COMP 3 NOEU LECT c1_pl TERM
COUR 2 'dz_pu' DEPL COMP 3 NOEU LECT c1_pu TERM
COUR 3 'dz_di' DEPL COMP 3 NOEU LECT c1_di TERM
TRAC 1 2 3 AXES 1.0 'DISP [M]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
COLO ROSE VERT TURQ
COUR 11 'z_pl' COOR COMP 3 NOEU LECT c1_pl TERM
COUR 12 'z_pu' COOR COMP 3 NOEU LECT c1_pu TERM
COUR 13 'z_di' COOR COMP 3 NOEU LECT c1_di TERM
TRAC 11 12 13 AXES 1.0 'COOR [M]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
COLO ROSE VERT TURQ
COUR 21 'vz_pl' VITE COMP 3 NOEU LECT c1_pl TERM
COUR 22 'vz_pu' VITE COMP 3 NOEU LECT c1_pu TERM
COUR 23 'vz_di' VITE COMP 3 NOEU LECT c1_di TERM
TRAC 21 22 23 AXES 1.0 'VELO [M/S]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
COLO ROSE VERT TURQ
COUR 31 'fz_pl'  FLIA COMP 3 ZONE LECT plate TERM
COUR 32 'fz_pu'  FLIA COMP 3 ZONE LECT punch TERM
COUR 33 'fz_di'  FLIA COMP 3 ZONE LECT die   TERM
COUR 34 'fdz_di' FDEC COMP 3 ZONE LECT basdie TERM
DCOU 35 'fz_ana' 2 0 1.1573E8 12.0E-3 1.1573E8
TRAC 31 32 33 34 35 AXES 1.0 'FORCE [N]' YZER XMIN 0 XMAX 12.E-3
                                                    DX 2.E-3
COLO ROSE VERT TURQ NOIR ROUG
*=====================================================================
FIN
```

bolt02.dgibi

```
*$$$$ PX4CIR3D
*
* Pour generer le maillage 3D (plan) d'un quart de cercle
* avec seulement des quadrilateres a 4 noeuds.
* Le quart de cercle est defini par les deux extremes
* d'un arc (de 90 degrees), par le centre du cercle
* et par un autre point qui definit l'axe de rotation
* (axe perpendiculaire au plan du cercle, passant pour son centre).
*
* Input:
* =====
* P1 = premiere extremite de l'arc
* P2 = deuxieme extremite de l'arc
* PC = centre de l'arc
* PZ = autre point de l'axe
* N  = nombre de mailles a generer sur chaque cote (doit etre pair)
* TOL= tolerance pour l'elimination des noeuds doubles
*
* Output:
* ======
* SUR = objet MAILLAGE d'elements de type QUA4
* IER = 0: pas d'erreur, .NE.0: erreur dans la generation de SUR
*
'DEBPROC' PX4CIR3D P1*'POINT' P2*'POINT' PC*'POINT' PZ*'POINT'
                   N*'ENTIER' TOL*'FLOTTANT';
*---------------------------------------------------------------------
*
ier=0;
n2 = n / 2;
p0 = 0 0 0;
pm1 = p1 plus p0;
depl pm1 tour 45 pc pz;
pm2 = 0.5*(pc plus p2);
pm3 = 0.5*(pc plus p1);
pm = 0.5*(pc plus pm1);
c1a = cerc n2 p1 pc pm1;
c1b = cerc n2 pm1 pc p2;
c2a = droi n2 p2 pm2;
c2b = droi n2 pm2 pc;
c3a = droi n2 pc pm3;
c3b = droi n2 pm3 p1;
c4a = droi n2 pm pm1;
c4b = droi n2 pm pm2;
c4c = droi n2 pm pm3;
sur1 = dall plan c4c c3b c1a (inve c4a);
sur2 = dall plan c4a c1b c2a (inve c4b);
sur3 = dall plan c2b c3a (inve c4c) c4b;
sur = sur1 et sur2 et sur3;
*
elim tol sur;
*
'FINPROC' sur ier;
*---------------------------------------------------------------------
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'bolt02.msh';
opti trac psc ftra 'bolt02_mesh.ps';
r = 3.0;
h = 3.0;
gap = 0.01;
ext = 0.01;
gap2 = 0.5*gap;
pc = 0 0 0;
p1 = r 0 0;
p2 = 0 r 0;
pz = pc plus (0 0 1);
n = 4;
tol = 0.1*gap;
bol1 ier = px4cir3d p1 p2 pc pz n tol;
*
p3 = (r + gap) 0 0;
p4 = (r + r) 0 0;
p5 = (r + r) (r + r) 0;
p6 = p3 tour 45 pc pz;
c1 = p3 d n p4;
c2 = p4 d (n / 2) p5;
c3 = p5 d n p6;
c4 = c (n / 2) p6 pc p3;
sur2 = dall c1 c2 c3 c4 plan;
sur3 = orie (sur2 syme plan p6 p5 pz) dire pz;
pla1 = elim tol (sur2 et sur3);
pla2 = pla1 tour 90 pc pz;
pla3 = pla2 tour 90 pc pz;
pla4 = pla3 tour 90 pc pz;
plate = pla1 et pla2 et pla3 et pla4;
elim tol plate;
*
bol2 = bol1 tour 90 pc pz;
bol3 = bol2 tour 90 pc pz;
bol4 = bol3 tour 90 pc pz;
basbol = bol1 et bol2 et bol3 et bol4;
elim tol basbol;
basblow = basbol plus (0 0 (0 - h));
*
plc = pc plus (0 0 (0 - h));
pl3 = r 0 (0 - h);
pl4 = (r + r + ext) 0 (0 - h);
pl5 = (r + r + ext) (r + r + ext) (0 - h);
pl6 = pl3 tour 45 plc pz;
cl1 = pl3 d n pl4;
cl2 = pl4 d (n / 2) pl5;
cl3 = pl5 d n pl6;
cl4 = c (n / 2) pl6 plc pl3;
surl2 = dall cl1 cl2 cl3 cl4 plan;
surl3 = orie (surl2 syme plan pl6 pl5 pz) dire pz;
plal1 = elim tol (surl2 et surl3);
plal2 = plal1 tour 90 plc pz;
plal3 = plal2 tour 90 plc pz;
plal4 = plal3 tour 90 plc pz;
platel = plal1 et plal2 et plal3 et plal4;
basdie = platel et basblow;
orie basdie dire pz;
elim tol basdie;
lowdie = basdie volu n tran (0 0 (h - gap2));
*
depl basbol plus (0 0 (0 - gap2));
bolt = basbol volu n tran (0 0 (h + gap2));
die = lowdie et bolt;
elim tol die;
*
pex3 = (r + gap) 0 0;
pex4 = (r + r + ext) 0 0;
pex5 = (r + r + ext) (r + r + ext) 0;
pex6 = pex3 tour 45 pc pz;
cex1 = pex3 d n pex4;
cex2 = pex4 d (n / 2) pex5;
cex3 = pex5 d n pex6;
cex4 = c (n / 2) pex6 pc pex3;
surex2 = dall cex1 cex2 cex3 cex4 plan;
surex3 = orie (surex2 syme plan p6 p5 pz) dire pz;
plaex1 = elim tol (surex2 et surex3);
plaex2 = plaex1 tour 90 pc pz;
plaex3 = plaex2 tour 90 pc pz;
plaex4 = plaex3 tour 90 pc pz;
platext = plaex1 et plaex2 et plaex3 et plaex4;
elim tol platext;
*
baspun = platext plus (0 0 gap2);
punch = baspun volu n tran (0 0 (h - gap2));
surpre = baspun plus (0 0 (h - gap2));
elim tol (surpre et punch);
*
mesh = plate et die et punch et surpre;
trac cach qual mesh;
tass mesh noop;
```

```
sauv form mesh;
fin;
```

bolt02.epx

```
BOLT02
ECHO
 CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die Q4GS plate CL3D surpre TERM
COMP EPAI 0.01 LECT plate  TERM
     NGRO 3 'c1_pl' LECT plate TERM COND NEAR POIN -6 -6 0
            'c1_pu' LECT punch TERM COND NEAR POIN -6 -6 0
            'c1_di' LECT die   TERM COND NEAR POIN -6 -6 0
     COUL VERT LECT punch  TERM
          TURQ LECT die    TERM
          ROSE LECT plate  TERM
          JAUN LECT surpre TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT plate TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT punch die TERM
     IMPE PIMP RO 7850.0 PRES 10.E5 PREF 0.0
          LECT surpre TERM
LINK COUP SPLT NONE
     GLIS 2 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            PGAP 0.005
            MAIT LECT punch TERM
            PESC LECT plate TERM
            FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #2
            PGAP 0.005
            MAIT LECT die   TERM
            PESC LECT plate TERM
LINK DECO
     BLOQ 123 LECT basdie TERM
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 12.E-3 PASF 2.5E-5 NMAX 480
*=====================================================================
PLAY
CAME   1 EYE   0.00000E+00 -3.18198E+01  3.18198E+01
!        Q     9.23880E-01  3.82683E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  7.07107E-01 -7.07107E-01
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  7.07107E-01  7.07107E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  0.00000E+00
!RSPHERE:  9.00000E+00
!RADIUS :  4.50000E+01
!ASPECT :  1.00000E+00
!NEAR   :  3.51000E+01
!FAR    :  6.30000E+01
SCEN GEOM NAVI FREE
          LINE SSHA SFRE
!    ISO  FILL FIEL VITE SCAL USER PROG 0.1 PAS 0.1 1.4 TERM
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 481 FPS 15 KFRE 10 COMP -1
     OBJE LECT plate punch die TERM REND
!    OBJE LECT plate TERM REND
GOTR LOOP 479 OFFS FICH AVI CONT NOCL
     OBJE LECT plate punch die TERM REND
!    OBJE LECT plate TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT plate punch die TERM REND
!    OBJE LECT plate TERM REND
ENDPLAY
*=====================================================================
SUIT
Post-processing
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_pl' DEPL COMP 3 NOEU LECT c1_pl TERM
COUR 2 'dz_pu' DEPL COMP 3 NOEU LECT c1_pu TERM
COUR 3 'dz_di' DEPL COMP 3 NOEU LECT c1_di TERM
TRAC 1 2 3 AXES 1.0 'DISP [M]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
COLO ROSE VERT TURQ
COUR 11 'z_pl' COOR COMP 3 NOEU LECT c1_pl TERM
COUR 12 'z_pu' COOR COMP 3 NOEU LECT c1_pu TERM
COUR 13 'z_di' COOR COMP 3 NOEU LECT c1_di TERM
TRAC 11 12 13 AXES 1.0 'COOR [M]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
COLO ROSE VERT TURQ
COUR 21 'vz_pl' VITE COMP 3 NOEU LECT c1_pl TERM
COUR 22 'vz_pu' VITE COMP 3 NOEU LECT c1_pu TERM
COUR 23 'vz_di' VITE COMP 3 NOEU LECT c1_di TERM
TRAC 21 22 23 AXES 1.0 'VELO [M/S]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
COLO ROSE VERT TURQ
COUR 31 'fz_pl'  FLIA COMP 3 ZONE LECT plate TERM
COUR 32 'fz_pu'  FLIA COMP 3 ZONE LECT punch TERM
COUR 33 'fz_di'  FLIA COMP 3 ZONE LECT die   TERM
COUR 34 'fdz_di' FDEC COMP 3 ZONE LECT basdie TERM
DCOU 35 'fz_ana' 2 0 1.1573E8 12.0E-3 1.1573E8
TRAC 31 32 33 34 35 AXES 1.0 'FORCE [N]' YZER XMIN 0 XMAX 12.E-3
                                                    DX 2.E-3
COLO ROSE VERT TURQ NOIR ROUG
*=====================================================================
FIN
```

bolt03.dgibi

```
*$$$$ PX4CIR3D
*
* Pour generer le maillage 3D (plan) d'un quart de cercle
* avec seulement des quadrilateres a 4 noeuds.
* Le quart de cercle est defini par les deux extremes
* d'un arc (de 90 degrees), par le centre du cercle
* et par un autre point qui definit l'axe de rotation
* (axe perpendiculaire au plan du cercle, passant pour son centre).
*
* Input:
* =====
* P1 = premiere extremite de l'arc
* P2 = deuxieme extremite de l'arc
* PC = centre de l'arc
* PZ = autre point de l'axe
* N  = nombre de mailles a generer sur chaque cote (doit etre pair)
* TOL= tolerance pour l'elimination des noeuds doubles
*
* Output:
* ======
* SUR = objet MAILLAGE d'elements de type QUA4
* IER = 0: pas d'erreur, .NE.0: erreur dans la generation de SUR
*
'DEBPROC' PX4CIR3D P1*'POINT' P2*'POINT' PC*'POINT' PZ*'POINT'
                   N*'ENTIER' TOL*'FLOTTANT';
*---------------------------------------------------------------
*
ier=0;
n2 = n / 2;
p0 = 0 0 0;
pm1 = p1 plus p0;
depl pm1 tour 45 pc pz;
pm2 = 0.5*(pc plus p2);
pm3 = 0.5*(pc plus p1);
pm = 0.5*(pc plus pm1);
c1a = cerc n2 p1 pc pm1;
c1b = cerc n2 pm1 pc p2;
c2a = droi n2 p2 pm2;
c2b = droi n2 pm2 pc;
c3a = droi n2 pc pm3;
c3b = droi n2 pm3 p1;
c4a = droi n2 pm pm1;
c4b = droi n2 pm pm2;
c4c = droi n2 pm pm3;
sur1 = dall plan c4c c3b c1a (inve c4a);
sur2 = dall plan c4a c1b c2a (inve c4b);
sur3 = dall plan c2b c3a (inve c4c) c4b;
sur = sur1 et sur2 et sur3;
*
elim tol sur;
*
'FINPROC' sur ier;
*---------------------------------------------------------------------
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'bolt03.msh';
opti trac psc ftra 'bolt03_mesh.ps';
r = 3.0;
h = 3.0;
gap = 0.01;
ext = 0.01;
gap2 = 0.5*gap;
pc = 0 0 0;
p1 = r 0 0;
p2 = 0 r 0;
pz = pc plus (0 0 1);
n = 4;
tol = 0.1*gap;
bol1 ier = px4cir3d p1 p2 pc pz n tol;
*
p3 = (r + gap) 0 0;
p4 = (r + r) 0 0;
p5 = (r + r) (r + r) 0;
p6 = p3 tour 45 pc pz;
c1 = p3 d n p4;
c2 = p4 d (n / 2) p5;
c3 = p5 d n p6;
c4 = c (n / 2) p6 pc p3;
sur2 = dall c1 c2 c3 c4 plan;
sur3 = orie (sur2 syme plan p6 p5 pz) dire pz;
pla1 = elim tol (sur2 et sur3);
pla2 = pla1 tour 90 pc pz;
pla3 = pla2 tour 90 pc pz;
```

```
pla4 = pla3 tour 90 pc pz;
plate = pla1 et pla2 et pla3 et pla4;
elim tol plate;
*
bol2 = bol1 tour 90 pc pz;
bol3 = bol2 tour 90 pc pz;
bol4 = bol3 tour 90 pc pz;
basbol = bol1 et bol2 et bol3 et bol4;
elim tol basbol;
basblow = basbol plus (0 0 (0 - h));
*
plc = pc plus (0 0 (0 - h));
pl3 = r 0 (0 - h);
pl4 = (r + r + ext) 0 (0 - h);
pl5 = (r + r + ext) (r + r + ext) (0 - h);
pl6 = pl3 tour 45 plc pz;
cl1 = pl3 d n pl4;
cl2 = pl4 d (n / 2) pl5;
cl3 = pl5 d n pl6;
cl4 = c (n / 2) pl6 plc pl3;
surl2 = dall cl1 cl2 cl3 cl4 plan;
surl3 = orie (surl2 syme plan pl6 pl5 pz) dire pz;
plal1 = elim tol (surl2 et surl3);
plal2 = plal1 tour 90 plc pz;
plal3 = plal2 tour 90 plc pz;
plal4 = plal3 tour 90 plc pz;
platel = plal1 et plal2 et plal3 et plal4;
basdie = platel et basblow;
orie basdie dire pz;
elim tol basdie;
lowdie = basdie volu n tran (0 0 (h - gap2));
*
depl basbol plus (0 0 (0 - gap2));
bolt = basbol volu n tran (0 0 (h + gap2));
die = lowdie et bolt;
elim tol die;
*
pex3 = (r + gap) 0 0;
pex4 = (r + r + ext) 0 0;
pex5 = (r + r + ext) (r + r + ext) 0;
pex6 = pex3 tour 45 pc pz;
cex1 = pex3 d n pex4;
cex2 = pex4 d (n / 2) pex5;
cex3 = pex5 d n pex6;
cex4 = c (n / 2) pex6 pc pex3;
surex2 = dall cex1 cex2 cex3 cex4 plan;
surex3 = orie (surex2 syme plan p6 p5 pz) dire pz;
plaex1 = elim tol (surex2 et surex3);
plaex2 = plaex1 tour 90 pc pz;
plaex3 = plaex2 tour 90 pc pz;
plaex4 = plaex3 tour 90 pc pz;
platext = plaex1 et plaex2 et plaex3 et plaex4;
elim tol platext;
*
baspun = platext plus (0 0 gap2);
punch = baspun volu n tran (0 0 (h - gap2));
surpre = baspun plus (0 0 (h - gap2));
elim tol (surpre et punch);
*
mesh = plate et die et punch et surpre;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

bolt03.epx

```
BOLT03
ECHO
 CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die Q4GS plate CL3D surpre TERM
COMP EPAI 0.01 LECT plate  TERM
     NGRO 4 'nodfor' LECT plate TERM COND Y LT -5.99
            'c1_pl'  LECT plate TERM COND NEAR POIN -6 -6 0
            'c1_pu'  LECT punch TERM COND NEAR POIN -6 -6 0
            'c1_di'  LECT die   TERM COND NEAR POIN -6 -6 0
     COUL VERT LECT punch  TERM
          TURQ LECT die    TERM
          ROSE LECT plate  TERM
          JAUN LECT surpre TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT plate TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT punch die TERM
     IMPE PIMP RO 7850.0 PRES 1.E5 PREF 0.0
          LECT surpre TERM
LINK COUP SPLT NONE
     GLIS 2 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            PGAP 0.005
            MAIT LECT punch TERM
            PESC LECT plate TERM
            FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #2
            PGAP 0.005
            MAIT LECT die   TERM
            PESC LECT plate TERM
LINK DECO
     BLOQ 123 LECT basdie TERM
LOAD FCTE NODE LECT nodfor TERM
          FORC 40.E5 VECT 0 -1 0
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 12.E-3 PASF 2.5E-5 NMAX 480
*=====================================================================
PLAY
CAME   1 EYE   0.00000E+00 -3.18198E+01  3.18198E+01
!        Q     9.23880E-01  3.82683E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  7.07107E-01 -7.07107E-01
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  7.07107E-01  7.07107E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  0.00000E+00
!RSPHERE:  9.00000E+00
!RADIUS :  4.50000E+01
!ASPECT :  1.00000E+00
!NEAR   :  3.51000E+01
!FAR    :  6.30000E+01
SCEN GEOM NAVI FREE
          LINE SSHA SFRE
!    ISO  FILL FIEL VITE SCAL USER PROG 0.1 PAS 0.1 1.4 TERM
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 481 FPS 15 KFRE 10 COMP -1
!    OBJE LECT plate punch die TERM REND
     OBJE LECT plate die TERM REND
!    OBJE LECT plate TERM REND
GOTR LOOP 479 OFFS FICH AVI CONT NOCL
!    OBJE LECT plate punch die TERM REND
     OBJE LECT plate die TERM REND
!    OBJE LECT plate TERM REND
GO
TRAC OFFS FICH AVI CONT
!    OBJE LECT plate punch die TERM REND
     OBJE LECT plate die TERM REND
!    OBJE LECT plate TERM REND
ENDPLAY
*=====================================================================
SUIT
Post-processing
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_pl' DEPL COMP 3 NOEU LECT c1_pl TERM
COUR 2 'dz_pu' DEPL COMP 3 NOEU LECT c1_pu TERM
COUR 3 'dz_di' DEPL COMP 3 NOEU LECT c1_di TERM
TRAC 1 2 3 AXES 1.0 'DISP [M]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
COLO ROSE VERT TURQ
COUR 11 'z_pl' COOR COMP 3 NOEU LECT c1_pl TERM
COUR 12 'z_pu' COOR COMP 3 NOEU LECT c1_pu TERM
COUR 13 'z_di' COOR COMP 3 NOEU LECT c1_di TERM
TRAC 11 12 13 AXES 1.0 'COOR [M]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
COLO ROSE VERT TURQ
COUR 21 'vz_pl' VITE COMP 3 NOEU LECT c1_pl TERM
COUR 22 'vz_pu' VITE COMP 3 NOEU LECT c1_pu TERM
COUR 23 'vz_di' VITE COMP 3 NOEU LECT c1_di TERM
TRAC 21 22 23 AXES 1.0 'VELO [M/S]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
COLO ROSE VERT TURQ
COUR 31 'fz_pl'  FLIA COMP 3 ZONE LECT plate TERM
COUR 32 'fz_pu'  FLIA COMP 3 ZONE LECT punch TERM
COUR 33 'fz_di'  FLIA COMP 3 ZONE LECT die   TERM
COUR 34 'fdz_di' FDEC COMP 3 ZONE LECT basdie TERM
DCOU 35 'fz_ana' 2 0 1.1573E7 12.0E-3 1.1573E7
TRAC 31 32 33 34 35 AXES 1.0 'FORCE [N]' YZER XMIN 0 XMAX 12.E-3
                                                    DX 2.E-3
COLO ROSE VERT TURQ NOIR ROUG
*=====================================================================
FIN
```

bolt04.dgibi

```
*$$$$ PX4CIR3D
*
* Pour generer le maillage 3D (plan) d'un quart de cercle
* avec seulement des quadrilateres a 4 noeuds.
* Le quart de cercle est defini par les deux extremes
* d'un arc (de 90 degrees), par le centre du cercle
* et par un autre point qui definit l'axe de rotation
* (axe perpendiculaire au plan du cercle, passant pour son centre).
*
* Input:
* =====
* P1 = premiere extremite de l'arc
* P2 = deuxieme extremite de l'arc
* PC = centre de l'arc
* PZ = autre point de l'axe
* N  = nombre de mailles a generer sur chaque cote (doit etre pair)
```

```
* TOL= tolerance pour l'elimination des noeuds doubles
*
* Output:
* ======
* SUR = objet MAILLAGE d'elements de type QUA4
* IER = 0: pas d'erreur, .NE.0: erreur dans la generation de SUR
*
'DEBPROC' PX4CIR3D P1*'POINT' P2*'POINT' PC*'POINT' PZ*'POINT'
                   N*'ENTIER' TOL*'FLOTTANT';
*-----------------------------------------------------------------
*
ier=0;
n2 = n / 2;
p0 = 0 0 0;
pm1 = p1 plus p0;
depl pm1 tour 45 pc pz;
pm2 = 0.5*(pc plus p2);
pm3 = 0.5*(pc plus p1);
pm = 0.5*(pc plus pm1);
c1a = cerc n2 p1 pc pm1;
c1b = cerc n2 pm1 pc p2;
c2a = droi n2 p2 pm2;
c2b = droi n2 pm2 pc;
c3a = droi n2 pc pm3;
c3b = droi n2 pm3 p1;
c4a = droi n2 pm pm1;
c4b = droi n2 pm pm2;
c4c = droi n2 pm pm3;
sur1 = dall plan c4c c3b c1a (inve c4a);
sur2 = dall plan c4a c1b c2a (inve c4b);
sur3 = dall plan c2b c3a (inve c4c) c4b;
sur = sur1 et sur2 et sur3;
*
elim tol sur;
*
'FINPROC' sur ier;
*-----------------------------------------------------------------------
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'bolt04.msh';
opti trac psc ftra 'bolt04_mesh.ps';
r = 3.0;
h = 3.0;
gap = 0.01;
ext = 0.01;
gap2 = 0.5*gap;
pc = 0 0 0;
p1 = r 0 0;
p2 = 0 r 0;
pz = pc plus (0 0 1);
n = 4;
tol = 0.1*gap;
bol1 ier = px4cir3d p1 p2 pc pz n tol;
*
p3 = (r + gap) 0 0;
p4 = (r + r) 0 0;
p5 = (r + r) (r + r) 0;
p6 = p3 tour 45 pc pz;
c1 = p3 d n p4;
c2 = p4 d (n / 2) p5;
c3 = p5 d n p6;
c4 = c (n / 2) p6 pc p3;
sur2 = dall c1 c2 c3 c4 plan;
sur3 = orie (sur2 syme plan p6 p5 pz) dire pz;
pla1 = elim tol (sur2 et sur3);
pla2 = pla1 tour 90 pc pz;
pla3 = pla2 tour 90 pc pz;
pla4 = pla3 tour 90 pc pz;
plate = pla1 et pla2 et pla3 et pla4;
elim tol plate;
*
bol2 = bol1 tour 90 pc pz;
bol3 = bol2 tour 90 pc pz;
bol4 = bol3 tour 90 pc pz;
basbol = bol1 et bol2 et bol3 et bol4;
elim tol basbol;
basblow = basbol plus (0 0 (0 - h));
*
plc = pc plus (0 0 (0 - h));
pl3 = r 0 (0 - h);
pl4 = (r + r + ext) 0 (0 - h);
pl5 = (r + r + ext) (r + r + ext) (0 - h);
pl6 = pl3 tour 45 plc pz;
cl1 = pl3 d n pl4;
cl2 = pl4 d (n / 2) pl5;
cl3 = pl5 d n pl6;
cl4 = c (n / 2) pl6 plc pl3;
surl2 = dall cl1 cl2 cl3 cl4 plan;
surl3 = orie (surl2 syme plan pl6 pl5 pz) dire pz;
plal1 = elim tol (surl2 et surl3);
plal2 = plal1 tour 90 plc pz;
plal3 = plal2 tour 90 plc pz;
plal4 = plal3 tour 90 plc pz;
platel = plal1 et plal2 et plal3 et plal4;
basdie = platel et basblow;
orie basdie dire pz;
elim tol basdie;
lowdie = basdie volu n tran (0 0 (h - gap2));
*
depl basbol plus (0 0 (0 - gap2));
bolt = basbol volu n tran (0 0 (h + gap2));
die = lowdie et bolt;
elim tol die;
*
pex3 = (r + gap) 0 0;
pex4 = (r + r + ext) 0 0;
pex5 = (r + r + ext) (r + r + ext) 0;
pex6 = pex3 tour 45 pc pz;
cex1 = pex3 d n pex4;
cex2 = pex4 d (n / 2) pex5;
cex3 = pex5 d n pex6;
cex4 = c (n / 2) pex6 pc pex3;
surex2 = dall cex1 cex2 cex3 cex4 plan;
surex3 = orie (surex2 syme plan p6 p5 pz) dire pz;
plaex1 = elim tol (surex2 et surex3);
plaex2 = plaex1 tour 90 pc pz;
plaex3 = plaex2 tour 90 pc pz;
plaex4 = plaex3 tour 90 pc pz;
platext = plaex1 et plaex2 et plaex3 et plaex4;
elim tol platext;
*
baspun = platext plus (0 0 gap2);
punch = baspun volu n tran (0 0 (h - gap2));
surpre = baspun plus (0 0 (h - gap2));
elim tol (surpre et punch);
*
mesh = plate et die et punch et surpre;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

bolt04.epx

```
BOLT04
ECHO
 CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die Q4GS plate CL3D surpre TERM
COMP EPAI 0.01 LECT plate  TERM
     NGRO 4 'nodfor' LECT plate TERM COND Y LT -5.99
            'c1_pl'  LECT plate TERM COND NEAR POIN -6 -6 0
            'c1_pu'  LECT punch TERM COND NEAR POIN -6 -6 0
            'c1_di'  LECT die   TERM COND NEAR POIN -6 -6 0
     COUL VERT LECT punch  TERM
          TURQ LECT die    TERM
          ROSE LECT plate  TERM
          JAUN LECT surpre TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT plate TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT punch die TERM
     IMPE PIMP RO 7850.0 PRES 1.E5 PREF 0.0
          LECT surpre TERM
LINK COUP SPLT NONE
     VITE 2 -100.0 FONC 1 LECT nodfor TERM
     GLIS 2 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            PGAP 0.005
            MAIT LECT punch TERM
            PESC LECT plate TERM
            FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #2
            PGAP 0.005
            MAIT LECT die   TERM
            PESC LECT plate TERM
FONC NUM 1 TABL 2 0.0 1.0 1.0 1.0
LINK DECO
     BLOQ 123 LECT basdie TERM
INIT VITE 2 -100.0 LECT nodfor TERM
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 12.E-3 PASF 2.5E-5 NMAX 480
*=====================================================================
PLAY
CAME   1 EYE   0.00000E+00 -3.18198E+01  3.18198E+01
!        Q     9.23880E-01  3.82683E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  7.07107E-01 -7.07107E-01
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  7.07107E-01  7.07107E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  0.00000E+00
!RSPHERE:  9.00000E+00
!RADIUS :  4.50000E+01
!ASPECT :  1.00000E+00
!NEAR   :  3.51000E+01
!FAR    :  6.30000E+01
SCEN GEOM NAVI FREE
          LINE SSHA SFRE
!    ISO  FILL FIEL VITE SCAL USER PROG 0.1 PAS 0.1 1.4 TERM
     LIMA ON
```

```
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 481 FPS 15 KFRE 10 COMP -1
!    OBJE LECT plate punch die TERM REND
     OBJE LECT plate die TERM REND
!    OBJE LECT plate TERM REND
GOTR LOOP 479 OFFS FICH AVI CONT NOCL
!    OBJE LECT plate punch die TERM REND
     OBJE LECT plate die TERM REND
!    OBJE LECT plate TERM REND
GO
TRAC OFFS FICH AVI CONT
!    OBJE LECT plate punch die TERM REND
     OBJE LECT plate die TERM REND
!    OBJE LECT plate TERM REND
ENDPLAY
*=====================================================================
SUIT
Post-processing
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_pl' DEPL COMP 3 NOEU LECT c1_pl TERM
COUR 2 'dz_pu' DEPL COMP 3 NOEU LECT c1_pu TERM
COUR 3 'dz_di' DEPL COMP 3 NOEU LECT c1_di TERM
TRAC 1 2 3 AXES 1.0 'DISP [M]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
COLO ROSE VERT TURQ
COUR 11 'z_pl' COOR COMP 3 NOEU LECT c1_pl TERM
COUR 12 'z_pu' COOR COMP 3 NOEU LECT c1_pu TERM
COUR 13 'z_di' COOR COMP 3 NOEU LECT c1_di TERM
TRAC 11 12 13 AXES 1.0 'COOR [M]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
COLO ROSE VERT TURQ
COUR 21 'vz_pl' VITE COMP 3 NOEU LECT c1_pl TERM
COUR 22 'vz_pu' VITE COMP 3 NOEU LECT c1_pu TERM
COUR 23 'vz_di' VITE COMP 3 NOEU LECT c1_di TERM
TRAC 21 22 23 AXES 1.0 'VELO [M/S]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
COLO ROSE VERT TURQ
COUR 31 'fz_pl'  FLIA COMP 3 ZONE LECT plate TERM
COUR 32 'fz_pu'  FLIA COMP 3 ZONE LECT punch TERM
COUR 33 'fz_di'  FLIA COMP 3 ZONE LECT die   TERM
COUR 34 'fdz_di' FDEC COMP 3 ZONE LECT basdie TERM
DCOU 35 'fz_ana' 2 0 1.1573E7 12.0E-3 1.1573E7
TRAC 31 32 33 34 35 AXES 1.0 'FORCE [N]' YZER XMIN 0 XMAX 12.E-3
                                                    DX 2.E-3
COLO ROSE VERT TURQ NOIR ROUG
*=====================================================================
FIN
```

bolt05.dgibi

```
*$$$$ PX4CIR3D
*
* Pour generer le maillage 3D (plan) d'un quart de cercle
* avec seulement des quadrilateres a 4 noeuds.
* Le quart de cercle est defini par les deux extremes
* d'un arc (de 90 degrees), par le centre du cercle
* et par un autre point qui definit l'axe de rotation
* (axe perpendiculaire au plan du cercle, passant pour son centre).
*
* Input:
* =====
* P1 = premiere extremite de l'arc
* P2 = deuxieme extremite de l'arc
* PC = centre de l'arc
* PZ = autre point de l'axe
* N  = nombre de mailles a generer sur chaque cote (doit etre pair)
* TOL= tolerance pour l'elimination des noeuds doubles
*
* Output:
* ======
* SUR = objet MAILLAGE d'elements de type QUA4
* IER = 0: pas d'erreur, .NE.0: erreur dans la generation de SUR
*
'DEBPROC' PX4CIR3D P1*'POINT' P2*'POINT' PC*'POINT' PZ*'POINT'
                   N*'ENTIER' TOL*'FLOTTANT';
*----------------------------------------------------------------------
*
ier=0;
n2 = n / 2;
p0 = 0 0 0;
pm1 = p1 plus p0;
depl pm1 tour 45 pc pz;
pm2 = 0.5*(pc plus p2);
pm3 = 0.5*(pc plus p1);
pm = 0.5*(pc plus pm1);
c1a = cerc n2 p1 pc pm1;
c1b = cerc n2 pm1 pc p2;
c2a = droi n2 p2 pm2;
c2b = droi n2 pm2 pc;
c3a = droi n2 pc pm3;
c3b = droi n2 pm3 p1;
c4a = droi n2 pm pm1;
c4b = droi n2 pm pm2;
c4c = droi n2 pm pm3;
sur1 = dall plan c4c c3b c1a (inve c4a);
sur2 = dall plan c4a c1b c2a (inve c4b);
sur3 = dall plan c2b c3a (inve c4c) c4b;
sur = sur1 et sur2 et sur3;
*
elim tol sur;
*
'FINPROC' sur ier;
*----------------------------------------------------------------------
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'bolt05.msh';
opti trac psc ftra 'bolt05_mesh.ps';
r = 3.0;
h = 3.0;
gap = 0.01;
ext = 0.01;
gap2 = 0.5*gap;
pc = 0 0 0;
p1 = r 0 0;
p2 = 0 r 0;
pz = pc plus (0 0 1);
n = 4;
tol = 0.1*gap;
bol1 ier = px4cir3d p1 p2 pc pz n tol;
*
p3 = (r + gap) 0 0;
p4 = (r + r) 0 0;
p5 = (r + r) (r + r) 0;
p6 = p3 tour 45 pc pz;
c1 = p3 d n p4;
c2 = p4 d (n / 2) p5;
c3 = p5 d n p6;
c4 = c (n / 2) p6 pc p3;
sur2 = dall c1 c2 c3 c4 plan;
sur3 = orie (sur2 syme plan p6 p5 pz) dire pz;
pla1 = elim tol (sur2 et sur3);
pla2 = pla1 tour 90 pc pz;
pla3 = pla2 tour 90 pc pz;
pla4 = pla3 tour 90 pc pz;
placon = pla1 et pla2 et pla3 et pla4;
pea = (0 - h - h) (0 - h - h - 3.0) 0;
peb = (0 + h + h) (0 - h - h - 3.0) 0;
pedge = pea d n peb;
pext = pedge tran 1 (0 3.0 0);
plate = placon et pext;
elim tol plate;
*
bol2 = bol1 tour 90 pc pz;
bol3 = bol2 tour 90 pc pz;
bol4 = bol3 tour 90 pc pz;
basbol = bol1 et bol2 et bol3 et bol4;
elim tol basbol;
basblow = basbol plus (0 0 (0 - h));
*
plc = pc plus (0 0 (0 - h));
pl3 = r 0 (0 - h);
pl4 = (r + r + ext) 0 (0 - h);
pl5 = (r + r + ext) (r + r + ext) (0 - h);
pl6 = pl3 tour 45 plc pz;
cl1 = pl3 d n pl4;
cl2 = pl4 d (n / 2) pl5;
cl3 = pl5 d n pl6;
cl4 = c (n / 2) pl6 plc pl3;
surl2 = dall cl1 cl2 cl3 cl4 plan;
surl3 = orie (surl2 syme plan pl6 pl5 pz) dire pz;
plal1 = elim tol (surl2 et surl3);
plal2 = plal1 tour 90 plc pz;
plal3 = plal2 tour 90 plc pz;
plal4 = plal3 tour 90 plc pz;
platel = plal1 et plal2 et plal3 et plal4;
basdie = platel et basblow;
orie basdie dire pz;
elim tol basdie;
lowdie = basdie volu n tran (0 0 (h - gap2));
*
depl basbol plus (0 0 (0 - gap2));
bolt = basbol volu n tran (0 0 (h + gap2));
die = lowdie et bolt;
elim tol die;
*
pex3 = (r + gap) 0 0;
pex4 = (r + r + ext) 0 0;
pex5 = (r + r + ext) (r + r + ext) 0;
pex6 = pex3 tour 45 pc pz;
cex1 = pex3 d n pex4;
cex2 = pex4 d (n / 2) pex5;
cex3 = pex5 d n pex6;
cex4 = c (n / 2) pex6 pc pex3;
surex2 = dall cex1 cex2 cex3 cex4 plan;
surex3 = orie (surex2 syme plan p6 p5 pz) dire pz;
plaex1 = elim tol (surex2 et surex3);
plaex2 = plaex1 tour 90 pc pz;
plaex3 = plaex2 tour 90 pc pz;
plaex4 = plaex3 tour 90 pc pz;
platext = plaex1 et plaex2 et plaex3 et plaex4;
elim tol platext;
*
baspun = platext plus (0 0 gap2);
punch = baspun volu n tran (0 0 (h - gap2));
surpre = baspun plus (0 0 (h - gap2));
elim tol (surpre et punch);
*
mesh = plate et die et punch et surpre;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

bolt05.epx

```
BOLT05
ECHO
 CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die Q4GS plate CL3D surpre TERM
COMP EPAI 0.01 LECT plate  TERM
     NGRO 3 'c1_pl'  LECT plate TERM COND NEAR POIN -6 -6 0
            'c1_pu'  LECT punch TERM COND NEAR POIN -6 -6 0
            'c1_di'  LECT die   TERM COND NEAR POIN -6 -6 0
     COUL VERT LECT punch  TERM
          TURQ LECT die    TERM
          ROSE LECT plate  TERM
          JAUN LECT surpre TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT plate TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT punch die TERM
     IMPE PIMP RO 7850.0 PRES 1.E5 PREF 0.0
          LECT surpre TERM
LINK COUP SPLT NONE
     DEPL 2 1.0 FONC 1 LECT pedge TERM
     GLIS 2 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            PGAP 0.005
            MAIT LECT punch  TERM
            PESC LECT placon TERM
            FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #2
            PGAP 0.005
            MAIT LECT die    TERM
            PESC LECT placon TERM
LINK DECO
     BLOQ 123 LECT basdie TERM
INIT VITE 2 -100.0 LECT pedge TERM
FONC NUM 1 TABL 2 0.0 0.0 1.0 -100.0
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 12.E-3 PASF 2.5E-5 NMAX 480
*=====================================================================
PLAY
CAME   1 EYE   0.00000E+00 -3.18198E+01  3.18198E+01
!        Q     9.23880E-01  3.82683E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  7.07107E-01 -7.07107E-01
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  7.07107E-01  7.07107E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  0.00000E+00
!RSPHERE:  9.00000E+00
!RADIUS :  4.50000E+01
!ASPECT :  1.00000E+00
!NEAR   :  3.51000E+01
!FAR    :  6.30000E+01
SCEN GEOM NAVI FREE
          LINE SSHA SFRE
!    ISO  FILL FIEL VITE SCAL USER PROG 0.1 PAS 0.1 1.4 TERM
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 481 FPS 15 KFRE 10 COMP -1
!    OBJE LECT plate punch die TERM REND
     OBJE LECT plate die TERM REND
!    OBJE LECT plate TERM REND
GOTR LOOP 479 OFFS FICH AVI CONT NOCL
!    OBJE LECT plate punch die TERM REND
     OBJE LECT plate die TERM REND
!    OBJE LECT plate TERM REND
GO
TRAC OFFS FICH AVI CONT
!    OBJE LECT plate punch die TERM REND
     OBJE LECT plate die TERM REND
!    OBJE LECT plate TERM REND
ENDPLAY
*=====================================================================
SUIT
Post-processing
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_pl' DEPL COMP 3 NOEU LECT c1_pl TERM
COUR 2 'dz_pu' DEPL COMP 3 NOEU LECT c1_pu TERM
COUR 3 'dz_di' DEPL COMP 3 NOEU LECT c1_di TERM
TRAC 1 2 3 AXES 1.0 'DISP [M]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
COLO ROSE VERT TURQ
COUR 11 'z_pl' COOR COMP 3 NOEU LECT c1_pl TERM
COUR 12 'z_pu' COOR COMP 3 NOEU LECT c1_pu TERM
COUR 13 'z_di' COOR COMP 3 NOEU LECT c1_di TERM
TRAC 11 12 13 AXES 1.0 'COOR [M]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
COLO ROSE VERT TURQ
COUR 21 'vz_pl' VITE COMP 3 NOEU LECT c1_pl TERM
COUR 22 'vz_pu' VITE COMP 3 NOEU LECT c1_pu TERM
COUR 23 'vz_di' VITE COMP 3 NOEU LECT c1_di TERM
TRAC 21 22 23 AXES 1.0 'VELO [M/S]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
COLO ROSE VERT TURQ
COUR 31 'fz_pl'  FLIA COMP 3 ZONE LECT plate TERM
COUR 32 'fz_pu'  FLIA COMP 3 ZONE LECT punch TERM
COUR 33 'fz_di'  FLIA COMP 3 ZONE LECT die   TERM
COUR 34 'fdz_di' FDEC COMP 3 ZONE LECT basdie TERM
DCOU 35 'fz_ana' 2 0 1.1573E7 12.0E-3 1.1573E7
TRAC 31 32 33 34 35 AXES 1.0 'FORCE [N]' YZER XMIN 0 XMAX 12.E-3
                                                      DX 2.E-3
COLO ROSE VERT TURQ NOIR ROUG
*=====================================================================
FIN
```

bolt05a.epx

```
BOLT05A
ECHO
RESU ALIC 'bolt05.ali' GARD PSCR
OPTI PRIN
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'Fy_pl' FLIA COMP 2 ZONE LECT pedge TERM
TRAC 1 AXES 1.0 'FORCE [N]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
LIST 1 AXES 1.0 'FORCE [N]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
FIN
```

bolt05b.epx

```
BOLT05B
ECHO
RESU ALIC 'bolt05.ali' GARD PSCR
SORT VISU NSTO 481
*=====================================================================
PLAY
CAME   1 EYE   6.19888E-06 -2.09499E+00  4.52653E+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
!NAVIGATION MODE: FREE CAMERA
!CENTER :  6.19888E-06 -2.09499E+00  2.08139E-04
!RSPHERE:  1.05268E+01
!RADIUS :  4.52651E+01
!ASPECT :  1.00000E+00
!NEAR   :  3.47383E+01
!FAR    :  5.57918E+01
SCEN GEOM NAVI FREE
          LINE SFRE
     ISO  FILI FIEL DEPL SCAL USER PROG 0.05 PAS 0.05 0.7 TERM
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH BMP OBJE LECT plate TERM REND
ENDPLAY
*=====================================================================
FIN
```

bolt06.dgibi

```
*$$$$ PX4CIR3D
*
* Pour generer le maillage 3D (plan) d'un quart de cercle
* avec seulement des quadrilateres a 4 noeuds.
* Le quart de cercle est defini par les deux extremes
* d'un arc (de 90 degrees), par le centre du cercle
* et par un autre point qui definit l'axe de rotation
* (axe perpendiculaire au plan du cercle, passant pour son centre).
*
* Input:
* =====
* P1 = premiere extremite de l'arc
* P2 = deuxieme extremite de l'arc
* PC = centre de l'arc
* PZ = autre point de l'axe
* N  = nombre de mailles a generer sur chaque cote (doit etre pair)
* TOL= tolerance pour l'elimination des noeuds doubles
*
* Output:
* ======
* SUR = objet MAILLAGE d'elements de type QUA4
* IER = 0: pas d'erreur, .NE.0: erreur dans la generation de SUR
*
'DEBPROC' PX4CIR3D P1*'POINT' P2*'POINT' PC*'POINT' PZ*'POINT'
                   N*'ENTIER' TOL*'FLOTTANT';
*---------------------------------------------------------------
*
ier=0;
n2 = n / 2;
p0 = 0 0 0;
pm1 = p1 plus p0;
depl pm1 tour 45 pc pz;
pm2 = 0.5*(pc plus p2);
pm3 = 0.5*(pc plus p1);
pm = 0.5*(pc plus pm1);
c1a = cerc n2 p1 pc pm1;
c1b = cerc n2 pm1 pc p2;
```

```
c2a = droi n2 p2 pm2;
c2b = droi n2 pm2 pc;
c3a = droi n2 pc pm3;
c3b = droi n2 pm3 p1;
c4a = droi n2 pm pm1;
c4b = droi n2 pm pm2;
c4c = droi n2 pm pm3;
sur1 = dall plan c4c c3b c1a (inve c4a);
sur2 = dall plan c4a c1b c2a (inve c4b);
sur3 = dall plan c2b c3a (inve c4c) c4b;
sur = sur1 et sur2 et sur3;
*
elim tol sur;
*
'FINPROC' sur ier;
*------------------------------------------------------------------
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'bolt06.msh';
opti trac psc ftra 'bolt06_mesh.ps';
r = 3.0;
h = 3.0;
gap = 0.01;
ext = 0.01;
gap2 = 0.5*gap;
pc = 0 0 0;
p1 = r 0 0;
p2 = 0 r 0;
pz = pc plus (0 0 1);
n = 4;
tol = 0.1*gap;
bol1 ier = px4cir3d p1 p2 pc pz n tol;
*
p3 = (r + gap) 0 0;
p4 = (r + r) 0 0;
p5 = (r + r) (r + r) 0;
p6 = p3 tour 45 pc pz;
c1 = p3 d n p4;
c2 = p4 d (n / 2) p5;
c3 = p5 d n p6;
c4 = c (n / 2) p6 pc p3;
sur2 = dall c1 c2 c3 c4 plan;
sur3 = orie (sur2 syme plan p6 p5 pz) dire pz;
pla1 = elim tol (sur2 et sur3);
pla2 = pla1 tour 90 pc pz;
pla3 = pla2 tour 90 pc pz;
pla4 = pla3 tour 90 pc pz;
placon = pla1 et pla2 et pla3 et pla4;
pea = (0 - h - h) (0 - h - h - 3.0) 0;
peb = (0 + h + h) (0 - h - h - 3.0) 0;
pedge = pea d n peb;
pext = pedge tran 1 (0 3.0 0);
plate = placon et pext;
elim tol plate;
*
bol2 = bol1 tour 90 pc pz;
bol3 = bol2 tour 90 pc pz;
bol4 = bol3 tour 90 pc pz;
basbol = bol1 et bol2 et bol3 et bol4;
elim tol basbol;
basblow = basbol plus (0 0 (0 - h));
*
plc = pc plus (0 0 (0 - h));
pl3 = r 0 (0 - h);
pl4 = (r + r + ext) 0 (0 - h);
pl5 = (r + r + ext) (r + r + ext) (0 - h);
pl6 = pl3 tour 45 plc pz;
cl1 = pl3 d n pl4;
cl2 = pl4 d (n / 2) pl5;
cl3 = pl5 d n pl6;
cl4 = c (n / 2) pl6 plc pl3;
surl2 = dall cl1 cl2 cl3 cl4 plan;
surl3 = orie (surl2 syme plan pl6 pl5 pz) dire pz;
plal1 = elim tol (surl2 et surl3);
plal2 = plal1 tour 90 plc pz;
plal3 = plal2 tour 90 plc pz;
plal4 = plal3 tour 90 plc pz;
platel = plal1 et plal2 et plal3 et plal4;
basdie = platel et basblow;
orie basdie dire pz;
elim tol basdie;
lowdie = basdie volu n tran (0 0 (h - gap2));
*
depl basbol plus (0 0 (0 - gap2));
bolt = basbol volu n tran (0 0 (h + gap2));
die = lowdie et bolt;
elim tol die;
*
pex3 = (r + gap) 0 0;
pex4 = (r + r + ext) 0 0;
pex5 = (r + r + ext) (r + r + ext) 0;
pex6 = pex3 tour 45 pc pz;
cex1 = pex3 d n pex4;
cex2 = pex4 d (n / 2) pex5;
cex3 = pex5 d n pex6;
cex4 = c (n / 2) pex6 pc pex3;
surex2 = dall cex1 cex2 cex3 cex4 plan;
surex3 = orie (surex2 syme plan p6 p5 pz) dire pz;
plaex1 = elim tol (surex2 et surex3);
plaex2 = plaex1 tour 90 pc pz;
plaex3 = plaex2 tour 90 pc pz;
plaex4 = plaex3 tour 90 pc pz;
platext = plaex1 et plaex2 et plaex3 et plaex4;
elim tol platext;
*
baspun = platext plus (0 0 gap2);
punch = baspun volu n tran (0 0 (h - gap2));
surpre = baspun plus (0 0 (h - gap2));
elim tol (surpre et punch);
*
mesh = plate et die et punch et surpre;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

bolt06.epx

```
BOLT06
ECHO
 CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die Q4GS plate CL3D surpre TERM
COMP EPAI 0.01 LECT plate  TERM
     NGRO 3 'c1_pl'  LECT plate TERM COND NEAR POIN -6 -6 0
            'c1_pu'  LECT punch TERM COND NEAR POIN -6 -6 0
            'c1_di'  LECT die   TERM COND NEAR POIN -6 -6 0
     COUL VERT LECT punch  TERM
          TURQ LECT die    TERM
          ROSE LECT plate  TERM
          JAUN LECT surpre TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT plate TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT punch die TERM
     IMPE PIMP RO 7850.0 PRES 1.E5 PREF 0.0
          LECT surpre TERM
LINK COUP SPLT NONE
     DEPL 2 1.0 FONC 1 LECT pedge TERM
     GLIS 2 PGAP 0.005                    ! Contact surface #1
            MAIT LECT punch  TERM
            PESC LECT placon TERM
            PGAP 0.005                    ! Contact surface #2
            MAIT LECT die    TERM
            PESC LECT placon TERM
LINK DECO
     BLOQ 123 LECT basdie TERM
INIT VITE 2 -100.0 LECT pedge TERM
FONC NUM 1 TABL 2 0.0 0.0 1.0 -100.0
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 12.E-3 PASF 2.5E-5 NMAX 480
*=====================================================================
PLAY
CAME   1 EYE   0.00000E+00 -3.18198E+01  3.18198E+01
!        Q     9.23880E-01  3.82683E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  7.07107E-01 -7.07107E-01
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  7.07107E-01  7.07107E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  0.00000E+00
!RSPHERE:  9.00000E+00
!RADIUS :  4.50000E+01
!ASPECT :  1.00000E+00
!NEAR   :  3.51000E+01
!FAR    :  6.30000E+01
SCEN GEOM NAVI FREE
          LINE SSHA SFRE
!    ISO  FILL FIEL VITE SCAL USER PROG 0.1 PAS 0.1 1.4 TERM
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 481 FPS 15 KFRE 10 COMP -1
!    OBJE LECT plate punch die TERM REND
     OBJE LECT plate die TERM REND
!    OBJE LECT plate TERM REND
GOTR LOOP 479 OFFS FICH AVI CONT NOCL
!    OBJE LECT plate punch die TERM REND
     OBJE LECT plate die TERM REND
!    OBJE LECT plate TERM REND
GO
TRAC OFFS FICH AVI CONT
!    OBJE LECT plate punch die TERM REND
     OBJE LECT plate die TERM REND
!    OBJE LECT plate TERM REND
ENDPLAY
*=====================================================================
SUIT
Post-processing
```

```
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_pl' DEPL COMP 3 NOEU LECT c1_pl TERM
COUR 2 'dz_pu' DEPL COMP 3 NOEU LECT c1_pu TERM
COUR 3 'dz_di' DEPL COMP 3 NOEU LECT c1_di TERM
TRAC 1 2 3 AXES 1.0 'DISP [M]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
COLO ROSE VERT TURQ
COUR 11 'z_pl' COOR COMP 3 NOEU LECT c1_pl TERM
COUR 12 'z_pu' COOR COMP 3 NOEU LECT c1_pu TERM
COUR 13 'z_di' COOR COMP 3 NOEU LECT c1_di TERM
TRAC 11 12 13 AXES 1.0 'COOR [M]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
COLO ROSE VERT TURQ
COUR 21 'vz_pl' VITE COMP 3 NOEU LECT c1_pl TERM
COUR 22 'vz_pu' VITE COMP 3 NOEU LECT c1_pu TERM
COUR 23 'vz_di' VITE COMP 3 NOEU LECT c1_di TERM
TRAC 21 22 23 AXES 1.0 'VELO [M/S]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
COLO ROSE VERT TURQ
COUR 31 'fz_pl'  FLIA COMP 3 ZONE LECT plate TERM
COUR 32 'fz_pu'  FLIA COMP 3 ZONE LECT punch TERM
COUR 33 'fz_di'  FLIA COMP 3 ZONE LECT die   TERM
COUR 34 'fdz_di' FDEC COMP 3 ZONE LECT basdie TERM
DCOU 35 'fz_ana' 2 0 1.1573E7 12.0E-3 1.1573E7
TRAC 31 32 33 34 35 AXES 1.0 'FORCE [N]' YZER XMIN 0 XMAX 12.E-3
                                                    DX 2.E-3
COLO ROSE VERT TURQ NOIR ROUG
*=====================================================================
FIN
```

bolt06a.epx

```
BOLT06A
ECHO
RESU ALIC 'bolt06.ali' GARD PSCR
OPTI PRIN
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'Fy_pl' FLIA COMP 2 ZONE LECT pedge TERM
TRAC 1 AXES 1.0 'FORCE [N]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
LIST 1 AXES 1.0 'FORCE [N]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
FIN
```

bolt06b.epx

```
BOLT06B
ECHO
RESU ALIC 'bolt06.ali' GARD PSCR
SORT VISU NSTO 481
*=====================================================================
PLAY
CAME   1 EYE   6.19888E-06 -2.09499E+00  4.52653E+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
!NAVIGATION MODE: FREE CAMERA
!CENTER :  6.19888E-06 -2.09499E+00  2.08139E-04
!RSPHERE:  1.05268E+01
!RADIUS :  4.52651E+01
!ASPECT :  1.00000E+00
!NEAR   :  3.47383E+01
!FAR    :  5.57918E+01
SCEN GEOM NAVI FREE
          LINE SFRE
     ISO  FILI FIEL DEPL SCAL USER PROG 0.05 PAS 0.05 0.7 TERM
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH BMP OBJE LECT plate TERM REND
ENDPLAY
*=====================================================================
FIN
```

bolt07.dgibi

```
*$$$$ PX4CIR3D
*
* Pour generer le maillage 3D (plan) d'un quart de cercle
* avec seulement des quadrilateres a 4 noeuds.
* Le quart de cercle est defini par les deux extremes
* d'un arc (de 90 degrees), par le centre du cercle
* et par un autre point qui definit l'axe de rotation
* (axe perpendiculaire au plan du cercle, passant pour son centre).
*
* Input:
* =====
* P1 = premiere extremite de l'arc
* P2 = deuxieme extremite de l'arc
* PC = centre de l'arc
* PZ = autre point de l'axe
* N  = nombre de mailles a generer sur chaque cote (doit etre pair)
* TOL= tolerance pour l'elimination des noeuds doubles
*
* Output:
* ======
* SUR = objet MAILLAGE d'elements de type QUA4
* IER = 0: pas d'erreur, .NE.0: erreur dans la generation de SUR
*
'DEBPROC' PX4CIR3D P1*'POINT' P2*'POINT' PC*'POINT' PZ*'POINT'
                   N*'ENTIER' TOL*'FLOTTANT';
*---------------------------------------------------------------
*
ier=0;
n2 = n / 2;
p0 = 0 0 0;
pm1 = p1 plus p0;
depl pm1 tour 45 pc pz;
pm2 = 0.5*(pc plus p2);
pm3 = 0.5*(pc plus p1);
pm = 0.5*(pc plus pm1);
c1a = cerc n2 p1 pc pm1;
c1b = cerc n2 pm1 pc p2;
c2a = droi n2 p2 pm2;
c2b = droi n2 pm2 pc;
c3a = droi n2 pc pm3;
c3b = droi n2 pm3 p1;
c4a = droi n2 pm pm1;
c4b = droi n2 pm pm2;
c4c = droi n2 pm pm3;
sur1 = dall plan c4c c3b c1a (inve c4a);
sur2 = dall plan c4a c1b c2a (inve c4b);
sur3 = dall plan c2b c3a (inve c4c) c4b;
sur = sur1 et sur2 et sur3;
*
elim tol sur;
*
'FINPROC' sur ier;
*---------------------------------------------------------------------
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'bolt07.msh';
opti trac psc ftra 'bolt07_mesh.ps';
r = 3.0;
h = 3.0;
gap = 0.01;
ext = 0.01;
gap2 = 0.5*gap;
pc = 0 0 0;
p1 = r 0 0;
p2 = 0 r 0;
pz = pc plus (0 0 1);
n = 4;
tol = 0.1*gap;
bol1 ier = px4cir3d p1 p2 pc pz n tol;
*
p3 = (r + gap) 0 0;
p4 = (r + r) 0 0;
p5 = (r + r) (r + r) 0;
p6 = p3 tour 45 pc pz;
c1 = p3 d n p4;
c2 = p4 d (n / 2) p5;
c3 = p5 d n p6;
c4 = c (n / 2) p6 pc p3;
sur2 = dall c1 c2 c3 c4 plan;
sur3 = orie (sur2 syme plan p6 p5 pz) dire pz;
pla1 = elim tol (sur2 et sur3);
pla2 = pla1 tour 90 pc pz;
pla3 = pla2 tour 90 pc pz;
pla4 = pla3 tour 90 pc pz;
placon = pla1 et pla2 et pla3 et pla4;
pea = (0 - h - h) (0 - h - h - 3.0) 0;
peb = (0 + h + h) (0 - h - h - 3.0) 0;
pedge = pea d n peb;
pext = pedge tran 1 (0 3.0 0);
plate = placon et pext;
elim tol plate;
*
bol2 = bol1 tour 90 pc pz;
bol3 = bol2 tour 90 pc pz;
bol4 = bol3 tour 90 pc pz;
basbol = bol1 et bol2 et bol3 et bol4;
elim tol basbol;
basblow = basbol plus (0 0 (0 - h));
*
plc = pc plus (0 0 (0 - h));
pl3 = r 0 (0 - h);
pl4 = (r + r + ext) 0 (0 - h);
pl5 = (r + r + ext) (r + r + ext) (0 - h);
pl6 = pl3 tour 45 plc pz;
cl1 = pl3 d n pl4;
cl2 = pl4 d (n / 2) pl5;
cl3 = pl5 d n pl6;
cl4 = c (n / 2) pl6 plc pl3;
surl2 = dall cl1 cl2 cl3 cl4 plan;
surl3 = orie (surl2 syme plan pl6 pl5 pz) dire pz;
plal1 = elim tol (surl2 et surl3);
plal2 = plal1 tour 90 plc pz;
plal3 = plal2 tour 90 plc pz;
plal4 = plal3 tour 90 plc pz;
platel = plal1 et plal2 et plal3 et plal4;
basdie = platel et basblow;
orie basdie dire pz;
elim tol basdie;
lowdie = basdie volu n tran (0 0 (h - gap2));
*
depl basbol plus (0 0 (0 - gap2));
bolt = basbol volu n tran (0 0 (h + gap2));
die = lowdie et bolt;
```

```
elim tol die;
*
pex3 = (r + gap) 0 0;
pex4 = (r + r + ext) 0 0;
pex5 = (r + r + ext) (r + r + ext) 0;
pex6 = pex3 tour 45 pc pz;
cex1 = pex3 d n pex4;
cex2 = pex4 d (n / 2) pex5;
cex3 = pex5 d n pex6;
cex4 = c (n / 2) pex6 pc pex3;
surex2 = dall cex1 cex2 cex3 cex4 plan;
surex3 = orie (surex2 syme plan p6 p5 pz) dire pz;
plaex1 = elim tol (surex2 et surex3);
plaex2 = plaex1 tour 90 pc pz;
plaex3 = plaex2 tour 90 pc pz;
plaex4 = plaex3 tour 90 pc pz;
platext = plaex1 et plaex2 et plaex3 et plaex4;
elim tol platext;
*
baspun = platext plus (0 0 gap2);
punch = baspun volu n tran (0 0 (h - gap2));
surpre = baspun plus (0 0 (h - gap2));
elim tol (surpre et punch);
*
mesh = plate et die et punch et surpre;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

bolt07.epx

```
BOLT07
ECHO
 CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die Q4GS plate CL3D surpre TERM
COMP EPAI 0.01 LECT plate  TERM
     GROU 2 'pres' LECT surpre TERM COND SPHE XC 0 YC 0 ZC 3 R 4.75
            'pre0' LECT surpre DIFF pres TERM
     NGRO 3 'c1_pl'  LECT plate TERM COND NEAR POIN -6 -6 0
            'c1_pu'  LECT punch TERM COND NEAR POIN -6 -6 0
            'c1_di'  LECT die   TERM COND NEAR POIN -6 -6 0
     COUL VERT LECT punch  TERM
          TURQ LECT die    TERM
          ROSE LECT plate  TERM
          JAUN LECT pres   TERM
          GR50 LECT pre0   TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT plate TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT punch die TERM
     IMPE PIMP RO 7850.0 PRES 0.0  PREF 0.0
          LECT pre0 TERM
     IMPE PIMP RO 7850.0 PRES 2.459248E5 PREF 0.0
          LECT pres TERM
LINK COUP SPLT NONE
     DEPL 2 1.0 FONC 1 LECT pedge TERM
     GLIS 2 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            PGAP 0.005
            MAIT LECT punch  TERM
            PESC LECT placon TERM
            FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #2
            PGAP 0.005
            MAIT LECT die    TERM
            PESC LECT placon TERM
LINK DECO
     BLOQ 123 LECT basdie TERM
INIT VITE 2 -100.0 LECT pedge TERM
FONC NUM 1 TABL 2 0.0 0.0 1.0 -100.0
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 12.E-3 PASF 2.5E-5 NMAX 480
*=================================================================
PLAY
CAME   1 EYE   0.00000E+00 -3.18198E+01  3.18198E+01
!        Q     9.23880E-01  3.82683E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  7.07107E-01 -7.07107E-01
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  7.07107E-01  7.07107E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  0.00000E+00
!RSPHERE:  9.00000E+00
!RADIUS :  4.50000E+01
!ASPECT :  1.00000E+00
!NEAR   :  3.51000E+01
!FAR    :  6.30000E+01
SCEN GEOM NAVI FREE
          LINE SSHA SFRE
!    ISO  FILL FIEL VITE SCAL USER PROG 0.1 PAS 0.1 1.4 TERM
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 481 FPS 15 KFRE 10 COMP -1
!    OBJE LECT plate punch die TERM REND
     OBJE LECT plate die TERM REND
!    OBJE LECT plate TERM REND
GOTR LOOP 479 OFFS FICH AVI CONT NOCL
!    OBJE LECT plate punch die TERM REND
     OBJE LECT plate die TERM REND
!    OBJE LECT plate TERM REND
GO
TRAC OFFS FICH AVI CONT
!    OBJE LECT plate punch die TERM REND
     OBJE LECT plate die TERM REND
!    OBJE LECT plate TERM REND
ENDPLAY
*=================================================================
SUIT
Post-processing
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_pl' DEPL COMP 3 NOEU LECT c1_pl TERM
COUR 2 'dz_pu' DEPL COMP 3 NOEU LECT c1_pu TERM
COUR 3 'dz_di' DEPL COMP 3 NOEU LECT c1_di TERM
TRAC 1 2 3 AXES 1.0 'DISP [M]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
COLO ROSE VERT TURQ
COUR 11 'z_pl' COOR COMP 3 NOEU LECT c1_pl TERM
COUR 12 'z_pu' COOR COMP 3 NOEU LECT c1_pu TERM
COUR 13 'z_di' COOR COMP 3 NOEU LECT c1_di TERM
TRAC 11 12 13 AXES 1.0 'COOR [M]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
COLO ROSE VERT TURQ
COUR 21 'vz_pl' VITE COMP 3 NOEU LECT c1_pl TERM
COUR 22 'vz_pu' VITE COMP 3 NOEU LECT c1_pu TERM
COUR 23 'vz_di' VITE COMP 3 NOEU LECT c1_di TERM
TRAC 21 22 23 AXES 1.0 'VELO [M/S]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
COLO ROSE VERT TURQ
COUR 31 'fz_pl'  FLIA COMP 3 ZONE LECT plate TERM
COUR 32 'fz_pu'  FLIA COMP 3 ZONE LECT punch TERM
COUR 33 'fz_di'  FLIA COMP 3 ZONE LECT die   TERM
COUR 34 'fdz_di' FDEC COMP 3 ZONE LECT basdie TERM
DCOU 35 'fz_ana' 2 0 1.1573E7 12.0E-3 1.1573E7
TRAC 31 32 33 34 35 AXES 1.0 'FORCE [N]' YZER XMIN 0 XMAX 12.E-3
                                                    DX 2.E-3
COLO ROSE VERT TURQ NOIR ROUG
*=================================================================
FIN
```

bolt07a.epx

```
BOLT07A
ECHO
RESU ALIC 'bolt07.ali' GARD PSCR
OPTI PRIN
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 3 'Fy_pl' FLIA COMP 2 ZONE LECT pedge TERM
TRAC 3 AXES 1.0 'FORCE [N]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
LIST 3 AXES 1.0 'FORCE [N]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
RCOU 1 'Fy_pl' FICH 'bolt05a.pun' RENA 'Fy_pl_05'
RCOU 2 'Fy_pl' FICH 'bolt06a.pun' RENA 'Fy_pl_06'
TRAC 1 2 3 AXES 1.0 'FORCE [N]' YZER XMIN 0 XMAX 12.E-3 DX 2.E-3
COLO VERT TURQ ROUG
FIN
```

bolt07b.epx

```
BOLT07B
ECHO
RESU ALIC 'bolt07.ali' GARD PSCR
SORT VISU NSTO 481
*=================================================================
PLAY
CAME   1 EYE   6.19888E-06 -2.09499E+00  4.52653E+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
!NAVIGATION MODE: FREE CAMERA
!CENTER :  6.19888E-06 -2.09499E+00  2.08139E-04
!RSPHERE:  1.05268E+01
!RADIUS :  4.52651E+01
!ASPECT :  1.00000E+00
!NEAR   :  3.47383E+01
!FAR    :  5.57918E+01
SCEN GEOM NAVI FREE
          LINE SFRE
     ISO  FILI FIEL DEPL SCAL USER PROG 0.05 PAS 0.05 0.7 TERM
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH BMP OBJE LECT plate TERM REND
ENDPLAY
*=================================================================
FIN
```

side01.dgibi

```
'DEBPROC' pxbox3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT' lz*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-----------------------------------------------
* Generates a parallelepiped mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly,lz) and density (mesh size) dd.
* The mesh consists of CUB8 hexahedral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly,lz : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-----------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
base = dall c1 c2 c3 c4 plan;
*
box = base volu tran (0 0 lz);
*
finproc box;
*-------------------------------------------------------------------------
'DEBPROC' pxrec3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-----------------------------------------------
* Generates a rectangle mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly) and density (mesh size) dd.
* The mesh consists of QUA4 quadrilateral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly    : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-----------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
rect = dall c1 c2 c3 c4 plan;
*
finproc rect;
*-------------------------------------------------------------------------
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'side01.msh';
opti trac psc ftra 'side01_mesh.ps';
gap = 0.01;
den = 0.5;
tol = 0.001;
die  = pxbox3d -1.0 -1.0 -1.0  2.0 2.0 2.0 den;
pla1 = pxrec3d -3.0 -3.0  0.0  (2.0 - gap) (2.0 - gap) den;
pla2 = pxrec3d (-1.0 - gap) -3.0  0.0  (2.0 + gap + gap) (2.0 - gap)
       den;
pla3 = pxrec3d -3.0 (-1.0 - gap)  0.0  (2.0 - gap) (2.0 + gap + gap)
       den;
pla4 = pla1 plus ((4.0 + gap) 0 0);
pla5 = pla3 plus ((4.0 + gap) 0 0);
pla6 = pla1 plus (0 (4.0 + gap) 0);
pla7 = pla2 plus (0 (4.0 + gap) 0);
pla8 = pla4 plus (0 (4.0 + gap) 0);
plate = elim tol (pla1 et pla2 et pla3 et pla4 et pla5 et pla6
        et pla7 et pla8);
mesh = die et plate;
trac cach qual plate;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

side01.epx

```
SIDE01
ECHO
 CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 die Q4GS plate TERM
COMP EPAI 0.1 LECT plate TERM
     NGRO 1 'pl_hole' LECT plate TERM COND BOX X0 -1.1 Y0 -1.1 Z0 -1
                                              DX  2.2 DY  2.2 DZ  2
     COUL TURQ LECT die   TERM
          ROSE LECT plate TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT die TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT plate TERM
LINK COUP SPLT NONE
     GLIS 1 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            MAIT LECT die   TERM
            PESC LECT plate TERM
INIT VITE 2 -300.0 LECT die TERM
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 3.E-3 PASF 2.5E-5 NMAX 120
*=====================================================================
PLAY
CAME   1 EYE  -1.42578E+01 -8.86120E+00  1.04034E+01 ! From side
!        Q     8.06474E-01  3.94166E-01 -2.83886E-01 -3.37109E-01
         VIEW  7.23646E-01  4.44367E-01 -5.28085E-01
         RIGH  6.11533E-01 -7.67535E-01  1.92139E-01
         UP    3.19943E-01  4.61982E-01  8.27169E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : -8.84771E-04 -1.06509E-01 -6.84857E-04
!RSPHERE:  4.47760E+00
!RADIUS :  1.97015E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.52239E+01
!FAR    :  2.86567E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          LNKS JOIN
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.42578E+01 -8.86120E+00  1.04034E+01
!        Q     8.06474E-01  3.94166E-01 -2.83886E-01 -3.37109E-01
         VIEW  7.23646E-01  4.44367E-01 -5.28085E-01
         RIGH  6.11533E-01 -7.67535E-01  1.92139E-01
         UP    3.19943E-01  4.61982E-01  8.27169E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : -8.84771E-04 -1.06509E-01 -6.84857E-04
!RSPHERE:  4.47760E+00
!RADIUS :  1.97015E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.52239E+01
!FAR    :  2.86567E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.42578E+01 -8.86120E+00  1.04034E+01
```

```
!        Q     8.06474E-01  3.94166E-01 -2.83886E-01 -3.37109E-01
         VIEW  7.23646E-01  4.44367E-01 -5.28085E-01
         RIGH  6.11533E-01 -7.67535E-01  1.92139E-01
         UP    3.19943E-01  4.61982E-01  8.27169E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : -8.84771E-04 -1.06509E-01 -6.84857E-04
!RSPHERE:  4.47760E+00
!RADIUS :  1.97015E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.52239E+01
!FAR    :  2.86567E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
     OBJE LECT die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
     OBJE LECT die TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.42578E+01 -8.86120E+00  1.04034E+01
!        Q     8.06474E-01  3.94166E-01 -2.83886E-01 -3.37109E-01
         VIEW  7.23646E-01  4.44367E-01 -5.28085E-01
         RIGH  6.11533E-01 -7.67535E-01  1.92139E-01
         UP    3.19943E-01  4.61982E-01  8.27169E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : -8.84771E-04 -1.06509E-01 -6.84857E-04
!RSPHERE:  4.47760E+00
!RADIUS :  1.97015E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.52239E+01
!FAR    :  2.86567E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL VITE SCAL USER PROG 20 PAS 20 280 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.42578E+01 -8.86120E+00  1.04034E+01
!        Q     8.06474E-01  3.94166E-01 -2.83886E-01 -3.37109E-01
         VIEW  7.23646E-01  4.44367E-01 -5.28085E-01
         RIGH  6.11533E-01 -7.67535E-01  1.92139E-01
         UP    3.19943E-01  4.61982E-01  8.27169E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : -8.84771E-04 -1.06509E-01 -6.84857E-04
!RSPHERE:  4.47760E+00
!RADIUS :  1.97015E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.52239E+01
!FAR    :  2.86567E+01
SCEN GEOM NAVI FREE
     LIMA ON
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
!SUIT
!Post treatment (time plots from alice file)
!ECHO
!RESU ALIC GARD PSCR
!COMP NGRO 3 'c_upper' LECT punch TERM COND NEAR POIN 0 0 0
!           'c_lower' LECT die   TERM COND NEAR POIN 0 0 0
!           'c_plate' LECT plate TERM COND NEAR POIN 0 0 0
!OPTI PRIN
!SORT GRAP
!AXTE 1.0 'Time [s]'
!COUR 1 'FLZ_punch' FLIA COMP 3 ZONE LECT punch TERM
!COUR 2 'FLZ_die'   FLIA COMP 3 ZONE LECT die   TERM
!COUR 3 'FDZ_die'   FDEC COMP 3 ZONE LECT die   TERM
!TRAC 1     AXES 1.0 'FORCE [N]' YZER XGRD YGRD
!     COLO NOIR
!TRAC   2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
!     COLO ROUG
!TRAC     3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
!     COLO VERT
!TRAC 1 2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
!     COLO NOIR ROUG
!TRAC 1 2 3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
!     COLO NOIR ROUG VERT
!LIST 1 2 3 AXES 1.0 'FORCE [N]'
!COUR 11 'Z_upper' COOR COMP 3 NOEU LECT c_upper TERM
!COUR 12 'Z_lower' COOR COMP 3 NOEU LECT c_lower TERM
!COUR 13 'Z_plate' COOR COMP 3 NOEU LECT c_plate TERM
!TRAC 11 12 13 AXES 1.0 'COOR. [M]' YZER XGRD YGRD
!     COLO NOIR ROUG VERT
!LIST 11 12 13 AXES 1.0 'COOR. [M]'
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.42578E+01 -8.86120E+00  1.04034E+01
!        Q     8.06474E-01  3.94166E-01 -2.83886E-01 -3.37109E-01
         VIEW  7.23646E-01  4.44367E-01 -5.28085E-01
         RIGH  6.11533E-01 -7.67535E-01  1.92139E-01
         UP    3.19943E-01  4.61982E-01  8.27169E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : -8.84771E-04 -1.06509E-01 -6.84857E-04
!RSPHERE:  4.47760E+00
!RADIUS :  1.97015E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.52239E+01
!FAR    :  2.86567E+01
SCEN GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT plate TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT plate TERM REND
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT plate TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.42578E+01 -8.86120E+00  1.04034E+01
!        Q     8.06474E-01  3.94166E-01 -2.83886E-01 -3.37109E-01
         VIEW  7.23646E-01  4.44367E-01 -5.28085E-01
         RIGH  6.11533E-01 -7.67535E-01  1.92139E-01
         UP    3.19943E-01  4.61982E-01  8.27169E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : -8.84771E-04 -1.06509E-01 -6.84857E-04
!RSPHERE:  4.47760E+00
!RADIUS :  1.97015E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.52239E+01
!FAR    :  2.86567E+01
SCEN GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT die TERM REND
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT die TERM REND
ENDPLAY
*=====================================================================
FIN
```

side02.dgibi

```
'DEBPROC' pxbox3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT' lz*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-------------------------------------------------
```

```
* Generates a parallelepiped mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly,lz) and density (mesh size) dd.
* The mesh consists of CUB8 hexahedral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly,lz : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
base = dall c1 c2 c3 c4 plan;
*
box = base volu tran (0 0 lz);
*
finproc box;
*-----------------------------------------------------------------------
'DEBPROC' pxrec3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-------------------------------------------------
* Generates a rectangle mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly) and density (mesh size) dd.
* The mesh consists of QUA4 quadrilateral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly    : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
rect = dall c1 c2 c3 c4 plan;
*
finproc rect;
*-----------------------------------------------------------------------
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'side02.msh';
opti trac psc ftra 'side02_mesh.ps';
gap = 0.01;
den = 0.5;
tol = 0.001;
die  = pxbox3d -1.0 -1.0 -1.0  2.0 2.0 2.0 den;
die_enve = chan poi1 (enve die);
pla1 = pxrec3d -3.0 -3.0  0.0  (2.0 - gap) (2.0 - gap) den;
pla2 = pxrec3d (-1.0 - gap) -3.0  0.0  (2.0 + gap + gap) (2.0 - gap)
       den;
pla3 = pxrec3d -3.0 (-1.0 - gap)  0.0  (2.0 - gap) (2.0 + gap + gap)
       den;
pla4 = pla1 plus ((4.0 + gap) 0 0);
pla5 = pla3 plus ((4.0 + gap) 0 0);
pla6 = pla1 plus (0 (4.0 + gap) 0);
pla7 = pla2 plus (0 (4.0 + gap) 0);
pla8 = pla4 plus (0 (4.0 + gap) 0);
plate = elim tol (pla1 et pla2 et pla3 et pla4 et pla5 et pla6
        et pla7 et pla8);
mesh = die et plate;
trac cach qual plate;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

side02.epx

```
SIDE02
ECHO
!CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 die Q4GS plate TERM
COMP EPAI 0.1 LECT plate TERM
     NGRO 2 'die_c_top' LECT die TERM COND NEAR POIN 0 0 1
            'die_c_bot' LECT die TERM COND NEAR POIN 0 0 -1
     COUL TURQ LECT die   TERM
          ROSE LECT plate TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT die TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT plate TERM
LINK COUP SPLT NONE
     GLIS 1 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            PGAP 0.05
            CMAI LECT plate    TERM EXTE LECT die_c_top TERM
            PESC LECT die_enve TERM
INIT VITE 2 -300.0 LECT die TERM
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 3.E-3 PASF 2.5E-5 NMAX 120
*===================================================================
PLAY
CAME   1 EYE  -1.42578E+01 -8.86120E+00  1.04034E+01 ! From side
!        Q     8.06474E-01  3.94166E-01 -2.83886E-01 -3.37109E-01
         VIEW  7.23646E-01  4.44367E-01 -5.28085E-01
         RIGH  6.11533E-01 -7.67535E-01  1.92139E-01
         UP    3.19943E-01  4.61982E-01  8.27169E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : -8.84771E-04 -1.06509E-01 -6.84857E-04
!RSPHERE:  4.47760E+00
!RADIUS :  1.97015E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.52239E+01
!FAR    :  2.86567E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          LNKS JOIN
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*===================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.42578E+01 -8.86120E+00  1.04034E+01
!        Q     8.06474E-01  3.94166E-01 -2.83886E-01 -3.37109E-01
         VIEW  7.23646E-01  4.44367E-01 -5.28085E-01
         RIGH  6.11533E-01 -7.67535E-01  1.92139E-01
         UP    3.19943E-01  4.61982E-01  8.27169E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : -8.84771E-04 -1.06509E-01 -6.84857E-04
!RSPHERE:  4.47760E+00
!RADIUS :  1.97015E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.52239E+01
!FAR    :  2.86567E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*===================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.42578E+01 -8.86120E+00  1.04034E+01
!        Q     8.06474E-01  3.94166E-01 -2.83886E-01 -3.37109E-01
         VIEW  7.23646E-01  4.44367E-01 -5.28085E-01
         RIGH  6.11533E-01 -7.67535E-01  1.92139E-01
         UP    3.19943E-01  4.61982E-01  8.27169E-01
```

```
        FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : -8.84771E-04 -1.06509E-01 -6.84857E-04
!RSPHERE:  4.47760E+00
!RADIUS :  1.97015E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.52239E+01
!FAR    :  2.86567E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
     OBJE LECT die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
     OBJE LECT die TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.42578E+01 -8.86120E+00  1.04034E+01
!        Q     8.06474E-01  3.94166E-01 -2.83886E-01 -3.37109E-01
         VIEW  7.23646E-01  4.44367E-01 -5.28085E-01
         RIGH  6.11533E-01 -7.67535E-01  1.92139E-01
         UP    3.19943E-01  4.61982E-01  8.27169E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : -8.84771E-04 -1.06509E-01 -6.84857E-04
!RSPHERE:  4.47760E+00
!RADIUS :  1.97015E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.52239E+01
!FAR    :  2.86567E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL VITE SCAL USER PROG 20 PAS 20 280 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.42578E+01 -8.86120E+00  1.04034E+01
!        Q     8.06474E-01  3.94166E-01 -2.83886E-01 -3.37109E-01
         VIEW  7.23646E-01  4.44367E-01 -5.28085E-01
         RIGH  6.11533E-01 -7.67535E-01  1.92139E-01
         UP    3.19943E-01  4.61982E-01  8.27169E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : -8.84771E-04 -1.06509E-01 -6.84857E-04
!RSPHERE:  4.47760E+00
!RADIUS :  1.97015E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.52239E+01
!FAR    :  2.86567E+01
SCEN OBJE USLM LECT plate TERM
          DHAS CGLA
     GEOM NAVI FREE
          LINE SSHA SFRE
     LIMA ON
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
!SUIT
!Post treatment (time plots from alice file)
!ECHO
!RESU ALIC GARD PSCR
!COMP NGRO 3 'c_upper' LECT punch TERM COND NEAR POIN 0 0 0
!            'c_lower' LECT die   TERM COND NEAR POIN 0 0 0
!            'c_plate' LECT plate TERM COND NEAR POIN 0 0 0
!OPTI PRIN
!SORT GRAP
!AXTE 1.0 'Time [s]'
!COUR 1 'FLZ_punch' FLIA COMP 3 ZONE LECT punch TERM
!COUR 2 'FLZ_die'   FLIA COMP 3 ZONE LECT die   TERM
!COUR 3 'FDZ_die'   FDEC COMP 3 ZONE LECT die   TERM
!TRAC 1     AXES 1.0 'FORCE [N]' YZER XGRD YGRD
!     COLO NOIR
!TRAC   2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
!     COLO ROUG
!TRAC     3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
!     COLO VERT
!TRAC 1 2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
!     COLO NOIR ROUG
!TRAC 1 2 3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
!     COLO NOIR ROUG VERT
!LIST 1 2 3 AXES 1.0 'FORCE [N]'
!COUR 11 'Z_upper' COOR COMP 3 NOEU LECT c_upper TERM
!COUR 12 'Z_lower' COOR COMP 3 NOEU LECT c_lower TERM
!COUR 13 'Z_plate' COOR COMP 3 NOEU LECT c_plate TERM
!TRAC 11 12 13 AXES 1.0 'COOR. [M]' YZER XGRD YGRD
!     COLO NOIR ROUG VERT
!LIST 11 12 13 AXES 1.0 'COOR. [M]'
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.42578E+01 -8.86120E+00  1.04034E+01
!        Q     8.06474E-01  3.94166E-01 -2.83886E-01 -3.37109E-01
         VIEW  7.23646E-01  4.44367E-01 -5.28085E-01
         RIGH  6.11533E-01 -7.67535E-01  1.92139E-01
         UP    3.19943E-01  4.61982E-01  8.27169E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : -8.84771E-04 -1.06509E-01 -6.84857E-04
!RSPHERE:  4.47760E+00
!RADIUS :  1.97015E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.52239E+01
!FAR    :  2.86567E+01
SCEN GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT plate TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT plate TERM REND
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT plate TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.42578E+01 -8.86120E+00  1.04034E+01
!        Q     8.06474E-01  3.94166E-01 -2.83886E-01 -3.37109E-01
         VIEW  7.23646E-01  4.44367E-01 -5.28085E-01
         RIGH  6.11533E-01 -7.67535E-01  1.92139E-01
         UP    3.19943E-01  4.61982E-01  8.27169E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER : -8.84771E-04 -1.06509E-01 -6.84857E-04
!RSPHERE:  4.47760E+00
!RADIUS :  1.97015E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.52239E+01
!FAR    :  2.86567E+01
SCEN GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT die TERM REND
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT die TERM REND
ENDPLAY
*=====================================================================
FIN
```

tgli01.dgibi

```
'DEBPROC' pxbox3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT' lz*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-------------------------------------------------
* Generates a parallelepiped mesh with origin in point
```

```
* (x0,y0,z0), sides of length (lx,ly,lz) and density (mesh size) dd.
* The mesh consists of CUB8 hexahedral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly,lz : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-----------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
base = dall c1 c2 c3 c4 plan;
*
box = base volu tran (0 0 lz);
*
finproc box;
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'tgli01.msh';
opti trac psc ftra 'tgli01_mesh.ps';
gap = 0.01;
den = 1.0;
punch = pxbox3d -1.0 -1.0 gap   2.0 2.0 2.0 den;
die =   pxbox3d -2.0 -2.0 -2.0  4.0 4.0 2.0 den;
mesh = punch et die;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

tgli01.epx

```
TGLI01
ECHO
!CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die TERM
COMP NGRO 1 'bloc' LECT die TERM COND Z LT -1.99
     COUL VERT LECT punch TERM
          TURQ LECT die TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT punch TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT die TERM
LINK COUP SPLT NONE
!    BLOQ 123 LECT bloc TERM
     GLIS 1 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            MAIT LECT die TERM
            ESCL LECT punch TERM
LINK DECO
     BLOQ 123 LECT bloc TERM
INIT VITE 3 -300.0 LECT punch TERM
ECRI VITE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT DIAG DUMP VISU
CALC TINI 0.0 TEND 3.E-3 PASF 5.E-5 NMAX 60
*=====================================================================
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          LNKS JOIN
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 61 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 59 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL A14 SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 61 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 59 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL A14 SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 61 FPS 15 KFRE 10 COMP -1
     OBJE LECT die TERM REND
GOTR LOOP 59 OFFS FICH AVI CONT NOCL
     OBJE LECT die TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL VITE SCAL USER PROG 20 PAS 20 280 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
```

```
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 61 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 59 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
     LIMA ON
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 61 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 59 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (time plots from alice file)
ECHO
RESU ALIC GARD PSCR
COMP NGRO 2 'c_upper' LECT punch TERM COND NEAR POIN 0 0 0
           'c_lower' LECT die   TERM COND NEAR POIN 0 0 0
OPTI PRIN
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'FLZ_punch' FLIA COMP 3 ZONE LECT punch TERM
COUR 2 'FLZ_die'   FLIA COMP 3 ZONE LECT die   TERM
COUR 3 'FDZ_die'   FDEC COMP 3 ZONE LECT die   TERM
TRAC 1     AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR
TRAC   2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO ROUG
TRAC     3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO VERT
TRAC 1 2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG
TRAC 1 2 3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG VERT
LIST 1 2 3 AXES 1.0 'FORCE [N]'
COUR 11 'Z_upper' COOR COMP 3 NOEU LECT c_upper TERM
COUR 12 'Z_lower' COOR COMP 3 NOEU LECT c_lower TERM
TRAC 11 12 AXES 1.0 'COOR. [M]' YZER XGRD YGRD
     COLO NOIR ROUG
LIST 11 12 AXES 1.0 'COOR. [M]'
*=====================================================================
FIN
```

tgli02.dgibi

```
'DEBPROC' pxbox3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT' lz*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-----------------------------------------------------
* Generates a parallelepiped mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly,lz) and density (mesh size) dd.
* The mesh consists of CUB8 hexahedral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly,lz : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-----------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
base = dall c1 c2 c3 c4 plan;
*
box = base volu tran (0 0 lz);
*
finproc box;
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'tgli02.msh';
opti trac psc ftra 'tgli02_mesh.ps';
gap = 0.01;
den = 0.5;
punch = pxbox3d -1.0 -1.0 gap   2.0 2.0 2.0 den;
die =   pxbox3d -2.0 -2.0 -2.0  4.0 4.0 2.0 den;
mesh = punch et die;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

tgli02.epx

```
TGLI02
ECHO
!CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die TERM
COMP NGRO 1 'bloc' LECT die TERM COND Z LT -1.99
     COUL VERT LECT punch TERM
          TURQ LECT die TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT punch TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT die TERM
LINK COUP SPLT NONE
!    BLOQ 123 LECT bloc TERM
     GLIS 1 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            MAIT LECT die TERM
            ESCL LECT punch TERM
LINK DECO
     BLOQ 123 LECT bloc TERM
INIT VITE 3 -300.0 LECT punch TERM
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 3.E-3 PASF 2.5E-5 NMAX 120
*=====================================================================
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          LNKS JOIN
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
```

```
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
     OBJE LECT die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
     OBJE LECT die TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL VITE SCAL USER PROG 20 PAS 20 280 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
     LIMA ON
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (time plots from alice file)
ECHO
RESU ALIC GARD PSCR
COMP NGRO 2 'c_upper' LECT punch TERM COND NEAR POIN 0 0 0
            'c_lower' LECT die   TERM COND NEAR POIN 0 0 0
OPTI PRIN
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'FLZ_punch' FLIA COMP 3 ZONE LECT punch TERM
COUR 2 'FLZ_die'   FLIA COMP 3 ZONE LECT die   TERM
COUR 3 'FDZ_die'   FDEC COMP 3 ZONE LECT die   TERM
TRAC 1     AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR
TRAC   2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO ROUG
TRAC     3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO VERT
TRAC 1 2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG
TRAC 1 2 3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG VERT
LIST 1 2 3 AXES 1.0 'FORCE [N]'
COUR 11 'Z_upper' COOR COMP 3 NOEU LECT c_upper TERM
COUR 12 'Z_lower' COOR COMP 3 NOEU LECT c_lower TERM
TRAC 11 12 AXES 1.0 'COOR. [M]' YZER XGRD YGRD
     COLO NOIR ROUG
LIST 11 12 AXES 1.0 'COOR. [M]'
*=====================================================================
FIN
```

tgli03.dgibi

```
'DEBPROC' pxbox3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT' lz*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-------------------------------------------------
* Generates a parallelepiped mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly,lz) and density (mesh size) dd.
* The mesh consists of CUB8 hexahedral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly,lz : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
base = dall c1 c2 c3 c4 plan;
*
box = base volu tran (0 0 lz);
*
finproc box;
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'tgli03.msh';
opti trac psc ftra 'tgli03_mesh.ps';
gap = 0.01;
den = 0.25;
punch = pxbox3d -1.0 -1.0 gap   2.0 2.0 2.0 den;
die =   pxbox3d -2.0 -2.0 -2.0  4.0 4.0 2.0 den;
mesh = punch et die;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

tgli03.epx

```
TGLI03
ECHO
!CONV WIN
```

```
CAST mesh
TRID LAGR
GEOM CUB8 punch die TERM
COMP NGRO 1 'bloc' LECT die TERM COND Z LT -1.99
     COUL VERT LECT punch TERM
          TURQ LECT die TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT punch TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT die TERM
LINK COUP SPLT NONE
!    BLOQ 123 LECT bloc TERM
     GLIS 1 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            MAIT LECT die TERM
            ESCL LECT punch TERM
LINK DECO
     BLOQ 123 LECT bloc TERM
INIT VITE 3 -300.0 LECT punch TERM
ECRI FLIA TFRE 2.E-3
     FICH ALIC TFRE 2.E-5
     FICH ALIC TEMP FREQ 1
          POIN LECT tous TERM
OPTI NOTE
     PAS AUTO
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 2.E-3
*=====================================================================
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          LNKS JOIN
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.25E7 PAS 0.25E7 3.5E7 TERM
          SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL VITE SCAL USER PROG 20 PAS 20 280 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
     LIMA ON
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (time plots from alice temps file)
ECHO
RESU ALIC TEMP GARD PSCR
COMP NGRO 2 'c_upper' LECT punch TERM COND NEAR POIN 0 0 0
           'c_lower' LECT die   TERM COND NEAR POIN 0 0 0
OPTI PRIN
SORT GRAP
AXTE 1.0 'Time [s]'
```

```
COUR 1 'FLZ_punch' FLIA COMP 3 ZONE LECT punch TERM
COUR 2 'FLZ_die'   FLIA COMP 3 ZONE LECT die   TERM
COUR 3 'FDZ_die'   FDEC COMP 3 ZONE LECT die   TERM
TRAC 1     AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR
TRAC   2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO ROUG
TRAC     3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO VERT
TRAC 1 2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG
TRAC 1 2 3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG VERT
LIST 1 2 3 AXES 1.0 'FORCE [N]'
COUR 11 'Z_upper' COOR COMP 3 NOEU LECT c_upper TERM
COUR 12 'Z_lower' COOR COMP 3 NOEU LECT c_lower TERM
TRAC 11 12 AXES 1.0 'COOR. [M]' YZER XGRD YGRD
     COLO NOIR ROUG
LIST 11 12 AXES 1.0 'COOR. [M]'
*=================================================================
FIN
```

tgli04.dgibi

```
'DEBPROC' pxbox3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT' lz*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-------------------------------------------------
* Generates a parallelepiped mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly,lz) and density (mesh size) dd.
* The mesh consists of CUB8 hexahedral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly,lz : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
base = dall c1 c2 c3 c4 plan;
*
box = base volu tran (0 0 lz);
*
finproc box;
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'tgli04.msh';
opti trac psc ftra 'tgli04_mesh.ps';
gap = 0.01;
den = 0.5;
punch = pxbox3d -1.0 -1.0 gap   2.0 2.0 2.0 den;
die =   pxbox3d -2.0 -2.0 -2.0  4.0 4.0 2.0 den;
mesh = punch et die;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

tgli04.epx

```
TGLI04
ECHO
!CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die TERM
COMP NGRO 1 'bloc' LECT die TERM COND Z LT -1.99
     COUL VERT LECT punch TERM
          TURQ LECT die TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT punch TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT die TERM
LINK COUP SPLT NONE
!    BLOQ 123 LECT bloc TERM
     GLIS 1 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            MAIT LECT die TERM
          ESCL LECT punch TERM
LINK DECO
     BLOQ 123 LECT bloc TERM
INIT VITE 3 -300.0 LECT punch TERM
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 3.E-3 PASF 2.5E-5 NMAX 120
*=================================================================
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          LNKS JOIN
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
     OBJE LECT die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
     OBJE LECT die TERM REND
```

```
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL VITE SCAL USER PROG 20 PAS 20 280 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
     LIMA ON
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (time plots from alice file)
ECHO
RESU ALIC GARD PSCR
COMP NGRO 2 'c_upper' LECT punch TERM COND NEAR POIN 0 0 0
            'c_lower' LECT die   TERM COND NEAR POIN 0 0 0
OPTI PRIN
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'FLZ_punch' FLIA COMP 3 ZONE LECT punch TERM
COUR 2 'FLZ_die'   FLIA COMP 3 ZONE LECT die   TERM
COUR 3 'FDZ_die'   FDEC COMP 3 ZONE LECT die   TERM
TRAC 1     AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR
TRAC   2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO ROUG
TRAC     3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO VERT
TRAC 1 2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG
TRAC 1 2 3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG VERT
LIST 1 2 3 AXES 1.0 'FORCE [N]'
COUR 11 'Z_upper' COOR COMP 3 NOEU LECT c_upper TERM
COUR 12 'Z_lower' COOR COMP 3 NOEU LECT c_lower TERM
TRAC 11 12 AXES 1.0 'COOR. [M]' YZER XGRD YGRD
     COLO NOIR ROUG
LIST 11 12 AXES 1.0 'COOR. [M]'
*=====================================================================
FIN
```

tgli05.dgibi

```
'DEBPROC' pxbox3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT' lz*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-----------------------------------------------
* Generates a parallelepiped mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly,lz) and density (mesh size) dd.
* The mesh consists of CUB8 hexahedral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly,lz : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-----------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
base = dall c1 c2 c3 c4 plan;
*
box = base volu tran (0 0 lz);
*
finproc box;
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'tgli05.msh';
opti trac psc ftra 'tgli05_mesh.ps';
gap = 0.01;
den = 0.5;
punch = pxbox3d -1.0 -1.0 gap   2.0 2.0 2.0 den;
die =   pxbox3d -2.0 -2.0 -2.0  4.0 4.0 2.0 den;
mesh = punch et die;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

tgli05.epx

```
TGLI05
ECHO
!CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die TERM
COMP NGRO 1 'bloc' LECT die TERM COND Z LT -1.99
     COUL VERT LECT punch TERM
          TURQ LECT die TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT punch TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT die TERM
LINK DECO
     BLOQ 123 LECT bloc TERM
     GLIS 1 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            MAIT LECT die TERM
            ESCL LECT punch TERM
INIT VITE 3 -300.0 LECT punch TERM
ECRI FDEC FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 3.E-3 PASF 2.5E-5 NMAX 120
*=====================================================================
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          LNKS JOIN
```

```
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FDEC SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FDEC SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
     OBJE LECT die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
     OBJE LECT die TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL VITE SCAL USER PROG 20 PAS 20 280 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
     LIMA ON
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (time plots from alice file)
ECHO
RESU ALIC GARD PSCR
COMP NGRO 4 'c_upper' LECT punch TERM COND NEAR POIN 0 0 0
            'c_lower' LECT die   TERM COND NEAR POIN 0 0 0
            'die_up'  LECT die   TERM COND Z GT -0.01
            'die_low' LECT die   TERM COND Z LT -1.99
OPTI PRIN
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'FDZ_punch'   FDEC COMP 3 ZONE LECT punch TERM
COUR 2 'FDZ_die_up'  FDEC COMP 3 ZONE LECT die_up  TERM
COUR 3 'FDZ_die_low' FDEC COMP 3 ZONE LECT die_low TERM
TRAC 1     AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR
TRAC   2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO ROUG
TRAC     3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO VERT
TRAC 1 2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG
TRAC 1 2 3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     YMIN -3.E10 YMAX 3.E10 NY 6
     COLO NOIR ROUG VERT
LIST 1 2 3 AXES 1.0 'FORCE [N]'
COUR 11 'Z_upper' COOR COMP 3 NOEU LECT c_upper TERM
COUR 12 'Z_lower' COOR COMP 3 NOEU LECT c_lower TERM
TRAC 11 12 AXES 1.0 'COOR. [M]' YZER XGRD YGRD
     COLO NOIR ROUG
LIST 11 12 AXES 1.0 'COOR. [M]'
*=====================================================================
FIN
```

tgli06.dgibi

```
'DEBPROC' pxbox3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT' lz*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-------------------------------------------------
* Generates a parallelepiped mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly,lz) and density (mesh size) dd.
* The mesh consists of CUB8 hexahedral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly,lz : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
```

```
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
base = dall c1 c2 c3 c4 plan;
*
box = base volu tran (0 0 lz);
*
finproc box;
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'tgli06.msh';
opti trac psc ftra 'tgli06_mesh.ps';
gap = 0.01;
den = 1.0;
punch = pxbox3d -1.0 -1.0 gap   2.0 2.0 2.0 den;
die =   pxbox3d -2.0 -2.0 -2.0  4.0 4.0 2.0 den;
mesh = punch et die;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

tgli06.epx

```
TGLI06
ECHO
!CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die TERM
COMP NGRO 2 'bloc'  LECT die TERM COND Z LT -1.99
            'updie' LECT die TERM COND Z GT -0.01
     COUL VERT LECT punch TERM
          TURQ LECT die TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT punch TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT die TERM
LINK COUP SPLT NONE
!    BLOQ 123 LECT bloc TERM
     GLIS 1 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            MAIT NODE LECT updie TERM
            ESCL LECT punch TERM
LINK DECO
     BLOQ 123 LECT bloc TERM
INIT VITE 3 -300.0 LECT punch TERM
ECRI VITE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT DIAG DUMP VISU
CALC TINI 0.0 TEND 3.E-3 PASF 5.E-5 NMAX 60
*=====================================================================
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          LNKS JOIN
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 61 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 59 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL A14 SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 61 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 59 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL A14 SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 61 FPS 15 KFRE 10 COMP -1
     OBJE LECT die TERM REND
GOTR LOOP 59 OFFS FICH AVI CONT NOCL
     OBJE LECT die TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL VITE SCAL USER PROG 20 PAS 20 280 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 61 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 59 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
```

```
        FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
     LIMA ON
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 61 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 59 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (time plots from alice file)
ECHO
RESU ALIC GARD PSCR
COMP NGRO 2 'c_upper' LECT punch TERM COND NEAR POIN 0 0 0
           'c_lower' LECT die   TERM COND NEAR POIN 0 0 0
OPTI PRIN
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'FLZ_punch' FLIA COMP 3 ZONE LECT punch TERM
COUR 2 'FLZ_die'   FLIA COMP 3 ZONE LECT die   TERM
COUR 3 'FDZ_die'   FDEC COMP 3 ZONE LECT die   TERM
TRAC 1     AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR
TRAC   2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO ROUG
TRAC     3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO VERT
TRAC 1 2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG
TRAC 1 2 3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG VERT
LIST 1 2 3 AXES 1.0 'FORCE [N]'
COUR 11 'Z_upper' COOR COMP 3 NOEU LECT c_upper TERM
COUR 12 'Z_lower' COOR COMP 3 NOEU LECT c_lower TERM
TRAC 11 12 AXES 1.0 'COOR. [M]' YZER XGRD YGRD
     COLO NOIR ROUG
LIST 11 12 AXES 1.0 'COOR. [M]'
*=====================================================================
FIN
```

tgli07.dgibi

```
'DEBPROC' pxbox3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT' lz*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-------------------------------------------------
* Generates a parallelepiped mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly,lz) and density (mesh size) dd.
* The mesh consists of CUB8 hexahedral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly,lz : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
base = dall c1 c2 c3 c4 plan;
*
box = base volu tran (0 0 lz);
*
finproc box;
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'tgli07.msh';
opti trac psc ftra 'tgli07_mesh.ps';
gap = 0.01;
den = 0.5;
punch = pxbox3d -1.0 -1.0 gap   2.0 2.0 2.0 den;
die =   pxbox3d -2.0 -2.0 -2.0  4.0 4.0 2.0 den;
mesh = punch et die;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

tgli07.epx

```
TGLI07
ECHO
!CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die TERM
COMP NGRO 2 'bloc'  LECT die TERM COND Z LT -1.99
            'updie' LECT die TERM COND Z GT -0.01
     COUL VERT LECT punch TERM
          TURQ LECT die TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT punch TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT die TERM
LINK COUP SPLT NONE
!    BLOQ 123 LECT bloc TERM
     GLIS 1 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            MAIT NODE LECT updie TERM
            ESCL LECT punch TERM
LINK DECO
     BLOQ 123 LECT bloc TERM
INIT VITE 3 -300.0 LECT punch TERM
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 3.E-3 PASF 2.5E-5 NMAX 120
*=====================================================================
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          LNKS JOIN
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
```

```
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
     OBJE LECT die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
     OBJE LECT die TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL VITE SCAL USER PROG 20 PAS 20 280 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
     LIMA ON
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (time plots from alice file)
ECHO
RESU ALIC GARD PSCR
COMP NGRO 2 'c_upper' LECT punch TERM COND NEAR POIN 0 0 0
            'c_lower' LECT die   TERM COND NEAR POIN 0 0 0
OPTI PRIN
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'FLZ_punch' FLIA COMP 3 ZONE LECT punch TERM
COUR 2 'FLZ_die'   FLIA COMP 3 ZONE LECT die   TERM
COUR 3 'FDZ_die'   FDEC COMP 3 ZONE LECT die   TERM
TRAC 1     AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR
TRAC   2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO ROUG
TRAC     3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO VERT
TRAC 1 2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG
TRAC 1 2 3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG VERT
LIST 1 2 3 AXES 1.0 'FORCE [N]'
COUR 11 'Z_upper' COOR COMP 3 NOEU LECT c_upper TERM
COUR 12 'Z_lower' COOR COMP 3 NOEU LECT c_lower TERM
TRAC 11 12 AXES 1.0 'COOR. [M]' YZER XGRD YGRD
     COLO NOIR ROUG
LIST 11 12 AXES 1.0 'COOR. [M]'
*=====================================================================
FIN
```

tgli11.dgibi

```
'DEBPROC' pxbox3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT' lz*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-------------------------------------------------
* Generates a parallelepiped mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly,lz) and density (mesh size) dd.
* The mesh consists of CUB8 hexahedral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly,lz : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
base = dall c1 c2 c3 c4 plan;
*
box = base volu tran (0 0 lz);
*
finproc box;
*-------------------------------------------------------------------------
'DEBPROC' pxrec3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-------------------------------------------------
* Generates a rectangle mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly) and density (mesh size) dd.
* The mesh consists of QUA4 quadrilateral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly    : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
rect = dall c1 c2 c3 c4 plan;
*
finproc rect;
*-------------------------------------------------------------------------
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'tgli11.msh';
opti trac psc ftra 'tgli11_mesh.ps';
```

```
gap = 0.05;
den = 0.5;
punch = pxbox3d -1.0 -1.0 gap   2.0 2.0 2.0 den;
die =   pxbox3d -1.0 -1.0 -2.0  2.0 2.0 2.0 den;
gap2 = gap/2.0;
plate = pxrec3d -2.0 -2.0 gap2  4.0 4.0     den;
mesh = punch et die et plate;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

tgli11.epx

```
TGLI11
ECHO
 CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die Q4GS plate TERM
COMP EPAI 0.01 LECT plate TERM
     NGRO 1 'bloc' LECT die TERM COND Z LT -1.99
     COUL VERT LECT punch TERM
          TURQ LECT die   TERM
          ROSE LECT plate TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT punch die TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT plate TERM
LINK COUP SPLT NONE
     GLIS 2 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            PGAP 0.005
            MAIT LECT punch TERM
            PESC LECT plate TERM
            FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #2
            PGAP 0.005
            MAIT LECT die   TERM
            PESC LECT plate TERM
LINK DECO
     BLOQ 123 LECT bloc TERM
INIT VITE 3 -300.0 LECT punch TERM
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 3.E-3 PASF 2.5E-5 NMAX 120
*=====================================================================
PLAY
CAME   1 EYE   5.86086E+00 -1.13911E+01  5.31677E+00 ! From above
!        Q     8.23400E-01  5.24563E-01  1.82543E-01  1.16293E-01
         VIEW -4.22618E-01  8.21393E-01 -3.83023E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP   -7.04982E-07  4.22619E-01  9.06307E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
CAME   2 EYE   4.14426E+00 -1.21990E+01 -5.12640E+00 ! From below
!        Q     5.59981E-01  7.99735E-01  2.13151E-01  3.75845E-02
         VIEW -2.98836E-01  8.79650E-01  3.70018E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP    2.98835E-01 -2.81976E-01  9.11694E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          LNKS JOIN
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
     OBJE LECT die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
     OBJE LECT die TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL VITE SCAL USER PROG 20 PAS 20 280 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
```

```
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
     LIMA ON
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (time plots from alice file)
ECHO
RESU ALIC GARD PSCR
COMP NGRO 3 'c_upper' LECT punch TERM COND NEAR POIN 0 0 0
            'c_lower' LECT die   TERM COND NEAR POIN 0 0 0
            'c_plate' LECT plate TERM COND NEAR POIN 0 0 0
OPTI PRIN
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'FLZ_punch' FLIA COMP 3 ZONE LECT punch TERM
COUR 2 'FLZ_die'   FLIA COMP 3 ZONE LECT die   TERM
COUR 3 'FDZ_die'   FDEC COMP 3 ZONE LECT die   TERM
TRAC 1     AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR
TRAC   2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO ROUG
TRAC     3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO VERT
TRAC 1 2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG
TRAC 1 2 3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG VERT
LIST 1 2 3 AXES 1.0 'FORCE [N]'
COUR 11 'Z_upper' COOR COMP 3 NOEU LECT c_upper TERM
COUR 12 'Z_lower' COOR COMP 3 NOEU LECT c_lower TERM
COUR 13 'Z_plate' COOR COMP 3 NOEU LECT c_plate TERM
TRAC 11 12 13 AXES 1.0 'COOR. [M]' YZER XGRD YGRD
     COLO NOIR ROUG VERT
LIST 11 12 13 AXES 1.0 'COOR. [M]'
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE   5.86086E+00 -1.13911E+01  5.31677E+00 ! From above
!        Q     8.23400E-01  5.24563E-01  1.82543E-01  1.16293E-01
         VIEW -4.22618E-01  8.21393E-01 -3.83023E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP   -7.04982E-07  4.22619E-01  9.06307E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT plate die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT plate die TERM REND
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT plate die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   2 EYE   4.14426E+00 -1.21990E+01 -5.12640E+00 ! From below
!        Q     5.59981E-01  7.99735E-01  2.13151E-01  3.75845E-02
         VIEW -2.98836E-01  8.79650E-01  3.70018E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP    2.98835E-01 -2.81976E-01  9.11694E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 2 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT plate punch TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT plate punch TERM REND
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT plate punch TERM REND
ENDPLAY
*=====================================================================
FIN
```

tgli12.dgibi

```
'DEBPROC' pxbox3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT' lz*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-------------------------------------------------
* Generates a parallelepiped mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly,lz) and density (mesh size) dd.
* The mesh consists of CUB8 hexahedral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly,lz : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
base = dall c1 c2 c3 c4 plan;
*
box = base volu tran (0 0 lz);
*
finproc box;
*---------------------------------------------------------------------
'DEBPROC' pxrec3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-------------------------------------------------
* Generates a rectangle mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly) and density (mesh size) dd.
* The mesh consists of QUA4 quadrilateral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly    : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
rect = dall c1 c2 c3 c4 plan;
*
finproc rect;
*---------------------------------------------------------------------
*
opti echo 1;
```

```
opti dime 3 elem cub8;
opti sauv form 'tgli12.msh';
opti trac psc ftra 'tgli12_mesh.ps';
gap = 0.01;
den = 0.5;
punch = pxbox3d -1.0 -1.0 gap   2.0 2.0 2.0 den;
die =   pxbox3d -1.0 -1.0 -2.0  2.0 2.0 2.0 den;
gap2 = gap/2.0;
plate = pxrec3d -2.0 -2.0 gap2  4.0 4.0     den;
mesh = punch et die et plate;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

tgli12.epx

```
TGLI12
ECHO
 CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die Q4GS plate TERM
COMP EPAI 0.01 LECT plate TERM
     NGRO 1 'bloc' LECT die TERM COND Z LT -1.99
     COUL VERT LECT punch TERM
          TURQ LECT die   TERM
          ROSE LECT plate TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT punch die TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT plate TERM
LINK COUP SPLT NONE
     GLIS 2 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            PGAP 0.005
            MAIT LECT punch TERM
            PESC LECT plate TERM
            FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #2
            PGAP 0.005
            MAIT LECT die   TERM
            PESC LECT plate TERM
LINK DECO
     BLOQ 123 LECT bloc TERM
INIT VITE 3 -300.0 LECT punch TERM
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 3.E-3 PASF 2.5E-5 NMAX 120
*=====================================================================
PLAY
CAME   1 EYE   5.86086E+00 -1.13911E+01  5.31677E+00 ! From above
!        Q     8.23400E-01  5.24563E-01  1.82543E-01  1.16293E-01
         VIEW -4.22618E-01  8.21393E-01 -3.83023E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP   -7.04982E-07  4.22619E-01  9.06307E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
CAME   2 EYE   4.14426E+00 -1.21990E+01 -5.12640E+00 ! From below
!        Q     5.59981E-01  7.99735E-01  2.13151E-01  3.75845E-02
         VIEW -2.98836E-01  8.79650E-01  3.70018E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP    2.98835E-01 -2.81976E-01  9.11694E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          LNKS JOIN
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
     OBJE LECT die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
     OBJE LECT die TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL VITE SCAL USER PROG 20 PAS 20 280 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
```

```
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
     LIMA ON
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (time plots from alice file)
ECHO
RESU ALIC GARD PSCR
COMP NGRO 3 'c_upper' LECT punch TERM COND NEAR POIN 0 0 0
            'c_lower' LECT die   TERM COND NEAR POIN 0 0 0
            'c_plate' LECT plate TERM COND NEAR POIN 0 0 0
OPTI PRIN
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'FLZ_punch' FLIA COMP 3 ZONE LECT punch TERM
COUR 2 'FLZ_die'   FLIA COMP 3 ZONE LECT die   TERM
COUR 3 'FDZ_die'   FDEC COMP 3 ZONE LECT die   TERM
TRAC 1     AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR
TRAC   2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO ROUG
TRAC     3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO VERT
TRAC 1 2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG
TRAC 1 2 3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG VERT
LIST 1 2 3 AXES 1.0 'FORCE [N]'
COUR 11 'Z_upper' COOR COMP 3 NOEU LECT c_upper TERM
COUR 12 'Z_lower' COOR COMP 3 NOEU LECT c_lower TERM
COUR 13 'Z_plate' COOR COMP 3 NOEU LECT c_plate TERM
TRAC 11 12 13 AXES 1.0 'COOR. [M]' YZER XGRD YGRD
     COLO NOIR ROUG VERT
LIST 11 12 13 AXES 1.0 'COOR. [M]'
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE   5.86086E+00 -1.13911E+01  5.31677E+00 ! From above
!        Q     8.23400E-01  5.24563E-01  1.82543E-01  1.16293E-01
         VIEW -4.22618E-01  8.21393E-01 -3.83023E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP   -7.04982E-07  4.22619E-01  9.06307E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT plate die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT plate die TERM REND
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT plate die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   2 EYE   4.14426E+00 -1.21990E+01 -5.12640E+00 ! From below
!        Q     5.59981E-01  7.99735E-01  2.13151E-01  3.75845E-02
         VIEW -2.98836E-01  8.79650E-01  3.70018E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP    2.98835E-01 -2.81976E-01  9.11694E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 2 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT plate punch TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT plate punch TERM REND
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT plate punch TERM REND
ENDPLAY
*=====================================================================
FIN
```

tgli13.dgibi

```
'DEBPROC' pxbox3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT' lz*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-------------------------------------------------
* Generates a parallelepiped mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly,lz) and density (mesh size) dd.
* The mesh consists of CUB8 hexahedral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly,lz : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
base = dall c1 c2 c3 c4 plan;
*
box = base volu tran (0 0 lz);
*
finproc box;
*-------------------------------------------------------------------
'DEBPROC' pxrec3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-------------------------------------------------
* Generates a rectangle mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly) and density (mesh size) dd.
* The mesh consists of QUA4 quadrilateral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly    : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
rect = dall c1 c2 c3 c4 plan;
*
finproc rect;
```

```
*---------------------------------------------------------------------
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'tgli13.msh';
opti trac psc ftra 'tgli13_mesh.ps';
gap = 0.01;
den = 0.5;
punch = pxbox3d -1.0 -1.0 gap   2.0 2.0 2.0 den;
die =   pxbox3d -1.0 -1.0 -2.0  2.0 2.0 2.0 den;
gap2 = gap/2.0;
plate = pxrec3d -2.0 -2.0 gap2  4.0 4.0     den;
mesh = punch et die et plate;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

tgli13.epx

```
TGLI13
ECHO
 CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die Q4GS plate TERM
COMP EPAI 0.01 LECT plate TERM
     NGRO 1 'bloc' LECT die TERM COND Z LT -1.99
     COUL VERT LECT punch TERM
          TURQ LECT die   TERM
          ROSE LECT plate TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT punch die TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT plate TERM
LINK COUP SPLT NONE
     GLIS 2 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            PGAP 0.003
            MAIT LECT punch TERM
            PESC LECT plate TERM
            FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #2
            PGAP 0.003
            MAIT LECT die   TERM
            PESC LECT plate TERM
LINK DECO
     BLOQ 123 LECT bloc TERM
INIT VITE 3 -300.0 LECT punch TERM
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 3.E-3 PASF 2.5E-5 NMAX 120
*=====================================================================
PLAY
CAME   1 EYE   5.86086E+00 -1.13911E+01  5.31677E+00 ! From above
!        Q     8.23400E-01  5.24563E-01  1.82543E-01  1.16293E-01
         VIEW -4.22618E-01  8.21393E-01 -3.83023E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP   -7.04982E-07  4.22619E-01  9.06307E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
CAME   2 EYE   4.14426E+00 -1.21990E+01 -5.12640E+00 ! From below
!        Q     5.59981E-01  7.99735E-01  2.13151E-01  3.75845E-02
         VIEW -2.98836E-01  8.79650E-01  3.70018E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP    2.98835E-01 -2.81976E-01  9.11694E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          LNKS JOIN
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
     OBJE LECT die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
     OBJE LECT die TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL VITE SCAL USER PROG 20 PAS 20 280 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
```

```
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
     LIMA ON
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (time plots from alice file)
ECHO
RESU ALIC GARD PSCR
COMP NGRO 3 'c_upper' LECT punch TERM COND NEAR POIN 0 0 0
            'c_lower' LECT die   TERM COND NEAR POIN 0 0 0
            'c_plate' LECT plate TERM COND NEAR POIN 0 0 0
OPTI PRIN
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'FLZ_punch' FLIA COMP 3 ZONE LECT punch TERM
COUR 2 'FLZ_die'   FLIA COMP 3 ZONE LECT die   TERM
COUR 3 'FDZ_die'   FDEC COMP 3 ZONE LECT die   TERM
TRAC 1     AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR
TRAC   2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO ROUG
TRAC     3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO VERT
TRAC 1 2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG
TRAC 1 2 3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG VERT
LIST 1 2 3 AXES 1.0 'FORCE [N]'
COUR 11 'Z_upper' COOR COMP 3 NOEU LECT c_upper TERM
COUR 12 'Z_lower' COOR COMP 3 NOEU LECT c_lower TERM
COUR 13 'Z_plate' COOR COMP 3 NOEU LECT c_plate TERM
TRAC 11 12 13 AXES 1.0 'COOR. [M]' YZER XGRD YGRD
     COLO NOIR ROUG VERT
LIST 11 12 13 AXES 1.0 'COOR. [M]'
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE   5.86086E+00 -1.13911E+01  5.31677E+00 ! From above
!        Q     8.23400E-01  5.24563E-01  1.82543E-01  1.16293E-01
         VIEW -4.22618E-01  8.21393E-01 -3.83023E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP   -7.04982E-07  4.22619E-01  9.06307E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT plate die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT plate die TERM REND
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT plate die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   2 EYE   4.14426E+00 -1.21990E+01 -5.12640E+00 ! From below
!        Q     5.59981E-01  7.99735E-01  2.13151E-01  3.75845E-02
         VIEW -2.98836E-01  8.79650E-01  3.70018E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP    2.98835E-01 -2.81976E-01  9.11694E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 2 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT plate punch TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT plate punch TERM REND
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT plate punch TERM REND
ENDPLAY
*=====================================================================
FIN
```

tgli14.dgibi

```
'DEBPROC' pxbox3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT' lz*'FLOTTANT'
                  dd*'FLOTTANT';
*
*------------------------------------------------
* Generates a parallelepiped mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly,lz) and density (mesh size) dd.
* The mesh consists of CUB8 hexahedral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly,lz : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
base = dall c1 c2 c3 c4 plan;
*
box = base volu tran (0 0 lz);
*
finproc box;
*---------------------------------------------------------------------
'DEBPROC' pxrec3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT'
                  dd*'FLOTTANT';
*
*------------------------------------------------
* Generates a rectangle mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly) and density (mesh size) dd.
* The mesh consists of QUA4 quadrilateral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly    : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
```

```
rect = dall c1 c2 c3 c4 plan;
*
finproc rect;
*------------------------------------------------------------------
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'tgli14.msh';
opti trac psc ftra 'tgli14_mesh.ps';
gap = 0.01;
den = 0.5;
punch = pxbox3d -1.0 -1.0 gap   2.0 2.0 2.0 den;
die =   pxbox3d -1.0 -1.0 -2.0  2.0 2.0 2.0 den;
gap2 = gap/2.0;
plate = pxrec3d -2.0 -2.0 gap2  4.0 4.0     den;
mesh = punch et die et plate;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

tgli14.epx

```
TGLI14
ECHO
 CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die Q4GS plate TERM
COMP EPAI 0.01 LECT plate TERM
     NGRO 1 'bloc' LECT die TERM COND Z LT -1.99
     COUL VERT LECT punch TERM
          TURQ LECT die   TERM
          ROSE LECT plate TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT punch die TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT plate TERM
LINK COUP SPLT NONE
     GLIS 2 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            PGAP 0.005
            MAIT LECT punch TERM
            PESC LECT plate TERM
            FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #2
            PGAP 0.005
            MAIT LECT die   TERM
            PESC LECT plate TERM
LINK DECO
     BLOQ 123 LECT bloc TERM
INIT VITE 3 -300.0 LECT punch TERM
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 3.E-3 PASF 2.5E-5 NMAX 120
*=====================================================================
PLAY
CAME   1 EYE   5.86086E+00 -1.13911E+01  5.31677E+00 ! From above
!        Q     8.23400E-01  5.24563E-01  1.82543E-01  1.16293E-01
         VIEW -4.22618E-01  8.21393E-01 -3.83023E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP   -7.04982E-07  4.22619E-01  9.06307E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
CAME   2 EYE   4.14426E+00 -1.21990E+01 -5.12640E+00 ! From below
!        Q     5.59981E-01  7.99735E-01  2.13151E-01  3.75845E-02
         VIEW -2.98836E-01  8.79650E-01  3.70018E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP    2.98835E-01 -2.81976E-01  9.11694E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          LNKS JOIN
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
     OBJE LECT die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
     OBJE LECT die TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL VITE SCAL USER PROG 20 PAS 20 280 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
```

```
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
     LIMA ON
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (time plots from alice file)
ECHO
RESU ALIC GARD PSCR
COMP NGRO 3 'c_upper' LECT punch TERM COND NEAR POIN 0 0 0
            'c_lower' LECT die   TERM COND NEAR POIN 0 0 0
            'c_plate' LECT plate TERM COND NEAR POIN 0 0 0
OPTI PRIN
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'FLZ_punch' FLIA COMP 3 ZONE LECT punch TERM
COUR 2 'FLZ_die'   FLIA COMP 3 ZONE LECT die   TERM
COUR 3 'FDZ_die'   FDEC COMP 3 ZONE LECT die   TERM
TRAC 1     AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR
TRAC   2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO ROUG
TRAC     3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO VERT
TRAC 1 2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG
TRAC 1 2 3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG VERT
LIST 1 2 3 AXES 1.0 'FORCE [N]'
COUR 11 'Z_upper' COOR COMP 3 NOEU LECT c_upper TERM
COUR 12 'Z_lower' COOR COMP 3 NOEU LECT c_lower TERM
COUR 13 'Z_plate' COOR COMP 3 NOEU LECT c_plate TERM
TRAC 11 12 13 AXES 1.0 'COOR. [M]' YZER XGRD YGRD
     COLO NOIR ROUG VERT
LIST 11 12 13 AXES 1.0 'COOR. [M]'
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE   5.86086E+00 -1.13911E+01  5.31677E+00 ! From above
!        Q     8.23400E-01  5.24563E-01  1.82543E-01  1.16293E-01
         VIEW -4.22618E-01  8.21393E-01 -3.83023E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP   -7.04982E-07  4.22619E-01  9.06307E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT plate die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT plate die TERM REND
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT plate die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   2 EYE   4.14426E+00 -1.21990E+01 -5.12640E+00 ! From below
!        Q     5.59981E-01  7.99735E-01  2.13151E-01  3.75845E-02
         VIEW -2.98836E-01  8.79650E-01  3.70018E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP    2.98835E-01 -2.81976E-01  9.11694E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 2 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT plate punch TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT plate punch TERM REND
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT plate punch TERM REND
ENDPLAY
*=====================================================================
FIN
```

tgli20.dgibi

```
'DEBPROC' pxbox3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT' lz*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-------------------------------------------------
* Generates a parallelepiped mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly,lz) and density (mesh size) dd.
* The mesh consists of CUB8 hexahedral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly,lz : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
base = dall c1 c2 c3 c4 plan;
*
box = base volu tran (0 0 lz);
*
finproc box;
*---------------------------------------------------------------------
'DEBPROC' pxrec3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-------------------------------------------------
* Generates a rectangle mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly) and density (mesh size) dd.
* The mesh consists of QUA4 quadrilateral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly    : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
```

```
c3 = p3 d p4;
c4 = p4 d p1;
rect = dall c1 c2 c3 c4 plan;
*
finproc rect;
*------------------------------------------------------------------------
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'tgli20.msh';
opti trac psc ftra 'tgli20_mesh.ps';
gap = 0.01;
den = 0.5;
punch = pxbox3d -1.0 -1.0 gap   2.0 2.0 2.0 den;
die =   pxbox3d -1.0 -1.0 -2.0  2.0 2.0 2.0 den;
gap2 = gap/2.0;
plate = pxrec3d -2.0 -2.0 gap2  4.0 4.0     den;
mesh = punch et die et plate;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

tgli20.epx

```
TGLI20
ECHO
 CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die Q4GS plate TERM
COMP ORIE INVE LECT plate TERM
     EPAI 0.01 LECT plate TERM
     NGRO 1 'bloc' LECT die TERM COND Z LT -1.99
     COUL VERT LECT punch TERM
          TURQ LECT die   TERM
          ROSE LECT plate TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT punch die TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT plate TERM
LINK COUP SPLT NONE
     GLIS 2 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            PGAP 0.005
            MAIT LECT punch TERM
            PESC LECT plate TERM
            FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #2
            PGAP 0.005
            MAIT LECT die   TERM
            PESC LECT plate TERM
LINK DECO
     BLOQ 123 LECT bloc TERM
INIT VITE 3 -300.0 LECT punch TERM
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 3.E-3 PASF 2.5E-5 NMAX 120
*=====================================================================
PLAY
CAME   1 EYE   5.86086E+00 -1.13911E+01  5.31677E+00 ! From above
!        Q     8.23400E-01  5.24563E-01  1.82543E-01  1.16293E-01
         VIEW -4.22618E-01  8.21393E-01 -3.83023E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP   -7.04982E-07  4.22619E-01  9.06307E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
CAME   2 EYE   4.14426E+00 -1.21990E+01 -5.12640E+00 ! From below
!        Q     5.59981E-01  7.99735E-01  2.13151E-01  3.75845E-02
         VIEW -2.98836E-01  8.79650E-01  3.70018E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP    2.98835E-01 -2.81976E-01  9.11694E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          LNKS JOIN
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
     OBJE LECT die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
     OBJE LECT die TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL VITE SCAL USER PROG 20 PAS 20 280 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
```

```
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
     LIMA ON
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (time plots from alice file)
ECHO
RESU ALIC GARD PSCR
COMP NGRO 3 'c_upper' LECT punch TERM COND NEAR POIN 0 0 0
            'c_lower' LECT die   TERM COND NEAR POIN 0 0 0
            'c_plate' LECT plate TERM COND NEAR POIN 0 0 0
OPTI PRIN
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'FLZ_punch' FLIA COMP 3 ZONE LECT punch TERM
COUR 2 'FLZ_die'   FLIA COMP 3 ZONE LECT die   TERM
COUR 3 'FDZ_die'   FDEC COMP 3 ZONE LECT die   TERM
TRAC 1     AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR
TRAC   2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO ROUG
TRAC     3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO VERT
TRAC 1 2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG
TRAC 1 2 3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG VERT
LIST 1 2 3 AXES 1.0 'FORCE [N]'
COUR 11 'Z_upper' COOR COMP 3 NOEU LECT c_upper TERM
COUR 12 'Z_lower' COOR COMP 3 NOEU LECT c_lower TERM
COUR 13 'Z_plate' COOR COMP 3 NOEU LECT c_plate TERM
TRAC 11 12 13 AXES 1.0 'COOR. [M]' YZER XGRD YGRD
     COLO NOIR ROUG VERT
LIST 11 12 13 AXES 1.0 'COOR. [M]'
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE   5.86086E+00 -1.13911E+01  5.31677E+00 ! From above
!        Q     8.23400E-01  5.24563E-01  1.82543E-01  1.16293E-01
         VIEW -4.22618E-01  8.21393E-01 -3.83023E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP   -7.04982E-07  4.22619E-01  9.06307E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT plate die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT plate die TERM REND
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT plate die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   2 EYE   4.14426E+00 -1.21990E+01 -5.12640E+00 ! From below
!        Q     5.59981E-01  7.99735E-01  2.13151E-01  3.75845E-02
         VIEW -2.98836E-01  8.79650E-01  3.70018E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP    2.98835E-01 -2.81976E-01  9.11694E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 2 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT plate punch TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT plate punch TERM REND
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT plate punch TERM REND
ENDPLAY
*=====================================================================
FIN
```

tgli22.dgibi

```
'DEBPROC' pxbox3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT' lz*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-------------------------------------------------
* Generates a parallelepiped mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly,lz) and density (mesh size) dd.
* The mesh consists of CUB8 hexahedral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly,lz : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
base = dall c1 c2 c3 c4 plan;
*
box = base volu tran (0 0 lz);
*
finproc box;
*-------------------------------------------------------------------------
'DEBPROC' pxrec3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-------------------------------------------------
* Generates a rectangle mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly) and density (mesh size) dd.
* The mesh consists of QUA4 quadrilateral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly    : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
```

```
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
rect = dall c1 c2 c3 c4 plan;
*
finproc rect;
*-----------------------------------------------------------------------
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'tgli22.msh';
opti trac psc ftra 'tgli22_mesh.ps';
gap = 0.01;
den = 0.5;
*punch = pxbox3d -1.0 -1.0 gap   2.0 2.0 2.0 den;
die =   pxbox3d -1.0 -1.0 -2.0  2.0 2.0 2.0 den;
gap2 = gap/2.0;
plate = pxrec3d -2.0 -2.0 gap2  4.0 4.0     den;
*mesh = punch et die et plate;
mesh = die et plate;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

tgli22.epx

```
TGLI22
ECHO
 CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 die Q4GS plate TERM
COMP EPAI 0.01 LECT plate TERM
     COUL TURQ LECT die   TERM
          ROSE LECT plate TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT die TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT plate TERM
LINK COUP SPLT NONE
     GLIS 1 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #2
            PGAP 0.005
            MAIT LECT die   TERM
            PESC LECT plate TERM
INIT VITE 3 300.0 LECT die TERM
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 3.E-3 PASF 2.5E-5 NMAX 120
*=====================================================================
PLAY
CAME   1 EYE   5.86086E+00 -1.13911E+01  5.31677E+00 ! From above
!        Q     8.23400E-01  5.24563E-01  1.82543E-01  1.16293E-01
         VIEW -4.22618E-01  8.21393E-01 -3.83023E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP   -7.04982E-07  4.22619E-01  9.06307E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
CAME   2 EYE   4.14426E+00 -1.21990E+01 -5.12640E+00 ! From below
!        Q     5.59981E-01  7.99735E-01  2.13151E-01  3.75845E-02
         VIEW -2.98836E-01  8.79650E-01  3.70018E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP    2.98835E-01 -2.81976E-01  9.11694E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          LNKS JOIN
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
     OBJE LECT die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
     OBJE LECT die TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL VITE SCAL USER PROG 20 PAS 20 280 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
```

```
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
     LIMA ON
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (time plots from alice file)
ECHO
RESU ALIC GARD PSCR
COMP NGRO 2 'c_lower' LECT die   TERM COND NEAR POIN 0 0 0
           'c_plate' LECT plate TERM COND NEAR POIN 0 0 0
OPTI PRIN
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 2 'FLZ_die'   FLIA COMP 3 ZONE LECT die   TERM
COUR 3 'FDZ_die'   FDEC COMP 3 ZONE LECT die   TERM
TRAC   2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO ROUG
TRAC     3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO VERT
TRAC 2 3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO ROUG VERT
LIST 2 3 AXES 1.0 'FORCE [N]'
COUR 12 'Z_lower' COOR COMP 3 NOEU LECT c_lower TERM
COUR 13 'Z_plate' COOR COMP 3 NOEU LECT c_plate TERM
TRAC 12 13 AXES 1.0 'COOR. [M]' YZER XGRD YGRD
     COLO ROUG VERT
LIST 12 13 AXES 1.0 'COOR. [M]'
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE   5.86086E+00 -1.13911E+01  5.31677E+00 ! From above
!        Q     8.23400E-01  5.24563E-01  1.82543E-01  1.16293E-01
         VIEW -4.22618E-01  8.21393E-01 -3.83023E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP   -7.04982E-07  4.22619E-01  9.06307E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT plate die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT plate die TERM REND
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT plate die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE   5.86086E+00 -1.13911E+01  5.31677E+00 ! From above
!        Q     8.23400E-01  5.24563E-01  1.82543E-01  1.16293E-01
         VIEW -4.22618E-01  8.21393E-01 -3.83023E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP   -7.04982E-07  4.22619E-01  9.06307E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT die TERM REND
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE   5.86086E+00 -1.13911E+01  5.31677E+00 ! From above
!        Q     8.23400E-01  5.24563E-01  1.82543E-01  1.16293E-01
         VIEW -4.22618E-01  8.21393E-01 -3.83023E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP   -7.04982E-07  4.22619E-01  9.06307E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN OBJE USLM LECT plate TERM
          DHAS CGLA
     GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT plate die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT plate die TERM REND
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT plate die TERM REND
ENDPLAY
*=====================================================================
FIN
```

tgli30.dgibi

```
'DEBPROC' pxbox3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT' lz*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-------------------------------------------------
* Generates a parallelepiped mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly,lz) and density (mesh size) dd.
* The mesh consists of CUB8 hexahedral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly,lz : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
base = dall c1 c2 c3 c4 plan;
*
box = base volu tran (0 0 lz);
```

```
*
finproc box;
*------------------------------------------------------------------------
'DEBPROC' pxrec3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-------------------------------------------------
* Generates a rectangle mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly) and density (mesh size) dd.
* The mesh consists of QUA4 quadrilateral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly    : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
rect = dall c1 c2 c3 c4 plan;
*
finproc rect;
*------------------------------------------------------------------------
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'tgli30.msh';
opti trac psc ftra 'tgli30_mesh.ps';
gap = 0.01;
den = 0.5;
punch = pxbox3d -1.0 -1.0 gap   2.0 2.0 2.0 den;
die =   pxbox3d -1.0 -1.0 -2.0  2.0 2.0 2.0 den;
gap2 = gap/2.0;
plate = pxrec3d -2.0 -2.0 gap2  4.0 4.0     den;
mesh = punch et die et plate;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

tgli30.epx

```
TGLI30
ECHO
 CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die Q4GS plate TERM
COMP EPAI 0.01 LECT plate TERM
     NGRO 5 'bloc' LECT die TERM COND Z LT -1.99
            'pun_low' LECT punch TERM COND Z LT  2.E-2
            'die_top' LECT die   TERM COND Z GT -1.E-2
            'pun_cen' LECT punch TERM COND NEAR POIN 0 0 0
            'die_cen' LECT die   TERM COND NEAR POIN 0 0 0
     COUL VERT LECT punch TERM
          TURQ LECT die   TERM
          ROSE LECT plate TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT punch die TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT plate TERM
LINK COUP SPLT NONE
     GLIS 2 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            PGAP 0.005
            CMAI LECT plate TERM EXTE LECT pun_cen TERM
            PESC LECT pun_low TERM
            FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #2
            PGAP 0.005
            CMAI LECT plate TERM EXTE LECT die_cen TERM
            PESC LECT die_top TERM
INIT VITE 3 -150.0 LECT punch TERM
          3  150.0 LECT die   TERM
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 3.E-3 PASF 2.5E-5 NMAX 120
*================================================================
PLAY
CAME   1 EYE   5.86086E+00 -1.13911E+01  5.31677E+00 ! From above
!        Q     8.23400E-01  5.24563E-01  1.82543E-01  1.16293E-01
         VIEW -4.22618E-01  8.21393E-01 -3.83023E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP   -7.04982E-07  4.22619E-01  9.06307E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
CAME   2 EYE   4.14426E+00 -1.21990E+01 -5.12640E+00 ! From below
!        Q     5.59981E-01  7.99735E-01  2.13151E-01  3.75845E-02
         VIEW -2.98836E-01  8.79650E-01  3.70018E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP    2.98835E-01 -2.81976E-01  9.11694E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          LNKS JOIN
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
     OBJE LECT die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
```

```
     OBJE LECT die TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL VITE SCAL USER PROG 20 PAS 20 280 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
     LIMA ON
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (time plots from alice file)
ECHO
RESU ALIC GARD PSCR
COMP NGRO 3 'c_upper' LECT punch TERM COND NEAR POIN 0 0 0
           'c_lower' LECT die   TERM COND NEAR POIN 0 0 0
           'c_plate' LECT plate TERM COND NEAR POIN 0 0 0
OPTI PRIN
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'FLZ_punch' FLIA COMP 3 ZONE LECT punch TERM
COUR 2 'FLZ_die'   FLIA COMP 3 ZONE LECT die   TERM
COUR 3 'FDZ_die'   FDEC COMP 3 ZONE LECT die   TERM
TRAC 1     AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR
TRAC   2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO ROUG
TRAC     3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO VERT
TRAC 1 2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG
TRAC 1 2 3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG VERT
LIST 1 2 3 AXES 1.0 'FORCE [N]'
COUR 11 'Z_upper' COOR COMP 3 NOEU LECT c_upper TERM
COUR 12 'Z_lower' COOR COMP 3 NOEU LECT c_lower TERM
COUR 13 'Z_plate' COOR COMP 3 NOEU LECT c_plate TERM
TRAC 11 12 13 AXES 1.0 'COOR. [M]' YZER XGRD YGRD
     COLO NOIR ROUG VERT
LIST 11 12 13 AXES 1.0 'COOR. [M]'
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE   5.86086E+00 -1.13911E+01  5.31677E+00 ! From above
!        Q     8.23400E-01  5.24563E-01  1.82543E-01  1.16293E-01
         VIEW -4.22618E-01  8.21393E-01 -3.83023E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP   -7.04982E-07  4.22619E-01  9.06307E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT plate die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT plate die TERM REND
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT plate die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   2 EYE   4.14426E+00 -1.21990E+01 -5.12640E+00 ! From below
!        Q     5.59981E-01  7.99735E-01  2.13151E-01  3.75845E-02
         VIEW -2.98836E-01  8.79650E-01  3.70018E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP    2.98835E-01 -2.81976E-01  9.11694E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 2 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT plate punch TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT plate punch TERM REND
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT plate punch TERM REND
ENDPLAY
*=====================================================================
FIN
```

tgli30a.epx

```
TGLI30A
ECHO
RESU ALIC 'tgli30.ali' GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE   0.00000E+00  0.00000E+00  1.21395E+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
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.21345E+01
!ASPECT :  1.00000E+00
!NEAR   :  8.66748E+00
!FAR    :  1.90684E+01
SCEN GEOM NAVI FREE
     COLO PAPE
SLER CAM1 1 NFRA 1
TRAC OFFS FICH BMP OBJE LECT plate TERM REND
FREQ 120
GO
TRAC OFFS FICH BMP OBJE LECT plate TERM REND
ENDPLAY
*=====================================================================
FIN
```

tgli31.dgibi

```
'DEBPROC' pxbox3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT' lz*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-----------------------------------------------------
* Generates a parallelepiped mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly,lz) and density (mesh size) dd.
* The mesh consists of CUB8 hexahedral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly,lz : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-----------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
base = dall c1 c2 c3 c4 plan;
*
box = base volu tran (0 0 lz);
*
finproc box;
*-------------------------------------------------------------------------
'DEBPROC' pxrec3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-----------------------------------------------------
* Generates a rectangle mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly) and density (mesh size) dd.
* The mesh consists of QUA4 quadrilateral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly    : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-----------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
rect = dall c1 c2 c3 c4 plan;
*
finproc rect;
*-------------------------------------------------------------------------
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'tgli31.msh';
opti trac psc ftra 'tgli31_mesh.ps';
gap = 0.01;
den = 0.5;
punch = pxbox3d -1.0 -1.0 gap   2.0 2.0 2.0 den;
die =   pxbox3d -1.0 -1.0 -2.0  2.0 2.0 2.0 den;
gap2 = gap/2.0;
plate = pxrec3d -2.0 -2.0 gap2  4.0 4.0     den;
mesh = punch et die et plate;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

tgli31.epx

```
TGLI31
ECHO
 CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die Q4GS plate TERM
COMP EPAI 0.01 LECT plate TERM
     NGRO 5 'bloc' LECT die TERM COND Z LT -1.99
            'pun_low' LECT punch TERM COND Z LT  2.E-2
            'die_top' LECT die   TERM COND Z GT -1.E-2
            'pun_cen' LECT punch TERM COND NEAR POIN 0 0 0
            'die_cen' LECT die   TERM COND NEAR POIN 0 0 0
     COUL VERT LECT punch TERM
          TURQ LECT die   TERM
          ROSE LECT plate TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT punch die TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT plate TERM
LINK COUP SPLT NONE
     GLIS 2 PGAP 0.005 ! Contact surface #1
            CMAI LECT plate TERM EXTE LECT pun_cen TERM
            PESC LECT pun_low TERM
            PGAP 0.005 ! Contact surface #2
            CMAI LECT plate TERM EXTE LECT die_cen TERM
            PESC LECT die_top TERM
INIT VITE 3 -150.0 LECT punch TERM
          3  150.0 LECT die   TERM
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 3.E-3 PASF 2.5E-5 NMAX 120
*=====================================================================
PLAY
CAME   1 EYE   5.86086E+00 -1.13911E+01  5.31677E+00 ! From above
!        Q     8.23400E-01  5.24563E-01  1.82543E-01  1.16293E-01
         VIEW -4.22618E-01  8.21393E-01 -3.83023E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP   -7.04982E-07  4.22619E-01  9.06307E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
CAME   2 EYE   4.14426E+00 -1.21990E+01 -5.12640E+00 ! From below
!        Q     5.59981E-01  7.99735E-01  2.13151E-01  3.75845E-02
         VIEW -2.98836E-01  8.79650E-01  3.70018E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP    2.98835E-01 -2.81976E-01  9.11694E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          LNKS JOIN
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
```

```
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
     OBJE LECT die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
     OBJE LECT die TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL VITE SCAL USER PROG 20 PAS 20 280 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
     LIMA ON
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (time plots from alice file)
ECHO
RESU ALIC GARD PSCR
COMP NGRO 3 'c_upper' LECT punch TERM COND NEAR POIN 0 0 0
            'c_lower' LECT die   TERM COND NEAR POIN 0 0 0
            'c_plate' LECT plate TERM COND NEAR POIN 0 0 0
OPTI PRIN
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'FLZ_punch' FLIA COMP 3 ZONE LECT punch TERM
COUR 2 'FLZ_die'   FLIA COMP 3 ZONE LECT die   TERM
COUR 3 'FDZ_die'   FDEC COMP 3 ZONE LECT die   TERM
TRAC 1     AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR
TRAC   2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO ROUG
TRAC     3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO VERT
TRAC 1 2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG
TRAC 1 2 3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG VERT
LIST 1 2 3 AXES 1.0 'FORCE [N]'
COUR 11 'Z_upper' COOR COMP 3 NOEU LECT c_upper TERM
COUR 12 'Z_lower' COOR COMP 3 NOEU LECT c_lower TERM
COUR 13 'Z_plate' COOR COMP 3 NOEU LECT c_plate TERM
TRAC 11 12 13 AXES 1.0 'COOR. [M]' YZER XGRD YGRD
     COLO NOIR ROUG VERT
LIST 11 12 13 AXES 1.0 'COOR. [M]'
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE   5.86086E+00 -1.13911E+01  5.31677E+00 ! From above
!        Q     8.23400E-01  5.24563E-01  1.82543E-01  1.16293E-01
         VIEW -4.22618E-01  8.21393E-01 -3.83023E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP   -7.04982E-07  4.22619E-01  9.06307E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT plate die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT plate die TERM REND
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT plate die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   2 EYE   4.14426E+00 -1.21990E+01 -5.12640E+00 ! From below
!        Q     5.59981E-01  7.99735E-01  2.13151E-01  3.75845E-02
         VIEW -2.98836E-01  8.79650E-01  3.70018E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP    2.98835E-01 -2.81976E-01  9.11694E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 2 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT plate punch TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT plate punch TERM REND
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT plate punch TERM REND
ENDPLAY
*=====================================================================
```

```
FIN
```

tgli31a.epx

```
TGLI31A
ECHO
RESU ALIC 'tgli31.ali' GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE   0.00000E+00  0.00000E+00  1.21395E+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
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.21345E+01
!ASPECT :  1.00000E+00
!NEAR   :  8.66748E+00
!FAR    :  1.90684E+01
SCEN GEOM NAVI FREE
     COLO PAPE
SLER CAM1 1 NFRA 1
TRAC OFFS FICH BMP OBJE LECT plate TERM REND
FREQ 120
GO
TRAC OFFS FICH BMP OBJE LECT plate TERM REND
ENDPLAY
*=====================================================================
FIN
```

tgli32.dgibi

```
'DEBPROC' pxbox3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT' lz*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-------------------------------------------------
* Generates a parallelepiped mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly,lz) and density (mesh size) dd.
* The mesh consists of CUB8 hexahedral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly,lz : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
base = dall c1 c2 c3 c4 plan;
*
box = base volu tran (0 0 lz);
*
finproc box;
*---------------------------------------------------------------------
'DEBPROC' pxrec3d x0*'FLOTTANT' y0*'FLOTTANT' z0*'FLOTTANT'
                  lx*'FLOTTANT' ly*'FLOTTANT'
                  dd*'FLOTTANT';
*
*-------------------------------------------------
* Generates a rectangle mesh with origin in point
* (x0,y0,z0), sides of length (lx,ly) and density (mesh size) dd.
* The mesh consists of QUA4 quadrilateral elements and is oriented
* along the global axes.
*
* Input :
* -----
*     x0,y0,z0 : coordinates of 'origin' of the box
*     lx,ly    : length of the box sides
*     dd : "density" (size) of the mesh (the same in all directions)
* Output :
* ------
*     box : mesh consisting of CUB8 hexahedra
*-------------------------------------------------
*
dens dd;
p1 = x0 y0 z0;
p2 = (x0 + lx) y0 z0;
p3 = (x0 + lx) (y0 + ly) z0;
p4 = x0 (y0 + ly) z0;
*
c1 = p1 d p2;
c2 = p2 d p3;
c3 = p3 d p4;
c4 = p4 d p1;
rect = dall c1 c2 c3 c4 plan;
*
finproc rect;
*---------------------------------------------------------------------
*
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'tgli32.msh';
opti trac psc ftra 'tgli32_mesh.ps';
gap = 0.01;
den = 0.5;
punch = pxbox3d -1.0 -1.0 gap   2.0 2.0 2.0 den;
die =   pxbox3d -1.0 -1.0 -2.0  2.0 2.0 2.0 den;
gap2 = gap/2.0;
plate = pxrec3d -2.0 -2.0 gap2  4.0 4.0     den;
mesh = punch et die et plate;
trac cach qual mesh;
tass mesh noop;
sauv form mesh;
fin;
```

tgli32.epx

```
TGLI32
ECHO
 CONV WIN
CAST mesh
TRID LAGR
GEOM CUB8 punch die Q4GS plate TERM
COMP EPAI 0.01 LECT plate TERM
     NGRO 5 'bloc' LECT die TERM COND Z LT -1.99
            'pun_low' LECT punch TERM COND Z LT  2.E-2
            'die_top' LECT die   TERM COND Z GT -1.E-2
            'pun_cen' LECT punch TERM COND NEAR POIN 0 0 0
            'die_cen' LECT die   TERM COND NEAR POIN 0 0 0
     COUL VERT LECT punch TERM
          TURQ LECT die   TERM
          ROSE LECT plate TERM
MATE VPJC RO 2700.0 YOUN 70.0E9 NU 0.3 ELAS 80.0E6 mxit 500
          QR1 49.3E6 CR1 1457.1 QR2 5.2E6 CR2 121.5
          PDOT 5.E-4 C 0.014 TQ 0.9 CP 910.0
          TM 893.0 M 0.0 DC 1.0 WC 44.6E6
          LECT punch die TERM
     VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.7E8 mxit 500
          QR1 2.364E8 CR1 39.3 QR2 4.081E8 CR2 4.5
          PDOT 5.E-4 C 1.E-3 TQ 0.9 CP 452.0
          TM 1800.0 M 0.0 DC 0.9 WC 473.0E6
          LECT plate TERM
LINK COUP SPLT NONE
     GLIS 2 FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #1
            PGAP 0.005
            CMAI LECT plate TERM EXTE LECT pun_cen TERM
            PESC LECT pun_low TERM
            FROT MUST 0.3 MUDY 0.1 GAMM 0 ! Contact surface #2
            PGAP 0.005
            CMAI LECT plate TERM EXTE LECT die_cen TERM
            PESC LECT die_top TERM
LINK DECO
     BLOQ 123 LECT bloc TERM
INIT VITE 3 -300.0 LECT punch TERM
ECRI FLIA FREQ 120
     FICH ALIC FREQ 1
OPTI NOTE
     PAS UTIL
     CSTA 0.5
     GLIS NORM ELEM
     LOG 1
     LNKS STAT VISU
CALC TINI 0.0 TEND 3.E-3 PASF 2.5E-5 NMAX 120
*=====================================================================
PLAY
CAME   1 EYE   5.86086E+00 -1.13911E+01  5.31677E+00 ! From above
!        Q     8.23400E-01  5.24563E-01  1.82543E-01  1.16293E-01
         VIEW -4.22618E-01  8.21393E-01 -3.83023E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP   -7.04982E-07  4.22619E-01  9.06307E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
CAME   2 EYE   4.14426E+00 -1.21990E+01 -5.12640E+00 ! From below
!        Q     5.59981E-01  7.99735E-01  2.13151E-01  3.75845E-02
         VIEW -2.98836E-01  8.79650E-01  3.70018E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP    2.98835E-01 -2.81976E-01  9.11694E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
```

```
          FACE HFRO
          LNKS JOIN
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL FLIA SCAL USER PROG 0.5E7 PAS 0.5E7 7.E7 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
     OBJE LECT die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
     OBJE LECT die TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
          FACE HFRO
     VECT SCCO FIEL VITE SCAL USER PROG 20 PAS 20 280 TERM SIVE
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE  -1.00409E+01 -1.00409E+01  9.94792E+00
!        Q     8.19491E-01  4.26600E-01 -1.76704E-01 -3.39444E-01
         VIEW  5.79228E-01  5.79228E-01 -5.73576E-01
         RIGH  7.07107E-01 -7.07107E-01  1.11022E-16
         UP    4.05580E-01  4.05580E-01  8.19152E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.73350E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.35213E+01
!FAR    :  2.42689E+01
SCEN GEOM NAVI FREE
     LIMA ON
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (time plots from alice file)
ECHO
RESU ALIC GARD PSCR
COMP NGRO 3 'c_upper' LECT punch TERM COND NEAR POIN 0 0 0
            'c_lower' LECT die   TERM COND NEAR POIN 0 0 0
            'c_plate' LECT plate TERM COND NEAR POIN 0 0 0
OPTI PRIN
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'FLZ_punch' FLIA COMP 3 ZONE LECT punch TERM
COUR 2 'FLZ_die'   FLIA COMP 3 ZONE LECT die   TERM
COUR 3 'FDZ_die'   FDEC COMP 3 ZONE LECT die   TERM
TRAC 1     AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR
TRAC   2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO ROUG
TRAC     3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO VERT
TRAC 1 2   AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG
TRAC 1 2 3 AXES 1.0 'FORCE [N]' YZER XGRD YGRD
     COLO NOIR ROUG VERT
LIST 1 2 3 AXES 1.0 'FORCE [N]'
COUR 11 'Z_upper' COOR COMP 3 NOEU LECT c_upper TERM
COUR 12 'Z_lower' COOR COMP 3 NOEU LECT c_lower TERM
COUR 13 'Z_plate' COOR COMP 3 NOEU LECT c_plate TERM
TRAC 11 12 13 AXES 1.0 'COOR. [M]' YZER XGRD YGRD
     COLO NOIR ROUG VERT
LIST 11 12 13 AXES 1.0 'COOR. [M]'
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   1 EYE   5.86086E+00 -1.13911E+01  5.31677E+00 ! From above
!        Q     8.23400E-01  5.24563E-01  1.82543E-01  1.16293E-01
         VIEW -4.22618E-01  8.21393E-01 -3.83023E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP   -7.04982E-07  4.22619E-01  9.06307E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT plate die TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT plate die TERM REND
```

```
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT plate die TERM REND
ENDPLAY
*=====================================================================
SUIT
Post treatment (visualization from alice file)
ECHO
RESU ALIC GARD PSCR
OPTI PRIN
SORT VISU NSTO 1
PLAY
CAME   2 EYE   4.14426E+00 -1.21990E+01 -5.12640E+00 ! From below
!        Q     5.59981E-01  7.99735E-01  2.13151E-01  3.75845E-02
         VIEW -2.98836E-01  8.79650E-01  3.70018E-01
         RIGH  9.06308E-01  3.83022E-01 -1.78606E-01
         UP    2.98835E-01 -2.81976E-01  9.11694E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  5.00011E-03
!RSPHERE:  3.46699E+00
!RADIUS :  1.38680E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.04010E+01
!FAR    :  2.08019E+01
SCEN GEOM NAVI FREE
          FACE SBAC
          LINE SSHA SFRE
     COLO PAPE
     LIMA ON
SLER CAM1 2 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 121 FPS 15 KFRE 10 COMP -1
  OBJE LECT plate punch TERM REND
GOTR LOOP 119 OFFS FICH AVI CONT NOCL
  OBJE LECT plate punch TERM REND
GO
TRAC OFFS FICH AVI CONT
  OBJE LECT plate punch TERM REND
ENDPLAY
*=====================================================================
FIN
```

List of input files

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