ISSN 1831-9424

JRC Technical Report

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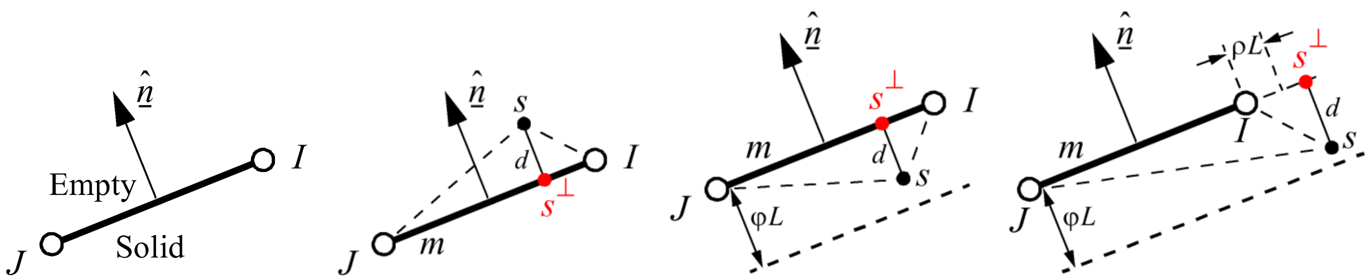
2023



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JRC134174

EUR 31626 EN

PDF ISBN 978-92-68-06564-8 ISSN 1831-9424 doi:10.2760/298646 KJ-NA-31-626-EN-N

Luxembourg: Publications Office of the European Union, 2023

How to cite this report: Casadei, F., Valsamos G., Larcher M., *SLID : a sliding line and sliding surface algorithm for smooth contact in EUROPLEXUS*, Publications Office of the European Union, Luxembourg, 2023, doi: 10.2760/298646, JRC134174.

SLID : a sliding-line and sliding-surface algorithm for smooth contact in EUROPLEXUS

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Abstract

This report presents the formulation and implementation in the EUROPLEXUS code [1] of a new contact algorithm named SLID, based on the sliding surface paradigm. The EUROPLEXUS code (also abbreviated as EPX) is jointly developed by the French Commissariat à l'Energie Atomique (CEA DMT Saclay) and by EC-JRC. Its application domain is the numerical simulation of fast transient phenomena such as explosions, crashes and impacts in complex three-dimensional fluid-structure systems.

Recently, EPX is being used to simulate vehicle crash against obstacles such as road barriers for safety and security studies. These studies involve complex contact-impact scenarios, which may include at the same time situations typical of crash, characterized by large deformation of the contacting bodies, and other situations more typical of (smooth) contact. In some test cases, the effect of friction may be important, especially in the parts of the model undergoing smooth contact, and it must be included in the numerical simulations.

Before the present work, three main contact-impact models were available in EPX. The pinball-based model PINB (classical spherical pinballs) is very robust at contact detection but presents some serious drawbacks in treating smooth contact, especially with friction, at least when the Lagrange Multiplier (LM) method is used for contact enforcement (the situation is better with the penalty formulation). The GPIN (generalized pinballs) model retains PINB's robustness in contact detection and is more efficient than PINB in smooth contact situations, but its implementation is complex and not yet fully developed. The GLIS model, based on the sliding surfaces paradigm, is ideal by design for the treatment of smooth contact, but suffers from serious pitfalls in contact detection.

The present SLID model, heavily inspired by GLIS and also based on the sliding surface paradigm, tries to improve on robustness in contact detection while retaining the good properties of GLIS in smooth contact situations, without or with friction. It is simpler to formulate and implement than the GPIN model. Unlike GLIS, the SLID algorithm is also implemented in 2D (sliding lines).

Keywords: *Sliding surfaces, Sliding lines, Contact-Impact, Friction, Smooth contact.*

Foreword

This report is part of a large series of scientific-technical documents that are meant to provide essential information and documentation to users and developers of the EUROPLEXUS code. EUROPLEXUS (also abbreviated as EPX) is a computer code jointly developed by the French Commissariat à l'Energie Atomique (CEA DMT Saclay) and by EC-Joint Research Centre (JRC Ispra) within the framework of contractual agreements between the two research bodies.

EPX is a mature, general-purpose Finite Element and Finite Volume explicit code under active development since 1999, for the simulation of fast transient dynamic events in complex fluid-structure systems. It is an evolution of its ancestor PLEXIS-3C, which was also jointly developed by CEA and JRC in the 1980s and early '90s.

The code has been traditionally used in safety studies, ranging from nuclear reactors, to energy plants, to chemical and industrial plants, off-shore structures, car and road barrier crashes, among others. More recently it has proven a very useful tool in providing certified and independent numerical solutions in support of EC policies regarding the security of critical infrastructures and public spaces (like buildings, train and metro stations and carriages, etc.), which may be vulnerable to terrorist attacks or to natural disasters.

While being mainly of technical nature, the information contained in this series of reports is an invaluable source of reference for the users (as a complement to the User's manual) but also in particular for the developers of EPX. New models made available in the code are described in detail from the theoretical viewpoint. Several verification and application examples are also usually provided, in order to illustrate the practical use and to verify the correct functioning of the models.

Usually, at the end of each report an Appendix lists the input files that were used to produce the examples presented in the report. This allows users to re-run the test cases with EPX at any time and to use them as a basis for their own numerical simulations.

A complete list of the reports (produced both at JRC and at CEA) in this series can be found in the Bibliography section of the EPX User's manual [1].

1 Introduction

This report presents the formulation and implementation in the EUROPLEXUS code of a new contact algorithm SLID, based on the sliding surface paradigm. The algorithm is best suited for smooth contact between mechanical parts, without or with friction, and with limited deformation of the contacting parts.

EUROPLEXUS [1] (also abbreviated as EPX) is a computer code jointly developed by the French Commissariat à 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.

Recently, EPX is being used to simulate vehicle crash against obstacles such as road barriers for safety and security studies, see e.g. references [3, 4]. These studies involve complex contact-impact scenarios, which may include at the same time situations typical of crash, characterized by large deformation of the contacting bodies, and other situations more typical of (smooth) contact. In some test cases, the effect of friction may be important, especially in the zones of the model undergoing smooth contact, and it must be included in the numerical simulations.

1.1 Contact models

Before the present work, three main contact-impact models were available in EPX. The pinball-based model PINB (classical spherical pinballs) is very robust at contact detection but presents some serious drawbacks in treating smooth contact, especially with friction, at least when the Lagrange Multiplier (LM) method is used for contact enforcement (the situation is better with the penalty formulation). The GPIN (generalized pinballs) model retains PINB's robustness in contact detection and is more efficient than PINB in smooth contact situations, but its implementation is complex and not yet fully developed. The GLIS model, based on the sliding surfaces paradigm, is ideal by design for the treatment of smooth contact, but suffers from serious pitfalls in contact detection.

The most popular contact algorithms available in Finite Element (FE) computer codes are probably the so-called slide line (in 2D) and slide surface (in 3D) algorithms proposed by Hallquist and Benson [5, 6]. They are based on the notion of penetration of slave nodes into master segments (in 2D) or into master surfaces (in 3D). In EPX an algorithm following this strategy is already implemented under the name of GLIS contact model [7–13, 15–20, 24]. For a comprehensive account of computational methods in contact mechanics, see e.g. the excellent book by Wriggers [27].

The present SLID model, heavily inspired by GLIS and also based on the sliding surface paradigm, tries to improve on robustness in contact detection while retaining the good properties of GLIS in smooth contact situations, without or with friction. It is simpler to formulate and implement than the GPIN model. Unlike GLIS, the SLID algorithm is also implemented in 2D (sliding lines).

While SLID (like GLIS) aims primarily at modeling smooth contact, some effort is put in trying to make it as general as possible so that it behaves decently also in non smooth contact situations. Thus, simplifying assumptions that would hinder its application outside the smooth regime (e.g. in the presence of sharp corners) are tentatively avoided in the formulation.

This said, experience shows that formulating and implementing a contact model good "for all seasons" is extremely hard, if not impossible. Therefore, care is taken so that the user will be able to combine SLID with other contact models in EPX (e.g. PINB), using the most suitable model in each contact zone of the simulation.

Finally, it should be noted that the present work is only a first attempt (albeit relatively general and ambitious) at the formulation and implementation of SLID. Further work will certainly be required to make the model as general and as robust as possible, so that it can be applied in a wide range of applications. To this end, the execution of many numerical tests and verifications on realistic cases is fundamental. This testing and validation activity extends far beyond the scope of the present report and will be documented in forthcoming publications.

2 Formulation of the SLID model

This Section describes the formulation of the novel SLID contact model.

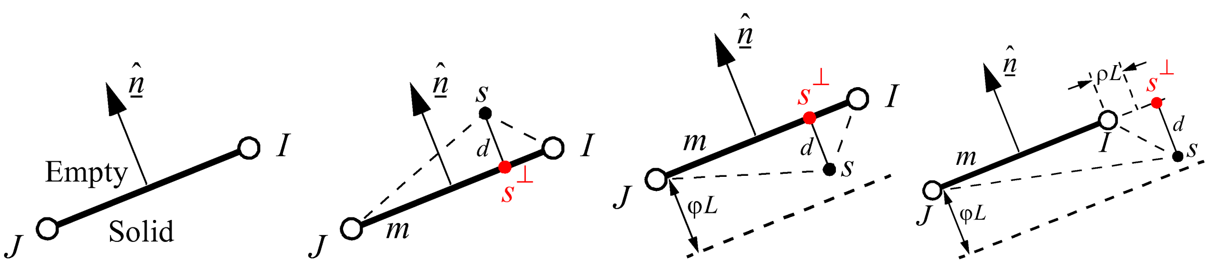
The SLID model uses an arbitrary number of *sliding surfaces*, hence the name. Each sliding surface is defined by a set of *master faces*, which may be thought of as being attached to the target body in the terminology of impact algorithms, and by a set of *slave nodes*, associated with the projectile. Of course, in smooth contact problems the distinction between target and projectile is often arbitrary and irrelevant.

Contact *detection* consists in checking the *penetration* of each slave node into the master faces belonging to the same sliding surface. If penetration occurs, a restoring force (contact force or reaction) is applied to both the master and the slave in order to prevent (further) inter-penetration of the two bodies. The contact *enforcement* part of the algorithm may be based either on a coupled approach using Lagrange multipliers [14], or on a decoupled approach based on penalty forces.

In the following, we concentrate on the detection part of the contact algorithm, i.e. the calculation of the penetrations. The enforcement part of the algorithms is identical to that of the GLIS model and will not be further detailed for brevity. Only the LM version has been implemented for the moment. The interested reader may find more details on this subject in the above mentioned GLIS references [7–13, 15–20, 24] and in [14] as concerns the LM method.

2.1 The 2D case

We start by considering the 2D case, which is much simpler than the 3D case. In 2D, the master faces are 2-node segments. Each segment is oriented by defining a corresponding unit normal $\hat{\boldsymbol{n}}$. The orientation of the normal $\hat{\boldsymbol{n}}$ corresponds to a *clockwise* rotation of the oriented segment IJ by 90°, see Figure 1(a). The normal is pointing *outward* the continuum (solid) body, i.e. towards the empty space. The solid lies to the left of the oriented segment, i.e. an observer walking from I to J sees the solid to his left.



(a) Master face (b) Non-penetrating slave (c) Penetrating slave (d) Non-penetrating slave

Figure 1: Penetration of a slave node into a (continuum) master face in 2D.

Figure 1(b) shows checking the penetration of a slave node s into a master face $m = IJ$ belonging to a continuum element. First we compute the signed distance d of s from m along $\hat{\boldsymbol{n}}$. If $||\vec{IS}|| > ||\vec{JS}||$ then $d = \vec{IS} \cdot \hat{\boldsymbol{n}}$, else $d = \vec{JS} \cdot \hat{\boldsymbol{n}}$.

If $d > 0$ or $d < -\phi L$, then there is no penetration. Here L is the characteristic length of the master face (in 2D simply the length of the segment $L = ||\vec{IJ}||$) and ϕ a small (positive) user-defined coefficient.

Else, we compute $\boldsymbol{s}^{\perp} = \boldsymbol{s} - d\hat{\boldsymbol{n}}$, the projection of s on m along $\hat{\boldsymbol{n}}$. Then we check the position of $s^{\perp}$ with respect to the master face segment IJ. If $s^{\perp}$ lies inside IJ or very slightly outside it, within a distance of ρL from I or J with ρ a small positive user-defined factor, then we have a penetration $p = -d$ (note that $0 \leq p \leq \phi L$). Otherwise, we have no penetration.

Summarizing, a slave node s penetrates into the master face m if it lies within the face's *penetration domain*, i.e. the rectangle shaded in green in Figure 2. The sides of the rectangle are $L(1 + 2\rho)$ along the face and ϕL transversally.

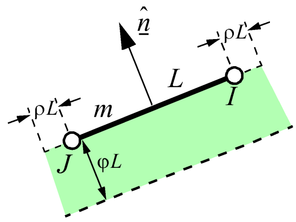


Figure 2: Penetration domain of a (continuum) master face in 2D.

2.1.1 Dealing with multiple penetrations

One should decide what to do if a slave node s penetrates several (more than one) master faces m_1, m_2 etc., all belonging to the same sliding surface. This situation may occur typically when a slave node is close to a master node at a locally curved (convex or concave) master surface, see e.g. Figure 3.

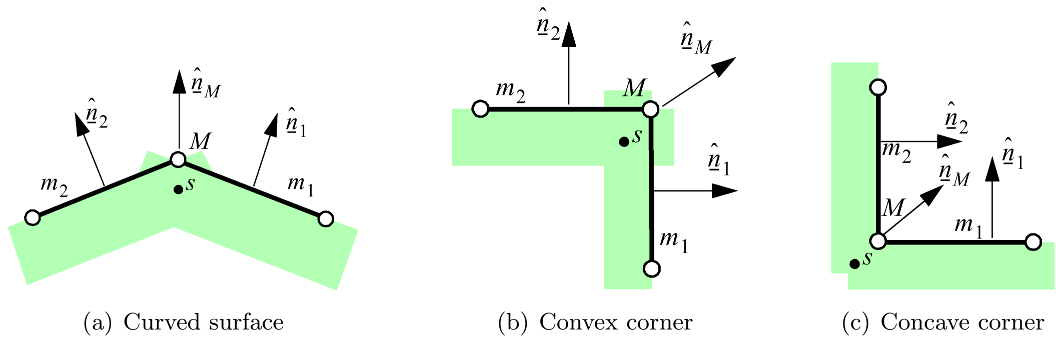


Figure 3: Multiple penetrations in 2D.

Various alternative strategies exist in principle. For example:

1. Retain only one penetration, for example the smallest one, or the largest one. Write only one link, along the direction of the retained penetration.
2. Retain only one penetration, as above, and write only one link, but along some sort of *average normal* $\hat{\boldsymbol{n}}_M$. This normal could be built at each master node by an Assembled Surface Normal (ASN) algorithm already described in other contact models.
3. Retain all detected penetrations and write multiple links, each one along its own (different) normal. Since these links involve all the same slave node s, the slave node would "stick" (i.e., it would be rigidly connected) to the common master node M until contact is broken and rebound starts.

The first technique requires the choice of a single penetration among those that are detected, an operation that looks quite arbitrary and hard to justify in general terms. For example, Wriggers [27] recommends using the penetration according to the minimum node-to-surface distance, which is probably the best method in static or mildly dynamic applications with smooth contact. However, in a situation like that of Figure 3(b) or 3(c), i.e. in the presence of a sharp corner (non-smooth contact surface), this may easily lead to selecting the "wrong" penetrated surface, especially in highly dynamic cases. A better discrimination would require considering the position of the slave node at the previous time step, but this would considerably complicate the algorithm and its implementation in an explicit fast transient context such as that of EPX.

The second technique requires the calculation of the ASNs and a strategy to compute an average penetration direction.

The third technique is the simplest one, but the mentioned sticking phenomenon risks to spoil the results, especially in contact with large relative horizontal velocity and with friction.

So we tentatively select the second technique, although it involves the largest programming effort. Testing will be required to see how the technique behaves in practice and whether it gives rise to any problems.

2.1.2 Dealing with protrusions of the penetration domain

The size of the penetration domain is controlled by the two parameters ϕ and ρ. While ϕ must be greater than 0 in order to provide a chance for penetration detection, the ρ parameter generates a "protrusion" of the penetration domain beyond the nodes of the master face, which can be chosen as 0 or larger.

In some cases the protrusion is beneficial as concerns penetration detection. For example, in the case of a concave sharp corner as shown in Figure 3(c) the protrusion ($\rho > 0$) ensures correct detection of the penetration in the region near the corner itself. Taking $\rho = 0$ in that case would leave a "blind" region where no penetration would be detected.

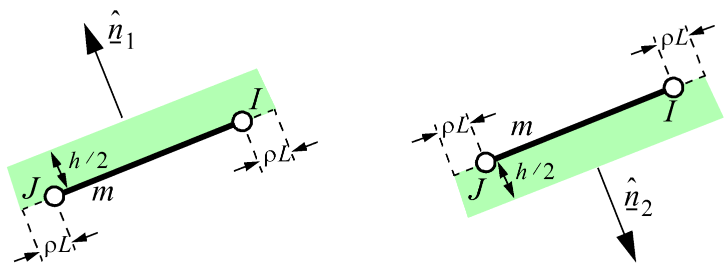
In other cases, however, the protrusions can represent a drawback. Observe the small green zones in Figure 3(a) and especially in Figure 3(b) which extend beyond (outside) the physical target and would give rise to incorrect (non-physical) penetration detections. This effect is small in zones of low curvature but it becomes important near sharp corners as in Figure 3(b).

In principle, one can avoid (or at least greatly reduce) these problems by inspecting the shape (curvature) of the surface near the contacted master node M. If the surface is locally concave, $\rho > 0$ should be retained. When the surface is locally convex, one should set $\rho = 0$. Although making such distinctions is computationally intensive and CPU-time consuming, it is believed to be an essential ingredient for a smooth contact algorithm such as the present one. Practical experimentation will show if there are any drawbacks.

2.1.3 Thick shells

The considerations made so far were appropriate for the case of a master body (target) made of continuum elements. Application to master shells requires some modifications.

Let us consider first the case of thick and moderately thin shells. In 2D a shell element has *two* equal and opposite master faces, as shown in Figure 4. Note that the first penetration domain of the master face, of normal $\hat{\boldsymbol{n}}_1$ (obtained by rotating the oriented segment by 90° clockwise, see Figure 4(a)), is located on the *opposite* side of the element compared with the continuum case, cfr. Figure 2.



(a) First master face (b) Second master face

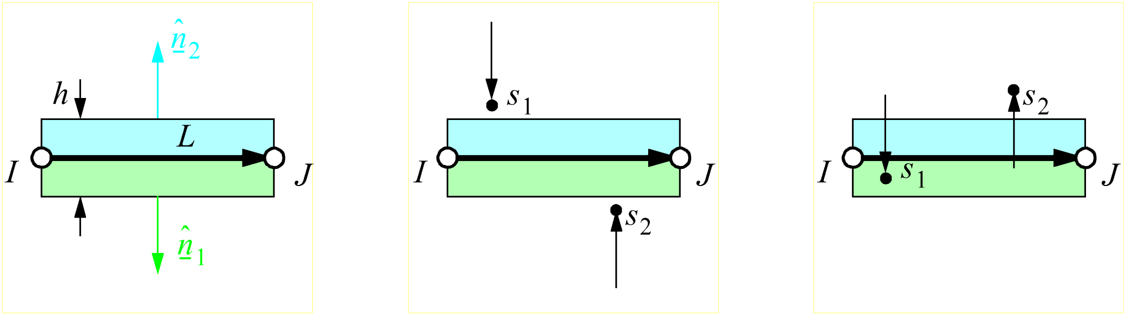
Figure 4: Shell master faces in 2D.

Note also that, unlike in the continuum case, for shells the thickness of the penetration domain has a physical meaning. Instead of taking an arbitrary value ϕL it makes sense to use $h/2$, i.e. half of the physical thickness of the shell. Only when the shell is extremely thin, one might want to replace that with a user-chosen (larger) value, in order to avoid missing some penetrations. Or, a specific strategy could be used in such a case, as described in the next Section.

2.1.4 Dealing with thin shells

When the master surface is composed of *very thin* shells, and/or the relative impact velocity is large, the strategy outlined in the previous Section and based on bilateral contact may fall short. The penetration may either be detected on the "wrong" side of the shell or be completely missed.

The shell geometry (2D for simplicity) is shown in Figure 5(a). By default, *bilateral* contact would be allowed and two contact domains each of thickness $h/2$ would be built, where h is the physical thickness of the shell, assumed here to be small with respect to the shell element's characteristic length ($h << L$). Each domain is shown in a different color. The two normals $\hat{\boldsymbol{n}}_1$ and $\hat{\boldsymbol{n}}_2$ are equal and opposite.



(a) Geometry (b) $t = t^n$ (c) $t = t^{n+1}$

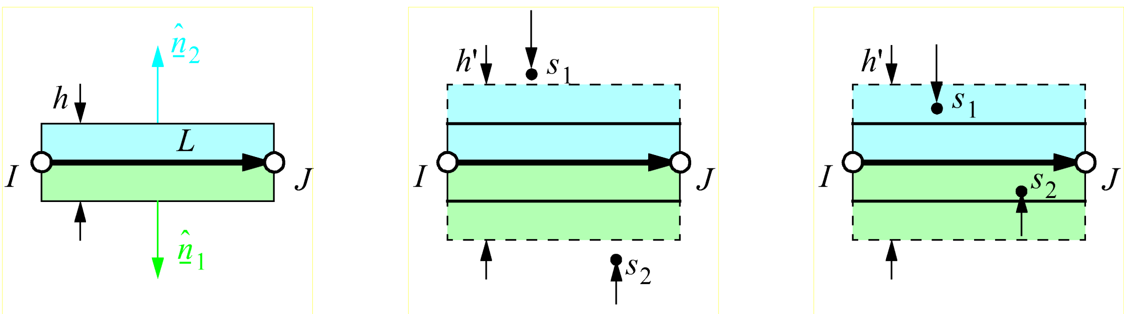
Figure 5: Bilateral contact on thin shell master faces in 2D.

Figure 5(b) shows for example two slave nodes s_1 and s_2 approaching the shell from either side at a generic time step t^n, but not yet penetrating it. Under certain conditions (very small h, high relative velocity, large time increment), at the next time step t^{n+1} one might end up in the situation depicted in Figure 5(c). The slave node s_1 would be found to penetrate the shell on the "wrong" side (lower penetration domain), therefore no contact force would be applied since the slave node would appear as moving "away from" the shell. The slave node s_2 would completely by-pass the shell in just one step, so no contact would be detected either.

To help avoid such situations, two alternative strategies could be considered:

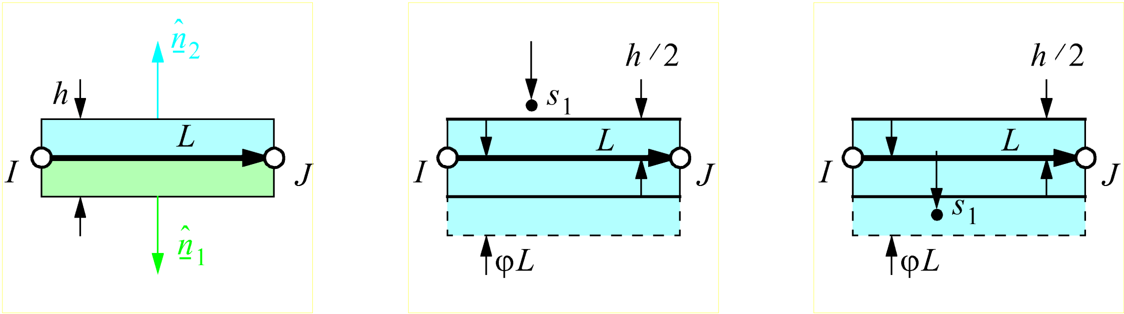
- Define in the input data a *fictitious* thickness $h' > h$ to be used instead of the physical thickness h only for the penetration detection, see Figure 6. This approach may not always be acceptable, since it alters the contact geometry, especially in the case of very tight mechanical assemblies.
- Use *unilateral* instead of bilateral sliding surfaces, see Figure 7, like in the continuum case. Contact would be checked only on one side of the shell. Treating bilateral contact would still be possible, by explicitly defining *two* equal and opposite sliding surfaces. This strategy requires that each master surface be *orientable* and that its mesh be *consistently oriented*, so that its "external" and "internal" side can be uniquely defined. Furthermore, any slave node s must *not* belong to two equal and opposite unilateral shell sliding surfaces, otherwise we would face the same problems as with the standard bilateral shell sliding surfaces.

Despite its practical limitations and requirements, which might not be respected in some geometrically complex applications, the second strategy looks more robust (albeit slightly less general) than the first one and should probably be preferred whenever possible. Note that this strategy is similar to the approach taken for the `GLIS` contact model where, for shells used as masters, the user must define the "external" or the "internal" direction.



(a) Geometry (b) $t = t^n$ (c) $t = t^{n+1}$

Figure 6: Use of fictitious thickness for bilateral shell contact detection.



(a) Geometry (b) $t = t^n$ (c) $t = t^{n+1}$

Figure 7: Unilateral shell master sliding surfaces.

The unilateral shell master surface in Figures 7(b) and 7(c) is shown only for the "upper" (cyan) penetration domain. A similar and opposite "lower" (green) penetration domain might also be activated by defining a second master surface. Each penetration domain would have a total thickness $H = (h/2) + \phi L$ where ϕ is the coefficient already defined for the continuum case.

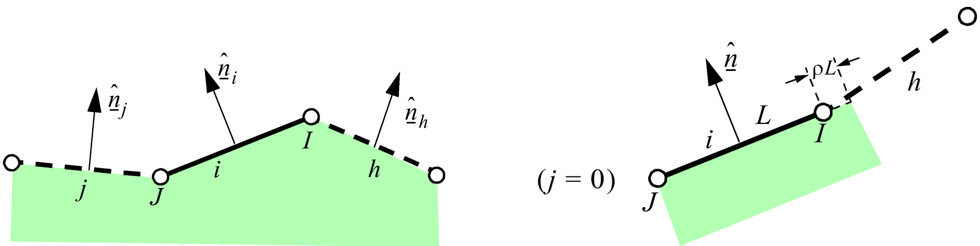
Unilateral master surfaces may be activated by selecting the `UNIL` and the `REVE` optional keywords, see [1] for details. These options might allow to treat critical cases, which should only occur rarely if the time increment is properly chosen, but may not be completely excluded in complex applications. These features are experimental for the moment and only extensive testing will allow to determine their practical usefulness.

2.1.5 Master face protrusions for continuum meshes

In a 2D continuum mesh we assume that a master surface is simply connected, in the sense that it has *no branches*. The surface is a polyline without bifurcations. If the line is not closed, it can be traversed starting at one extremity and going along it until the other extremity. If it is closed, one can start at any node and go along it until the same node is reached again.

This assumption allows us to *orient* the line, i.e. to consistently orient the master faces forming the master surface (master line in 2D) so that the solid body is always "to the left" of the line.

Under these assumptions, each master face i has (up to) two *adjacent* master faces, a *first* adjacent face h, attached to the first side (first node) of the face) and a *second* master face j, attached to the second side (second node), see Figure 8(a). Either h or j (or both) may not exist, and in that case one sets them to 0.

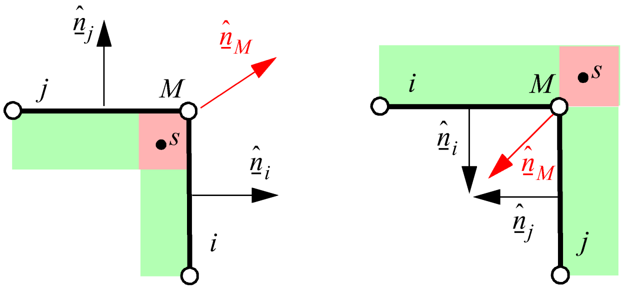


(a) Adjacents (b) Protrusion

Figure 8: Master faces protrusion in 2D for continuum.

If a master face i has no adjacent at one of its *sides* (nodes, in 2D), then it should not protrude on that side, see e.g. node J in Figure 8(b), in order to avoid spurious penetration detection. If there is an adjacent, we may or may not want to activate the protrusion, depending on the relative orientation of the two master faces. If the two faces form a *convex* corner at the common node, as shown in Figure 3(b), then we do not activate the protrusion. Instead, if the corner is *concave* protrusions are beneficial and should be activated, see Figure 3(c).

The situation is summarized in Figure 9 for a right (90°) corner. If the corner is convex as in Figure 9(a) the protrusions would create two spurious penetration zones outside the solid body, so we do not activate them. Near the common node M, a zone common to both master faces (shown in red) is created by the superposition of the two master face penetration domains. If a slave node s enters in this zone it penetrates both i and j. In this case we may use $\hat{\boldsymbol{n}}_i$ and $\hat{\boldsymbol{n}}_j$ to construct (on the fly) an *average normal* $\hat{\boldsymbol{n}}_M$. Then, *only one* contact constraint is imposed, along $\hat{\boldsymbol{n}}_M$.



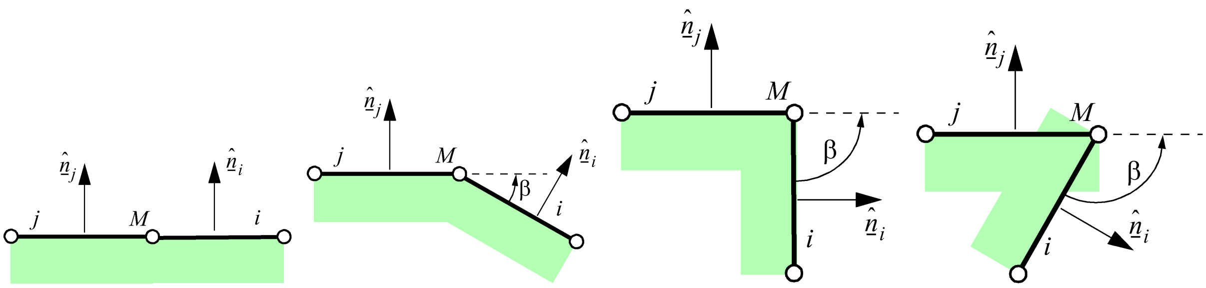
(a) Convex corner (b) Concave corner

Figure 9: Protrusions vs. corners for a continuum mesh.

If the corner is concave as in Figure 9(b) the protrusions are needed in order to create the red penetration zone near the common node M, so we activate them. Like in the case of a convex corner, if a slave node s enters in this zone it penetrates both i and j and we may use $\hat{\boldsymbol{n}}_i$ and $\hat{\boldsymbol{n}}_j$ to construct the average normal $\hat{\boldsymbol{n}}_M$ and to impose only one contact constraint, along $\hat{\boldsymbol{n}}_M$.

Figure 10 summarizes the possible situations for a convex corner. We denote β the angle between the two master faces i and j, which is also the angle between the normals $\hat{\boldsymbol{n}}_i$ and $\hat{\boldsymbol{n}}_j$. More precisely, β is the angle (less than π in absolute value) that face i must be rotated in order to become aligned with face j, which is also the angle that the normal $\hat{\boldsymbol{n}}_i$ must be rotated in order to become aligned with the normal $\hat{\boldsymbol{n}}_j$. The β angle is assumed positive if anti-clockwise.

As shown in Figure 10(a), the case $\beta = 0$ corresponds to a flat master surface (no corner). By progressively increasing the angle β ($\beta > 0$) we obtain the next pictures. The case of $\beta = \pi/2$ shown in Figure 10(c) is a limit. In fact, by continuing to increase β we obtain spurious penetration zones (on the wrong side of the line with respect to the solid body) as shown in Figure 10(d), and this even *without* activating protrusions.



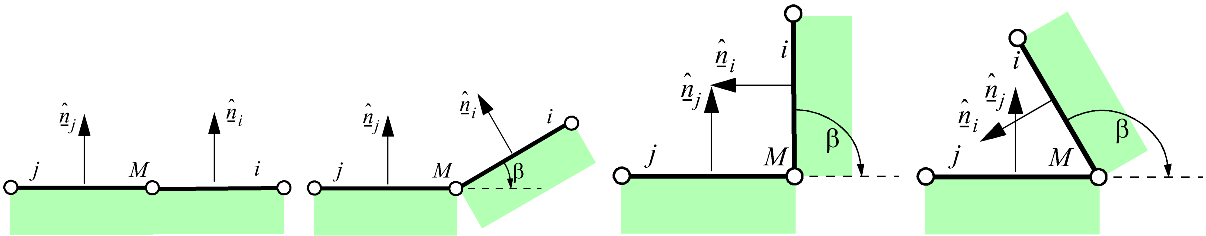
(a) $\beta = 0$ (b) $0 < \beta < \pi/2$ (c) $\beta = \pi/2$ (d) $\pi/2 < \beta < \pi$

Figure 10: Convex corner between two adjacent continuum master faces.

The case of a concave corner ($\beta < 0$) is illustrated in Figure 11. It is clear that by activating protrusions one may catch penetrations into the "blind zone" near the corner, but only until $\beta = -\pi/2$. It seems therefore that extreme situations with either $\beta > \pi/2$ or $\beta < -\pi/2$ should be avoided. The code should give at least a warning in such cases.

A procedure to determine whether the corner is convex or concave might be as follows. The scalar product of the two (unit) normals $s = \hat{\boldsymbol{n}}_i \cdot \hat{\boldsymbol{n}}_j$ is equal to $\cos\beta$. This gives the amplitude of the angle, but not its sign.

One way to determine the sign of the angle is to use the vector product: $\boldsymbol{v} = \hat{\boldsymbol{n}}_i \times \hat{\boldsymbol{n}}_j$. Then



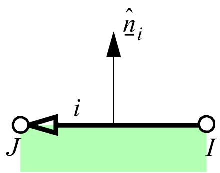
(a) $\beta = 0$ (b) $-\pi/2 < \beta < 0$ (c) $\beta = -\pi/2$ (d) $-\pi < \beta < -\pi/2$

Figure 11: Concave corner between two adjacent continuum master faces.

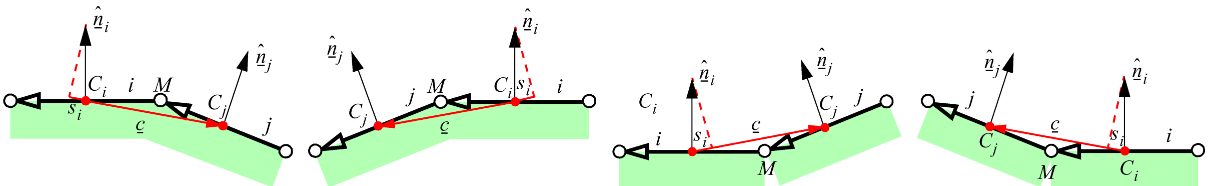
one inspects the component of $\boldsymbol{v}$ along the z axis (which is actually the only non-zero component in the 2D case). If $v_z > 0$ then $\beta > 0$ (convex corner), else $\beta < 0$ (concave corner). In other words, $\operatorname{sign}\beta = \operatorname{sign} v_z$.

Note that this holds if the master face i (current face) *precedes* the master face j (adjacent face) along the oriented master surface, as shown in Figures 10 and 11, i.e. when j is the *second* adjacent to i. In the opposite case, i.e. when the master face i *follows* the master face j along the oriented master surface, i.e. when j is the *first* adjacent to i, then the amplitude of β is still given by s (since the scalar product is commutative), but $\operatorname{sign}\beta = -\operatorname{sign} v_z$ (since the vector product is anti-commutative).

The procedure described so far is appropriate for 2D meshes. In 3D a more general procedure (which can be applied also in 2D if so desired) is as follows. With reference to Figure 12 which shows the situation in 2D for ease of drawing, let us consider first the case of continuum meshes. Let i denote the current master face and $\hat{\boldsymbol{n}}_i$ the unit normal to the face. As already mentioned, the normal is oriented outwards (towards the empty space). Let j be another master face, adjacent to i at node M.



(a) Continuum face



(b) $s_i < 0$: convex (c) $s_i < 0$: convex (d) $s_i > 0$: concave (e) $s_i > 0$: concave

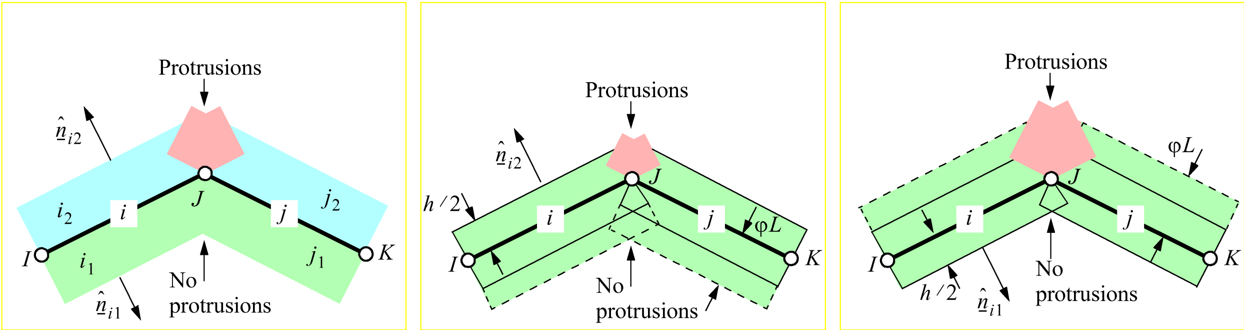
Figure 12: Local curvature of the master surface for a continuum.

We build up the centroids of the two faces C_i, C_j (simply as the average position of each face's nodes) and the vector $\boldsymbol{c} = \overrightarrow{C_iC_j}$ oriented from i towards j. Next, we evaluate the scalar product $s_i = \hat{\boldsymbol{n}}_i \cdot \boldsymbol{c}$. For the continuum case, one can see from Figure 12 that the master surface, *as seen from the empty space* from where a penetrator slave node might arrive, is *convex* if $s_i < 0$, while it is concave if $s_i > 0$. This holds irrespective of the position of face j with respect to i, i.e. for j either following or preceding i along the oriented master line in 2D.

It is easily seen that the same rule holds also in 3D for a couple of master surfaces i and j which are adjacent to each other along a common edge MN.

2.1.6 Master face protrusions for shell meshes

In a 2D shell mesh the situation concerning master face protrusions is schematized in Figure 13. We consider two adjacent shells $i = IJ$ and $j = JK$. By examining first the standard case of bilateral sliding surfaces of Figure 13(a), the two shell elements produce four master faces i_1, i_2, j_1 and j_2.



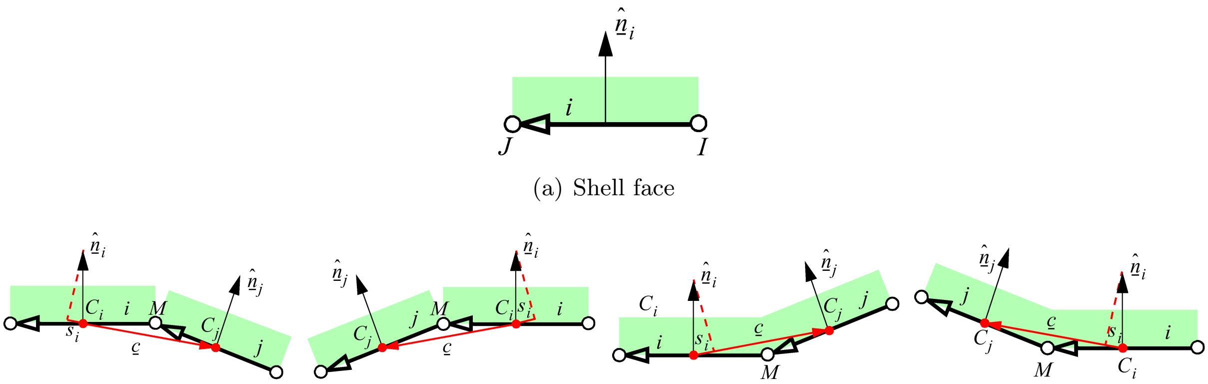
(a) Bilateral (b) Unilateral convex (c) Unilateral concave

Figure 13: Master face protrusions in a 2D shell mesh.

At nodes with no adjacent, such as I and K, no protrusions are activated. At internal nodes such as J, protrusions may or may not be activated depending on the local curvature of the shell surface, exactly like in the continuum case.

However, here the rule is the *opposite* with respect to the continuum case, cfr. Figure 9. Protrusions (drawn in red) should be activated on the *convex* side of the shell (in cyan), while they should *not* be activated on the *concave* side of the shell (in green). The term convex or concave refers here to how the shell (master surface) appears to a a slave node approaching the surface from each side of the shell. Thus a penetrator (slave node) approaching the shell from above in Figure 13, i.e. from the cyan zone, sees the shell as convex and requires protrusions in order to detect penetrations in the red part, while one approaching the shell from below (green zone) sees the shell as concave and requires no protrusions to detect penetration.

As it can be seen by comparing Figure 14 to Figure 12, in the case of shells exactly the same procedure as for the continuum can be applied to determine the convexity or concavity of the master surface.



(a) Shell face

(b) $s_i < 0$: convex (c) $s_i < 0$: convex (d) $s_i > 0$: concave (e) $s_i > 0$: concave

Figure 14: Local curvature of the master surface for a shell.

The shell master surface, *as seen from the empty space* from where a penetrator slave node might arrive, is *convex* if $s_i < 0$, while it is concave if $s_i > 0$. This holds irrespective of the position of face j with respect to i, i.e. for j either following or preceding i along the oriented master line in 2D. And, like for continuum, the same rule holds also in 3D for a couple of shell master surfaces i and j which are adjacent to each other along a common edge MN.

However, as already noted, the activation or not of protrusions depending on the sign of the local curvature is *opposite* for shells with respect to continuum.

Consider now the case of unilateral shell sliding surfaces introduced in Section 2.1.4 (Figure 7), which is more appropriate for very thin shells. We show only one (unilateral) sliding surface for simplicity of drawing but of course a second and opposite surface might exist as well if one wants to treat contact on both sides of the shell. Figure 13(b) illustrates the situation to deal with slave nodes (possible penetrators) approaching the shell from above, which see the shell as locally *convex*. Figure 13(c) illustrates the situation for slave nodes approaching the shell from below, which see the shell as locally *concave*. One sees that in both cases it is necessary to activate protrusions (shown in red) on the convex side of the shell, i.e. in the penetrated zone of thickness $h/2$ in the case of the first Figure, in the zone of thickness ϕL in the other case.

2.2 Building the adjacent master faces

As seen above, the identification of adjacent master faces is fundamental in order to activate or not the protrusions for the search of penetrations. Therefore, a carefully designed procedure for such identification must be set up.

2.2.1 Master faces and their sides

As shown in Figure 15, each master *face* has a number of *sides*. In 2D faces are 2-node segments and their sides are the nodes. A face IJ has two one-node sides, I and J, see Figure 15(a). In 3D faces are either 3-node triangles or 4-node quadrangles and their sides are the edges. A 3-node face IJK has three two-node sides, IJ, JK and KI, see Figure 15(b). A 4-node face $IJKL$ has four two-node sides, IJ, JK, KL and LI, see Figure 15(c).

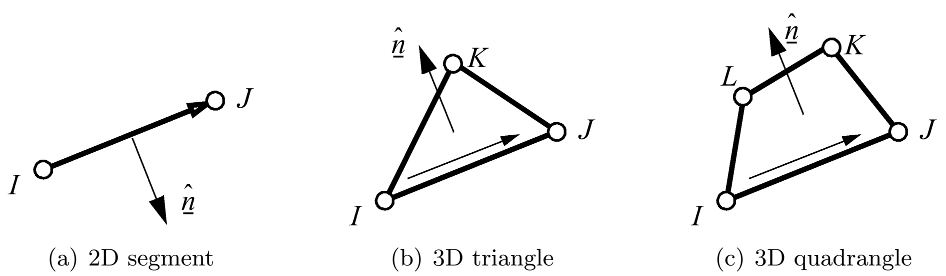


Figure 15: Master faces and their sides.

2.2.2 Master faces adjacency relation

Two faces i and j are *adjacent* to each other if they share the same side, as shown in Figure 16. For example, in 2D if face $i = IJ$ has face $j = JK$ as adjacent on side J, then face j has face i as adjacent on side J, see Figure 16(a). In 3D if face $i = IJK$ has face $j = MJIL$ as adjacent on side IJ, then face j has face i as adjacent on side JI, see Figure 16(b).

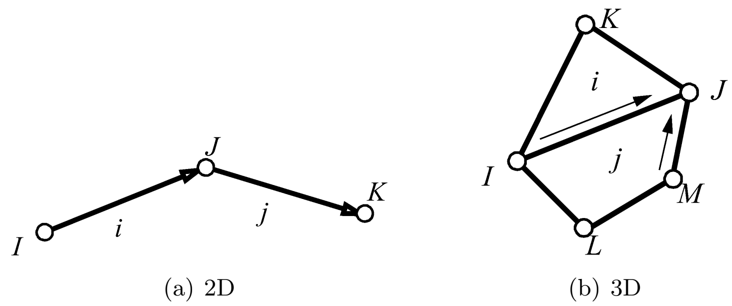


Figure 16: Adjacent faces.

2.2.3 Continuum meshes

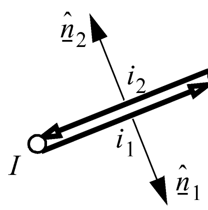
We assume that each master surface made of *continuum* elements is defined in such a way that each one of master faces has *at most one* adjacent (i.e. either no adjacent, or one adjacent) on each one of its sides.

Therefore, in 2D each *master node* belongs to either one or two master faces of the same sliding surface. Similarly, in 3D each *couple* of master nodes forming a face side belongs to either one or two master faces of the same sliding surface.

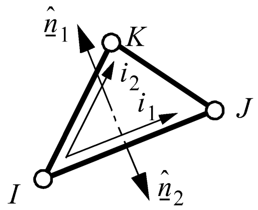
2.2.4 Shell meshes

In master surfaces composed of *shell* elements the situation is more complex, because each shell master element generates two *identical but opposite* master faces. The two faces share the same nodes, but have different (opposite) orientations. That is, the nodes of the second face form a *counter-cyclic permutation* of the nodes of the first face.

In 2D a shell i of nodes I, J generates two master faces $i_1 = IJ$ and $i_2 = JI$, of normals $\hat{\boldsymbol{n}}_1$ and $\hat{\boldsymbol{n}}_2 = -\hat{\boldsymbol{n}}_1$, as shown in Figure 17(a). In 3D a triangular shell i of nodes I, J, K generates two master faces $i_1 = IJK$ and $i_2 = IKJ$, of normals $\hat{\boldsymbol{n}}_1$ and $\hat{\boldsymbol{n}}_2 = -\hat{\boldsymbol{n}}_1$, as shown in Figure 17(b) (and similarly for the quadrangular shell).



(a) 2D



(b) 3D

Figure 17: Shell master faces.

Like in the case of continuum, we assume for simplicity that a shell master surface has *no joints* (no bifurcations). Note that this does *not* prevent the structure to be modeled from having bifurcations, but in that case the user *must* define *several* master surfaces, each one forming a continuous surface without bifurcations.

Under these circumstances, each shell master node in 2D belongs to either two or four master faces of the same master surface, stemming from either one or two master elements, respectively. Similarly, in 3D each couple of master nodes forming a face side belongs to either two or four master faces of the same master surface, stemming from either one or two master elements, respectively.

The various possibilities for 2D shells are sketched in the example of Figure 18. Node I belongs to the two faces i_1 and i_2, which stem from the same shell element $i = IJ$. Therefore, face i_1 has no adjacent on node I, and face i_2 has no adjacent on node I.

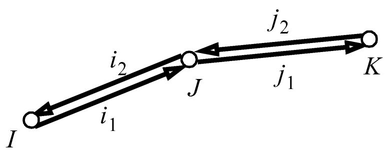


Figure 18: Shell adjacents in 2D.

Node J belongs to the four faces i_1, i_2 (stemming from shell element i) and j_1, j_2 (stemming from shell element j). Therefore, face i_1 (for example) has three *candidate* adjacents on node J, of which one and only one must be retained:

- i_2 is discarded because it stems from the same element as i_1.
- j_2 is discarded because, although it stems from a different element, it has J as its second node exactly like face i_1.

- j_1 is retained as the adjacent, since it stems from a different element than that of i_1 and J is its first node, while J is the second node for i_1.

Similarly, we find that i_2 has j_2 as adjacent on node J. And, due to reciprocity of the adjacency condition, j_1 has i_1 as adjacent on J while j_2 has i_2 as adjacent on J.

2.3 Treatment of symmetries

When contact is combined with symmetry conditions, special treatment is needed for the nodes subjected to such conditions. The strategy adopted is similar to that used for the GLIS contact model, see report [24].

2.3.1 The 2D case

In 2D, let N_s be the number of *distinct* (i.e. independent) symmetry conditions acting on a (penetrating) slave node. Then:

- If $N_s = 0$ the slave node is not subjected to any symmetry conditions and the normal treatment of contact is applied.
- Else if $N_s > 1$ then the slave node is already completely blocked by the symmetry conditions, so there is no need to treat contact for this node.
- Else $N_s = 1$. We impose a single link, along a corrected contact normal which, in this case, is directed along the tangent to the symmetry plane. even in the case of friction. Let $\hat{\boldsymbol{n}}'_c$ denote the (raw, un-corrected) contact normal resulting from the penetration calculations and let $\hat{\boldsymbol{n}}_s$ denote the normal to the symmetry plane. We first compute the scalar product $s = \hat{\boldsymbol{n}}'_c \cdot \hat{\boldsymbol{n}}_s$. Then the corrected contact normal (not normalized) is $\boldsymbol{n}^*_c = \hat{\boldsymbol{n}}'_c - s\hat{\boldsymbol{n}}_s$. Finally, the corrected unit contact normal is obtained as $\hat{\boldsymbol{n}}_c = \boldsymbol{n}^*_c/||\boldsymbol{n}^*_c||$.

2.3.2 Protrusions on symmetric nodes

If a 2D master face has a node subjected to a symmetry condition, then protrusion is activated on that node although there is no adjacent master face on the node.

2.4 Treatment of multiple penetrations

As anticipated in Section 2.1.1, when a slave node penetrates multiple (two or more) master surfaces belonging to the same master surface, a special treatment is applied, which is now described in full detail:

- Only one contact constraint is written. The nodes involved are the slave node (common to all penetrations in this group) and the nodes of the master face involved in the *first* penetration. This choice is arbitrary but in order to make the result as independent as possible from the mesh numbering we round-off the normalised coordinates of the penetration (see last point below).
- The normal along which the constraint is imposed is obtained as the arithmetic mean of the normals of the various penetrations (i.e. the normals of the various penetrated master faces).
- The penetration is obtained as the arithmetic mean of the various penetrations.
- Finally, the normalised coordinates ξ and η of the (first) penetration are rounded off so that the penetrated point will lie on the edge between the penetrated master faces, which are assumed to be adjacent to one another.
  - In 2D only ξ is relevant. We compute $\epsilon = |1 - |\xi||$, then if $\epsilon \le \rho$ we set $\xi = \mathrm{sign}\,(1, \xi)$, i.e. we round-off ξ to ± 1.
  - In 3D for a triangular master face we proceed as follows. If $|\xi| \le \rho$ then: we set $\xi = 0$ and, if $\eta > 1$, we set $\eta = 1$. If $|\eta| \le \rho$ then: we set $\eta = 0$ and, if $\xi > 1$, we set $\xi = 1$. Next, we compute $\zeta = 1 - \xi - \eta$. If $|\zeta| \le \rho$ then: if $\xi \ge \rho$ and $\xi \ge \rho$, we set $\xi = \xi + \zeta/2$ and $\eta = \eta + \zeta/2$. This corresponds to projecting the penetration point onto the first side of the triangle and ensures that after the round-off it will be $\zeta = 1 - \xi - \eta = 0$ in this case.

– In 3D for a quadrangular master face we compute $\epsilon_\xi = |1 - |\xi||$, then if $\epsilon_\xi \leq \rho$ we set $\xi = \text{sign}(1, \xi)$, i.e. we round-off ξ to ± 1. Then we compute $\epsilon_\eta = |1 - |\eta||$ and, if $\epsilon_\eta \leq \rho$, we set $\eta = \text{sign}(1, \eta)$, i.e. we round-off η to ± 1.

2.5 Search optimization

An important aspect for medium and large applications is the optimization of the search for penetrations. The brute force strategy of checking each slave node for penetration into every master face would rapidly become too expensive if complex geometrical calculations have to be done.

In the case of other contact algorithms, namely the pinball (`PINB`) and also the `GLIS` models, optimization is achieved by a fast bucket-search strategy based on the subdivision of space into equally sized boxes (or buckets). Then, each penetrator entity (either a pinball or a slave node) is checked only against the penetratable entities (either another pinball or a master face) which are contained either in the same bucket or in one of the directly adjacent buckets (for a total of 9 buckets in 2D or 27 buckets in 3D space).

However, implementing the bucket strategy is a bit laborious. So it is decided, at least in this first formulation of `SLID`, to apply a much simpler bounding box (bbox) strategy. If a slave node lies outside the bounding box (bbox) of a master face (to be defined more precisely below), a condition that can be checked rather quickly, then the algorithm assumes that there is no penetration and the more complicated geometrical calculations are skipped. This strategy is less efficient than the bucket search strategy in large applications, but it gives already a considerable speed up with respect to the brute force algorithm. The bbox-based strategy is as follows. At each time step:

- For each master face, compute the *true* bounding box, i.e. the minimum and maximum global coordinates x_i of the face's nodes J: $x_{i,\min} = \min_J(x_{iJ})$, $x_{i,\max} = \max_J(x_{iJ})$.
- Compute the center of the face's true bbox: $x_{iC} = (x_{i,\min} + x_{i,\max})/2$.
- Compute the maximum side of the face's true bbox: $d = \max_i(x_{i,\max} - x_{i,\min})$.
- Increment the maximum side to take into account the possible presence of protrusions: $D = d \cdot \max(1 + 2\rho, \phi)$.
- Compute the *enlarged* face's bbox to be used for the preliminary penetration checks: $X_{i,\min} = x_{iC} - (D/2)$, $X_{i,\max} = x_{iC} + (D/2)$. So the enlarged bbox is a regular cube of side D concentric with the true bbox.

Each slave node is still checked for penetration into each master face, like in the brute force algorithm. However, before doing the complex geometrical calculations, the node's current position is checked against the face's enlarged bbox. If the node lies outside the enlarged bbox, no penetration can occur and the rest of the geometrical calculations is skipped for this node.

2.6 Controlling the thickness of the penetration domain

An important parameter of the sliding contact algorithm is the thickness of the penetration domain associated with each master surface. By default the code tries to estimate a convenient thickness depending upon the nature of the master face. For a continuum master face the default thickness is related to the size (characteristic length) of the face itself, while for a shell master face it is related to the physical thickness of the shell structure.

However, the default thickness is not always the optimal one, depending on the nature of the problem. If the thickness is too small some contact penetrations might be overlooked, especially in the case of thin shells, large local curvature (small curvature radius) and high relative velocity of the contacting parts. If the thickness is too large there might be geometric problems in tightly packed mechanical assemblies.

Therefore, it is sometimes desirable to have more control on the choice of the actual thickness. Two optional input parameters `PHI` (ϕ) and `THIC` (θ) may be used to control the thickness H of the penetratable domain. Their effect is slightly different depending on the nature of the master surface.

2.6.1 Continuum master faces

For a *continuum* master face the code builds up one penetratable domain per master face and the precise meaning of ϕ and θ is summarized and illustrated in Table 1.

By default (neither ϕ nor θ specified) the code takes $H = 0.05L$ where L is the characteristic length of the master face. Thus, H varies from face to face in general. The default value of ϕ (0.05) may be overridden by specifying $\phi > 0$ in the input, so that the code takes $H = \phi L$.

To set a constant thickness H of the penetratable domain over the whole master surface, the θ parameter may be specified and the code sets $H = \theta$. In this case, specifying also the ϕ parameter is invalid.

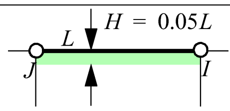
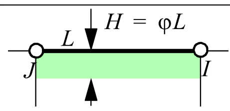
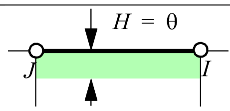
PHI (ϕ)	THIC (θ)	Effect	Illustration
—	—	$\phi = 0.05$ (default), $H = \phi L$	
> 0	—	$H = \phi L$	
—	> 0	$H = \theta$	
> 0	> 0	Invalid combination	—

Table 1: Meaning of PHI and THIC for continuum master faces.

2.6.2 Bilateral shell master faces

For a *bilateral shell* master face the code builds up two equal and opposite penetratable domains and the precise meaning of ϕ and θ is summarized and illustrated in Table 2, where the two equal and opposite penetration domains are shown in different colors for clarity.

By default (neither ϕ nor θ specified) the code takes $H = h/2$ where h is the thickness (EPAI) that has been assigned to the master face's shell element. Thus, H follows the physical properties of the shell and varies from face to face in general. By specifying the value of ϕ the code takes $H = \phi L/2$. In this way the thickness may be made independent of the physical shell thickness h and proportional to the face's characteristic length L, like for a continuum master face.

To set a constant thickness H of the penetratable domain over the whole master surface, the θ parameter may be specified and the code sets $H = \theta/2$. In this case, specifying also the ϕ parameter is invalid.

2.6.3 Unilateral shell master faces

For a *unilateral shell* master face the code builds up just one penetratable domain and the precise meaning of ϕ and θ is summarized and illustrated in Table 3.

By default (neither ϕ nor θ specified) the code takes $H = h/2$ where h is the thickness (EPAI) that has been assigned to the master face's shell element. Thus, H follows the physical properties of the shell and varies from face to face in general. By specifying the value of ϕ the code takes $H = \phi L/2$. In this way the thickness may be made independent of the physical shell thickness h and proportional to the face's characteristic length L like for a continuum master face.

By specifying θ the penetratable domain is composed of two parts. If ϕ is omitted, The first part faces the incoming slave node and has a (variable) thichness $h/2$ (i.e. half the physical thickness of the shell) like in the default case. The second part, on the opposite side of the shell, has a (constant) thickness θ. Thus the total thickness of the penetratable domain is $H = h/2 + \theta$. The effect is adding an extra thickness θ to the default behaviour. This may be useful in the case of very thin shells (h

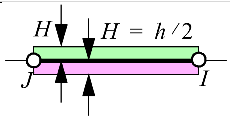
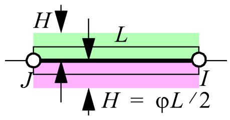
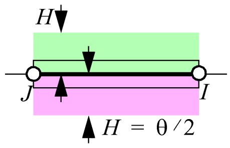
PHI (ϕ)	THIC (θ)	Effect	Illustration
—	—	$H = h/2$	
> 0	—	$H = \phi L/2$	
—	> 0	$H = \theta/2$	
> 0	> 0	Invalid combination	—

Table 2: Meaning of PHI and THIC for bilateral shell master faces.

very small) in order to avoid missing some penetrations. To distinguish this particular case from the next one (where ϕ may be 0), ϕ is automatically set to the special value -1.0.

Finally, by specifying also ϕ in addition to θ the thickness of the first part is set constant and equal to $\phi/2$ so that the total thickness becomes constant and equal to $H = \phi/2 + \theta$. Note that this is the only case in which it is possible to explicitly specify $\phi = 0$, thus getting $H = \theta$ and completely eliminating the first part of the penetratable domain, like if the shell was a continuum.

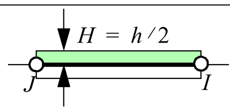
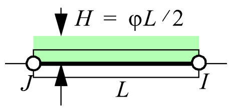
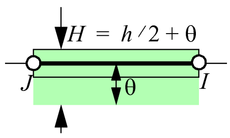
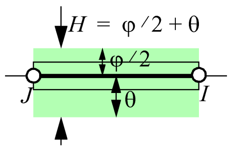
PHI (ϕ)	THIC (θ)	Effect	Illustration
—	—	$H = h/2$	
> 0	—	$H = \phi L/2$	
—	> 0	$H = h/2 + \theta$	
≥ 0	> 0	$H = \phi/2 + \theta$	

Table 3: Meaning of PHI and THIC for unilateral shell master faces.

3 Basic numerical examples

A series of simple numerical examples are performed in order to check the new contact model described in the previous Sections. When possible, solutions are compared with those obtained with other contact models available in EPX, namely the pinball model `PINB` or the sliding surface model `GLIS`.

3.1 Basic continuum tests without friction

We start by some basic tests using continuum meshes without friction. The calculations performed are summarized in Table 4.

Input file	Mesh	Description	t_{fin} (ms)	Steps	CPU (s)
SLID03	1 Q42L 1 PMAT	2D impact of mass on a continuum	3.0	28	0.1
SLIDL3	1 Q42L 1 PMAT	Same as 03 but `LIAJ ALPH 0.0`	3.0	28	0.2
SLID04	1 Q42L 1 PMAT	Same as 03 but `PINB`	3.0	28	0.2
SLID06	1 PR6 1 PMAT	3D impact of mass on a continuum	3.0	34	0.2
SLID07	1 PR6 1 PMAT	Same as 06 but `PINB`	3.0	34	0.1
SLID08	1 PR6 1 PMAT	Same as 06 but `GLIS`	3.0	34	0.2
SLID09	5 Q42L	2D impact continuum/continuum	3.0	28	0.1
SLID10	5 Q42L	Same as 06 but `PINB` with `ASN`	3.0	28	0.1
SLID11	2 Q42L 1 PMAT	2D impact mass/continuum (convex)	3.0	27	0.1
SLID12	2 Q42L 1 PMAT	2D impact mass/continuum (concave)	3.0	27	0.1
SLID13	6 Q42L	2D impact continuum/continuum	3.0	28	0.1
SLID26	3 Q42L	Idem 13 but 1/2 model with symmetry	3.0	28	0.1
SLID29	2 PR6 1 PMAT	3D impact of mass on a continuum	3.0	34	0.2
SLID31	4 PR6 1 PMAT	Idem 29 but with 4 prisms	3.0	48	0.1
SLID33	4 PR6 1 PMAT	Idem 31 but concave master surface	3.0	48	0.3
SLID34	4 PR6 1 PMAT	Idem 32 but change element topology	3.0	48	0.3
SLID35	4 PR6 1 PMAT	Idem 31 but convex master surface	3.0	48	0.2
SLID46	1 CUB8 1 PMAT	3D impact of mass on a continuum	3.0	28	0.2
SLID47	4 CUB8 1 PMAT	Idem 46 but with 4 hexahedra	3.0	54	0.3
SLID49	4 CUB8 1 PMAT	Idem 47 but convex master surface	3.0	55	0.3
SLID50	4 CUB8 1 PMAT	Idem 47 but concave master surface	3.0	55	0.3
SLID53	2 CUB8 1 PMAT	Idem 47 but with a symmetry plane	3.0	54	0.2
SLID54	1 CUB8 1 PMAT	Idem 47 but with two symmetry planes	3.0	54	0.2

Table 4: Basic continuum numerical examples without friction.

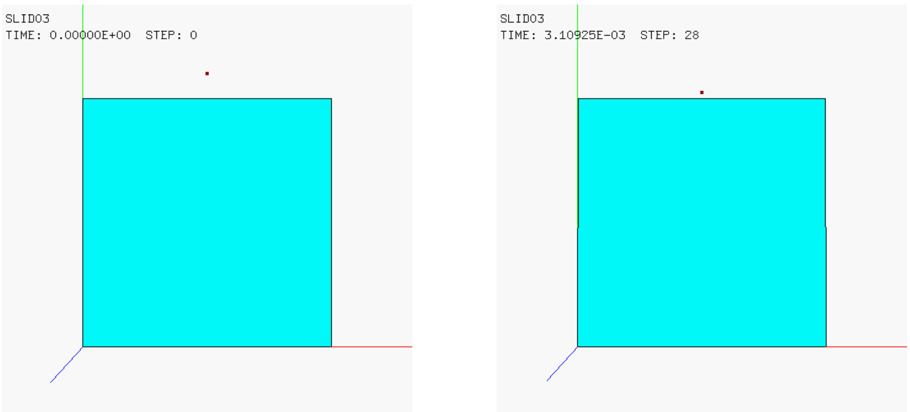
3.1.1 Case SLID03

This test considers a concentrated mass, represented by a PMAT element, impacting on a 2D continuum body, discretized with just one quadrilateral element of type Q42L. The material is elastic. The input file reads:

```
SLID03
ECHO
!CONV win
DPLA LAGR
GEOM LIBR POIN 5 Q42L 1 PMAT 1 TERM
 0 0  1 0
 0 1  1 1
 0.5 1.1
 1 2 4 3
 5
COMP EPAI 1.0 LECT tous TERM
     GROU 2 'targ' LECT 1 TERM
            'proj' LECT 2 TERM
     EPAI 1.0 LECT targ TERM
          0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 12 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 3 4 TERM
                 NSLA LECT 5 TERM
INIT VITE 2 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   5.00000E-01  5.50000E-01  3.75000E+00
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.50000E-01  0.00000E+00
!RSPHERE:  7.50000E-01
!RADIUS :  3.75000E+00
!ASPECT :  1.00000E+00
!NEAR   :  2.92500E+00
!FAR    :  5.25000E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
```

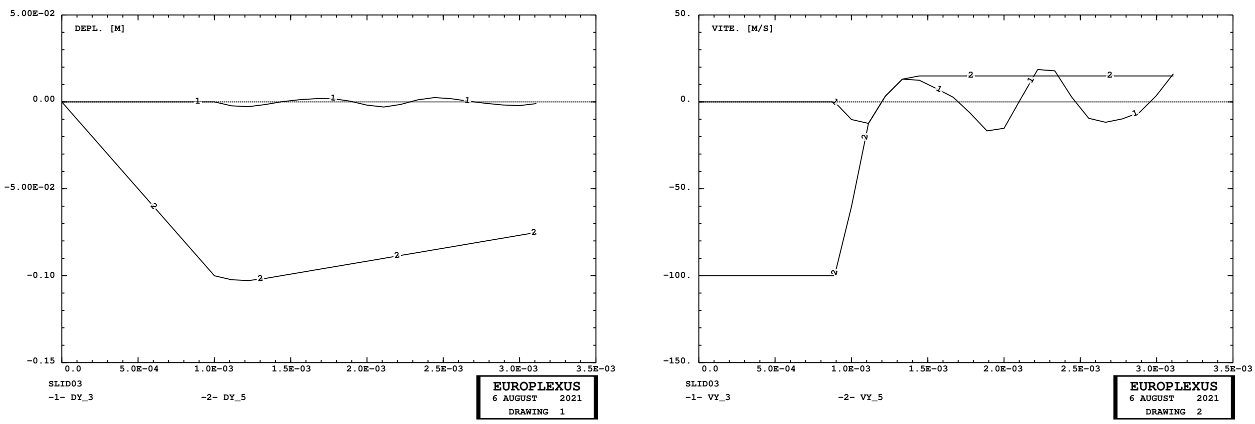
```
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 29 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 27 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR  2 'dy_5' DEPL COMP 2 NOEU LECT 5 TERM
COUR 11 'vy_3' VITE COMP 2 NOEU LECT 3 TERM
COUR 12 'vy_5' VITE COMP 2 NOEU LECT 5 TERM
COUR 21 'y_3'  COOR COMP 2 NOEU LECT 3 TERM
COUR 22 'y_5'  COOR COMP 2 NOEU LECT 5 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -7.51287E-02 TOLE 1.E-2
     COUR 12 REFE  1.48998E+01 TOLE 1.E-2
     COUR 22 REFE  1.02487E+00 TOLE 1.E-2
FIN
```

Figure 19 shows the initial and final mesh. Contact starts at step 9 ($t = 1$ ms) and terminates at step 13 ($t = 1.44$ ms), when rebound starts. Figure 20 shows the computed displacements and velocities of characteristic points. The rebound speed is much lower than the impact speed as shown in Figure 20(b).



(a) Step 0 (b) Step 28

Figure 19: Initial and final mesh of test SLID03.

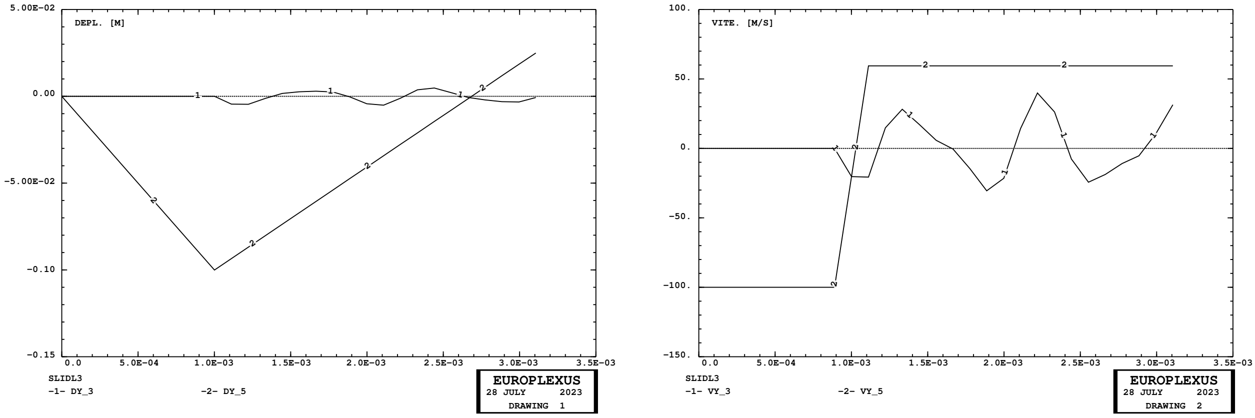


(a) Displacement (b) Velocity

Figure 20: Some results of test SLID03.

3.1.2 Case SLIDL3

This test is similar to SLID03 but adds the option `LIAJ ALPH 0.0`. As documented in reference [26], this chooses a different parametrization of the contact constraint (on full-step velocities rather than on mid-step velocities), which improves the conservation of energy and produces a higher rebound velocity, see Figure 21(b).



(a) Displacement (b) Velocity

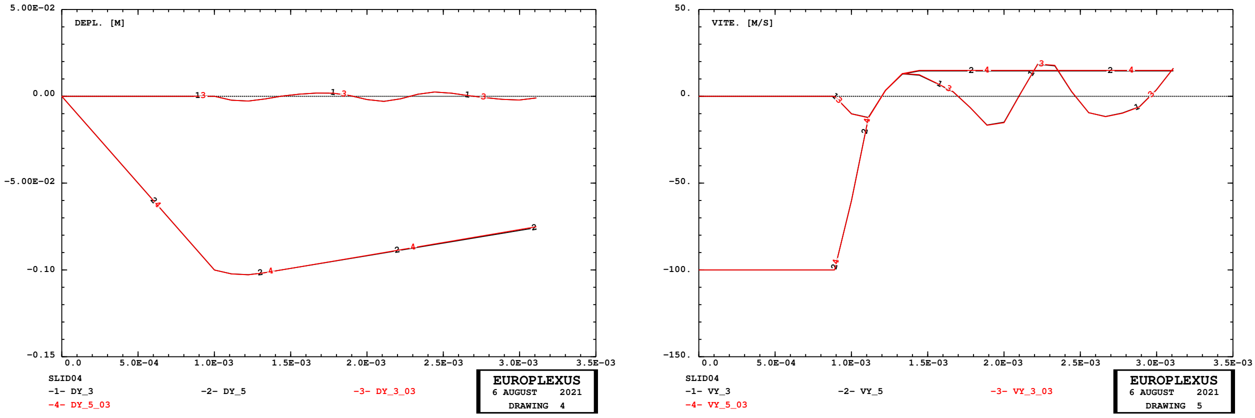
Figure 21: Some results of test SLIDL3.

3.1.3 Case SLID04

This test is similar to SLID03 but uses the pinball contact model. Since the PINB model takes into account the radius of the concentrated mass while SLID does not (yet), the vertical position of the concentrated mass is adjusted so that initial penetration occurs at the same time as in the previous solution. The input file reads:

```
SLID04
ECHO
!CONV win
DPLA LAGR
GEOM LIBR POIN 5 Q42L 1 PMAT 1 TERM
 0 0  1 0
 0 1  1 1
 0.5 1.2
 1 2 4 3
 5
COMP EPAI 1.0 LECT tous TERM
     GROU 2 'targ' LECT 1 TERM
            'proj' LECT 2 TERM
     EPAI 1.0 LECT targ TERM
          0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 12 LECT bloc TERM
     PINB BODY MLEV 5 LECT targ TERM
          BODY DIAM 0.2 LECT proj TERM
INIT VITE 2 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME    1 EYE    5.00000E-01  5.50000E-01  3.75000E+00
!         Q      1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
          VIEW   0.00000E+00  0.00000E+00 -1.00000E+00
          RIGH   1.00000E+00  0.00000E+00  0.00000E+00
          UP     0.00000E+00  1.00000E+00  0.00000E+00
          FOV    2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.50000E-01  0.00000E+00
!RSPHERE:  7.50000E-01
!RADIUS :  3.75000E+00
!ASPECT :  1.00000E+00
!NEAR   :  2.92500E+00
!FAR    :  5.25000E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 29 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 27 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR  2 'dy_5' DEPL COMP 2 NOEU LECT 5 TERM
COUR 11 'vy_3' VITE COMP 2 NOEU LECT 3 TERM
COUR 12 'vy_5' VITE COMP 2 NOEU LECT 5 TERM
COUR 21 'y_3'  COOR COMP 2 NOEU LECT 3 TERM
COUR 22 'y_5'  COOR COMP 2 NOEU LECT 5 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
RCOU 101 'dy_3' FICH 'slid03.pun' RENA 'dy_3_03'
RCOU 102 'dy_5' FICH 'slid03.pun' RENA 'dy_5_03'
RCOU 111 'vy_3' FICH 'slid03.pun' RENA 'vy_3_03'
RCOU 112 'vy_5' FICH 'slid03.pun' RENA 'vy_5_03'
RCOU 121 'y_3'  FICH 'slid03.pun' RENA 'y_3_03'
RCOU 122 'y_5'  FICH 'slid03.pun' RENA 'y_5_03'
TRAC  1  2 101 102 AXES 1.0 'DEPL. [M]' YZER
COLO NOIR NOIR ROUG ROUG
TRAC 11 12 111 112 AXES 1.0 'VITE. [M/S]' YZER
COLO NOIR NOIR ROUG ROUG
TRAC 21 22 121 122 AXES 1.0 'COOR. [M]' YZER
COLO NOIR NOIR ROUG ROUG
QUAL COUR  2 REFE -7.56787E-02 TOLE 1.E-2
     COUR 12 REFE  1.45632E+01 TOLE 1.E-2
     COUR 22 REFE  1.12432E+00 TOLE 1.E-2
FIN
```

The results obtained, shown in Figure 22 (black curves), are almost identical to those of the previous solution (red curves). This seems to indicate that the low rebound velocity is not a fault of the SLID model.



(a) Displacement

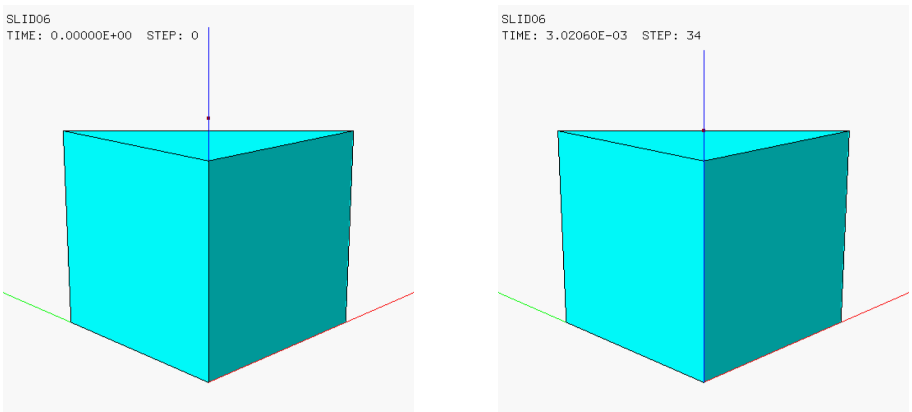
(b) Velocity

Figure 22: Some results of test SLID04.

3.1.4 Case SLID06

This test is similar to SLID03 but is in 3D and uses one prism element of type PR6 to discretize the continuum. Contact occurs on a triangular face of the prism.

Figure 23 shows the initial and final mesh. Contact starts at step 9 (t = 1 ms) and terminates at step 13 (t = 1.44 ms), when rebound starts. Figure 24 shows the computed displacements and velocities of characteristic points. The rebound speed is lower than the impact speed as shown in Figure 24(b), but the difference is smaller than in the previous 2D tests.



(a) Step 0

(b) Step 34

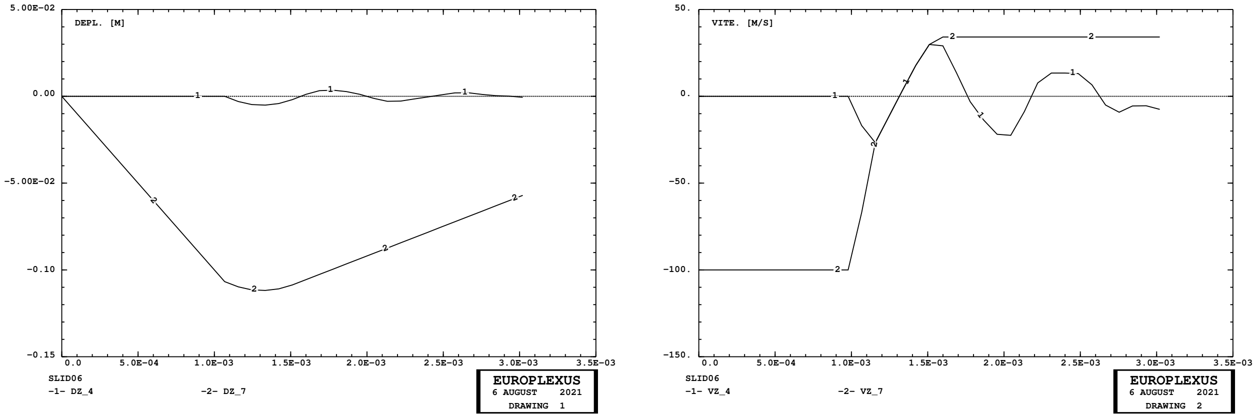
Figure 23: Initial and final mesh of test SLID06.

3.1.5 Case SLID07

This test is similar to SLID06 but uses the pinball contact method. The results obtained, shown in Figure 25 (black curves), are qualitatively similar to those of the previous solution (red curves). The discrepancy is mainly due to the fact that contact starts at different instants in the two solutions (some adjustment of the initial position of the projectile would be needed in the pinball solution to fix this).

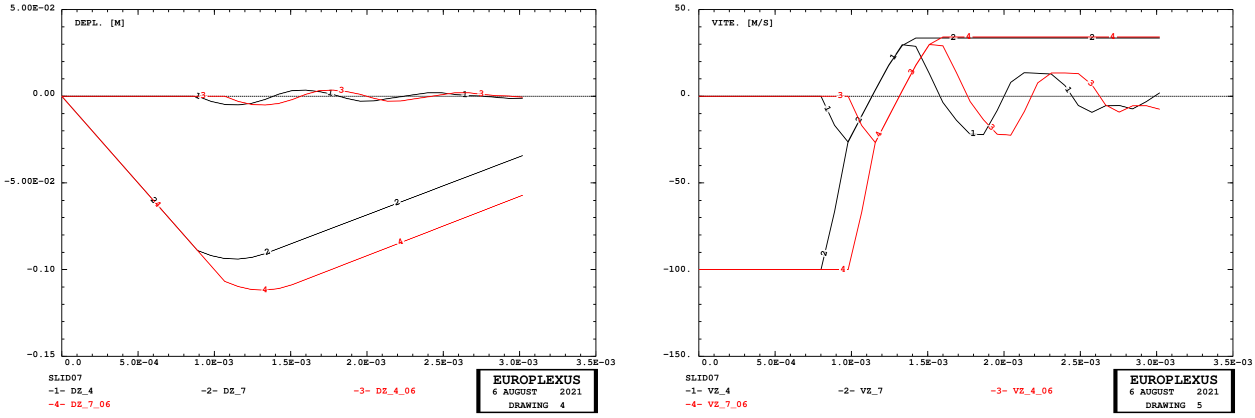
3.1.6 Case SLID08

This test is similar to SLID06 but uses the `GLIS` contact model. The results obtained, shown in Figure 26 (black curves), are qualitatively similar to those of the solution with `SLID` (red curves).



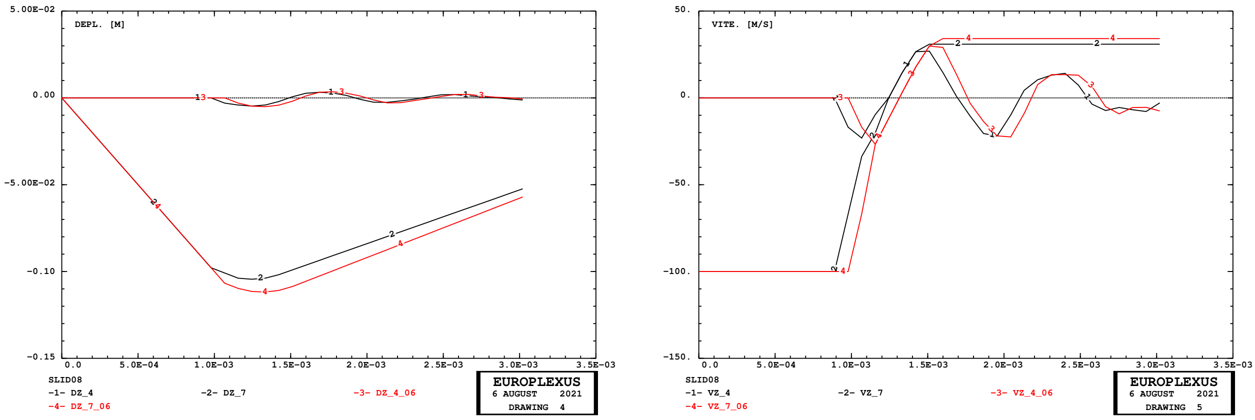
(a) Displacement (b) Velocity

Figure 24: Some results of test SLID06.



(a) Displacement (b) Velocity

Figure 25: Some results of test SLID07.



(a) Displacement (b) Velocity

Figure 26: Some results of test SLID08.

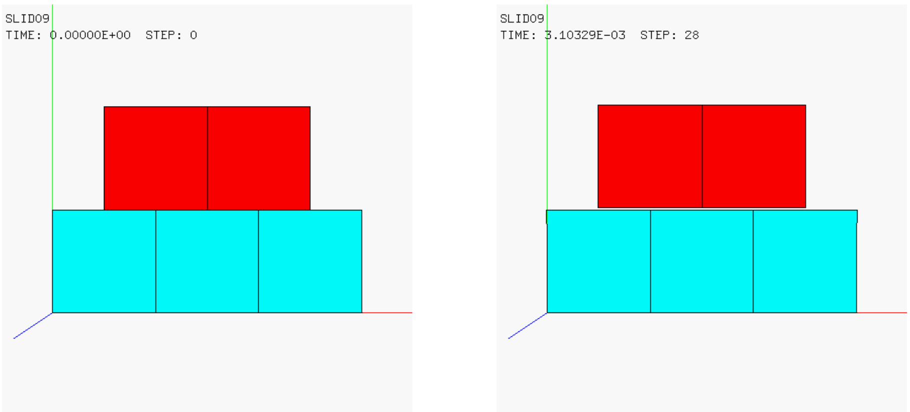
3.1.7 Case SLID09

This test studies the (perpendicular) impact between two solids (continuum) in 2D. The target is discretized by three quadrangles while the projectile is represented by only two quadrangles.

The boundary (including the SLID command) and initial conditions read:

```
LINK COUP ! SPLT NONE
     BLOQ 12 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                                       NMAS LECT 5 6 7 8 TERM
                                       NSLA LECT 9 10 11 TERM
INIT VITE 2 -50 LECT proj TERM
```

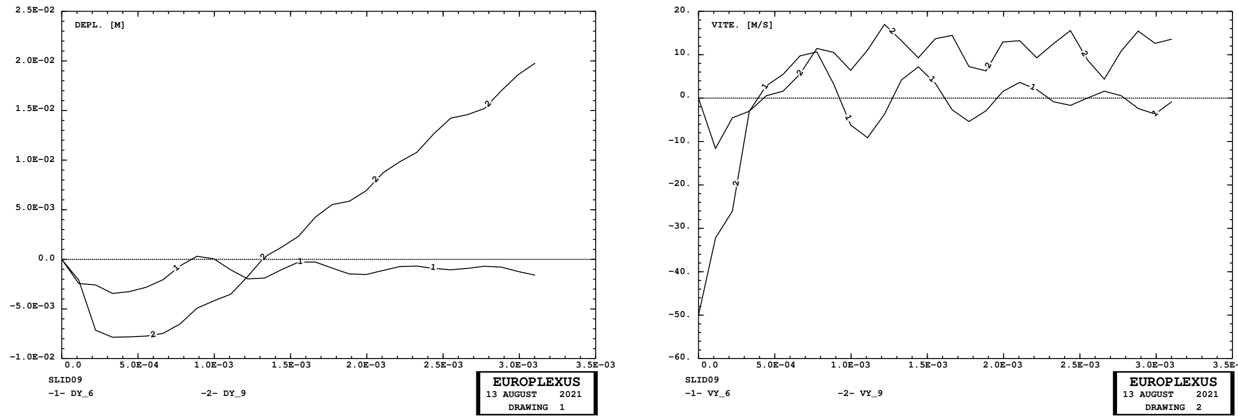
The two meshes are offset by 1/2 element so that penetration of the slave nodes occurs in the middle of the master faces, as shown in Figure 27(a). Protrusions are irrelevant in this example.



(a) Step 0 (b) Step 28

Figure 27: Initial and final mesh of test SLID09.

Some results in terms of displacement and velocity of characteristic points are shown in Figure 28.



(a) Displacement (b) Velocity

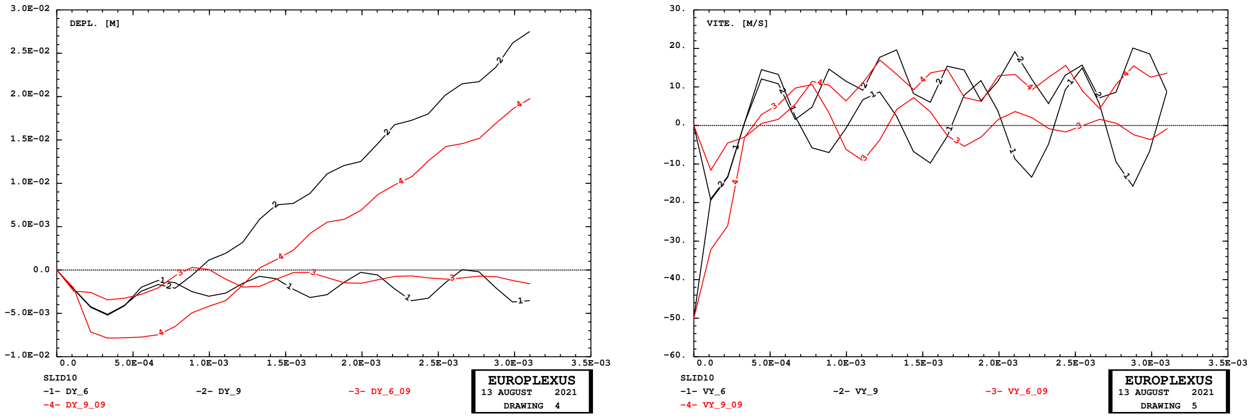
Figure 28: Some results of test SLID09.

3.1.8 Case SLID10

This test is identical to test SLID09 but the contact is imposed via the PINB directive (with pseudo-nodal pinballs in the projectile and with the ASN option) for comparison:

```
OPTI PINS ASN
LINK COUP ! SPLT NONE
     BLOQ 12 LECT bloc TERM
                                  PINB BODY MLEV 5 LECT targ TERM
                                       BODY DIAM 0.01 LECT npin TERM
INIT VITE 2 -50 LECT proj TERM
```

The results (black curves) are compared in Figure 29 with those of the previous case (red curves), showing that the two solutions are only qualitatively similar.



(a) Displacement (b) Velocity

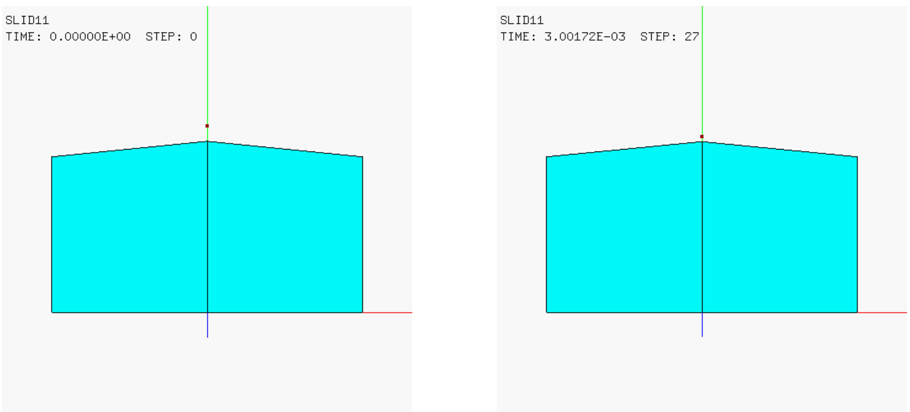
Figure 29: Some results of test SLID10 compared with SLID09.

3.1.9 Case SLID11

This test is meant to verify the protrusions in case of multiple penetrations of the same slave node into the master faces. A material point impacts a continuum meshed by only two quadrangles and forming a convex master surface, see Figure 30(a). The impact occurs at the central node of the master so that two penetrations occur.

```
LINK COUP ! SPLT NONE
     BLOQ 12 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 4 5 6 TERM
                 NSLA LECT 7 TERM
INIT VITE 2 -100 LECT proj TERM
```

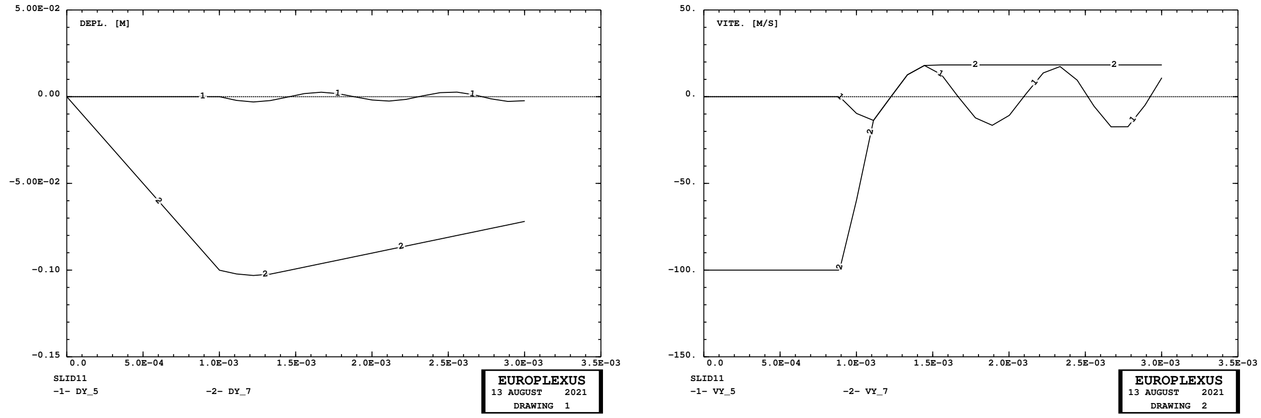
Since the master surface is locally convex, no protrusions are activated. The two penetrations give rise to a single contact link, which is imposed along the average normal, which in this case is vertical. Rebound occurs and the projectile moves along a vertical line, see Figure 30(b).



(a) Step 0 (b) Step 28

Figure 30: Initial and final mesh of test SLID11.

Some results in terms of displacement and velocity of characteristic points are shown in Figure 31.

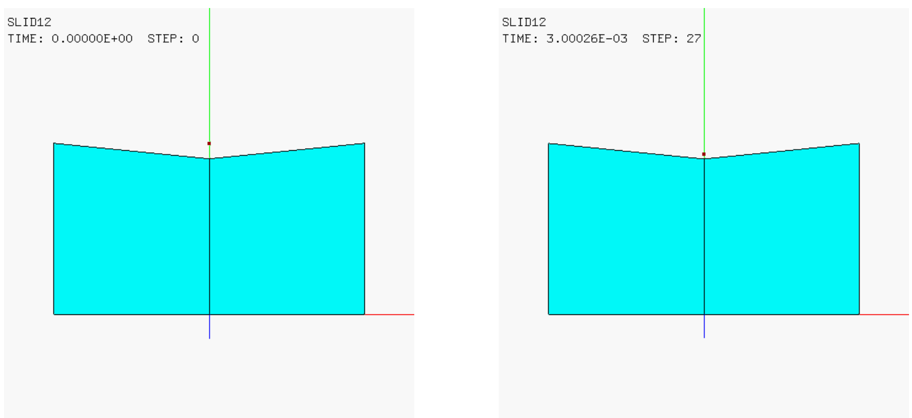


(a) Displacement (b) Velocity

Figure 31: Some results of test SLID11.

3.1.10 Case SLID12

This test is similar to SLID11 but the master surface is locally concave, see Figure 32. Protrusions of the master faces are automatically activated, so that two penetrations are detected as in the previous test. Again, only one contact link is imposed, along the average (vertical) normal. Some results are shown in Figure 33.



(a) Step 0 (b) Step 28

Figure 32: Initial and final mesh of test SLID12.

3.1.11 Case SLID13

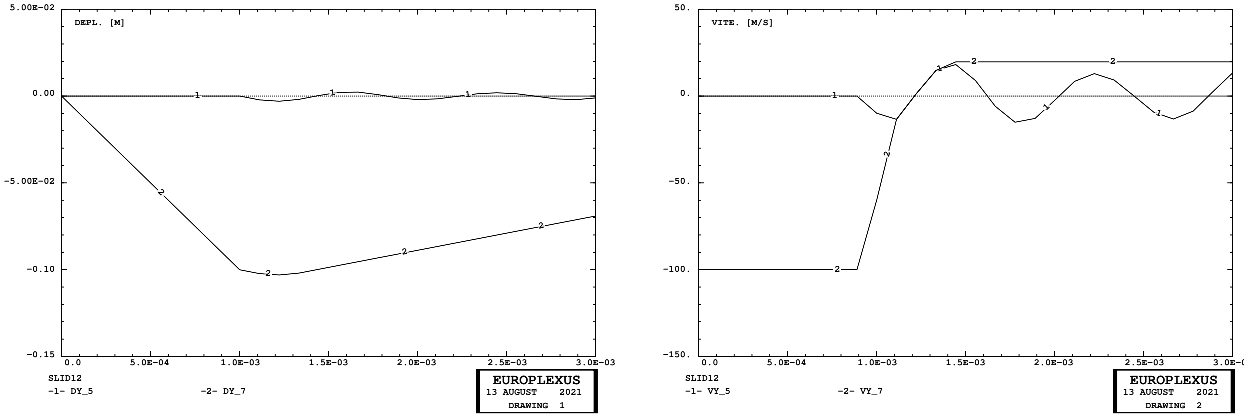
This test models the impact between two continuum meshes. It will be used as a reference for the subsequent test which uses only 1/2 of the model by exploiting symmetry. Some results are presented in Figures 34 and 35.

3.1.12 Case SLID26

This test is equivalent to case SLID13 but only one half of the problem is meshed and symmetry is imposed by the `CONT SPLA` directive:

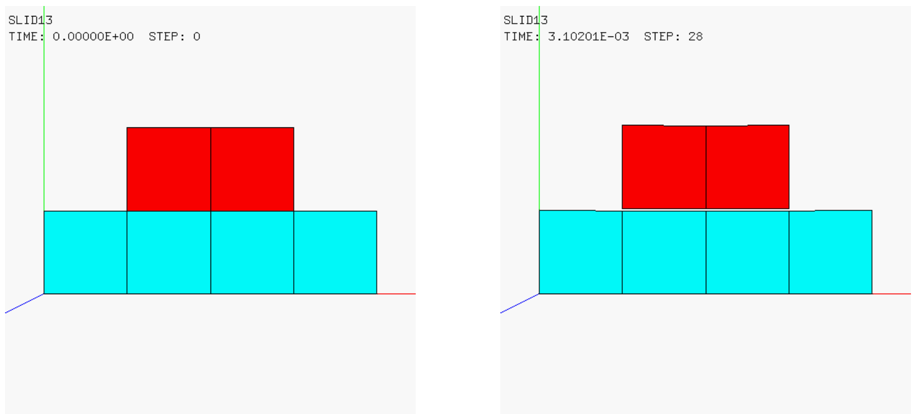
```
LINK COUP ! splt none
     BLOQ 1 LECT blox TERM
          2 LECT bloy TERM
     CONT SPLA NX 1 NY 0 LECT symm TERM
```

```
SLID 1 SURF EMAS LECT targ TERM
            NMAS LECT 4 5 6 TERM
            NSLA LECT 7 8 TERM
```



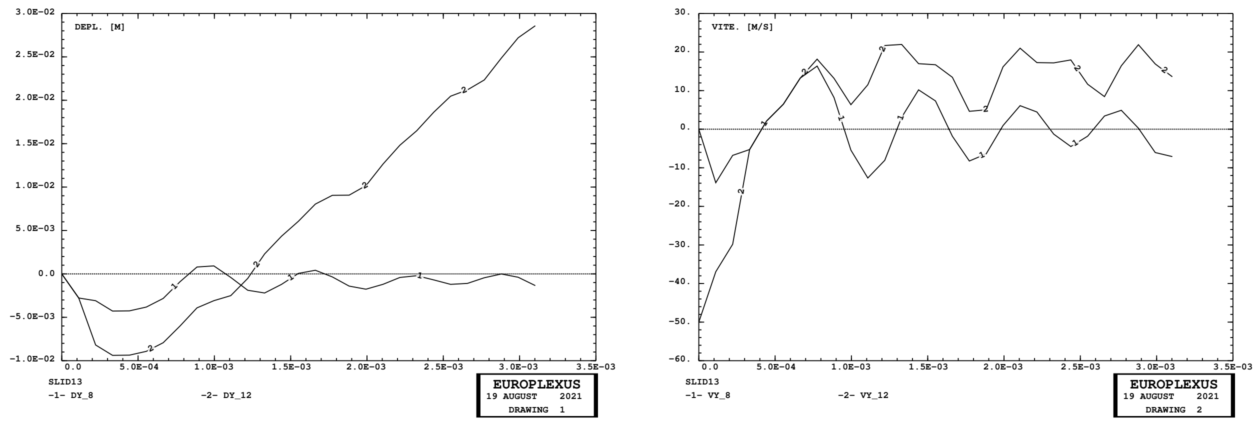
(a) Displacement (b) Velocity

Figure 33: Some results of test SLID12.



(a) Step 0 (b) Step 28

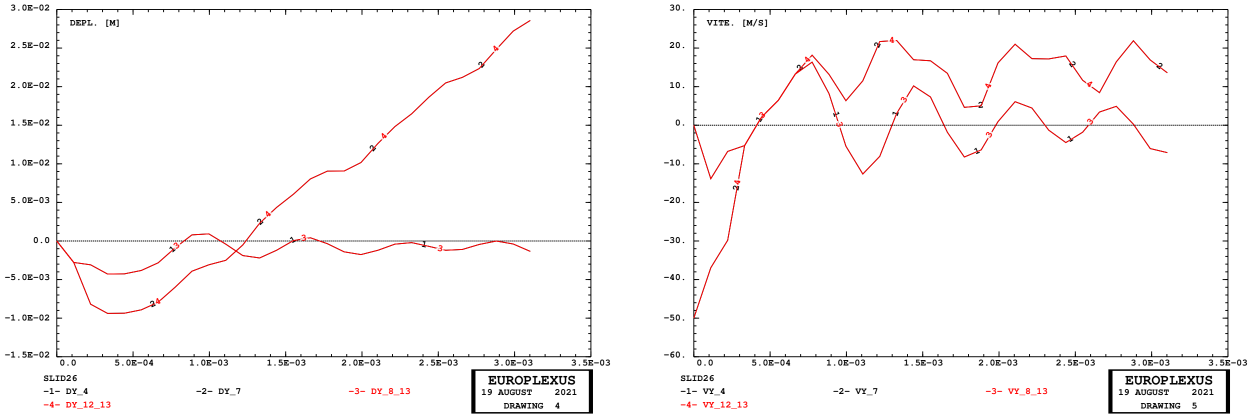
Figure 34: Initial and final mesh of test SLID13.



(a) Displacement (b) Velocity

Figure 35: Some results of test SLID13.

The solution (black curves) is compared against the reference SLID13 (red curves) in Figure 36, showing perfect agreement.



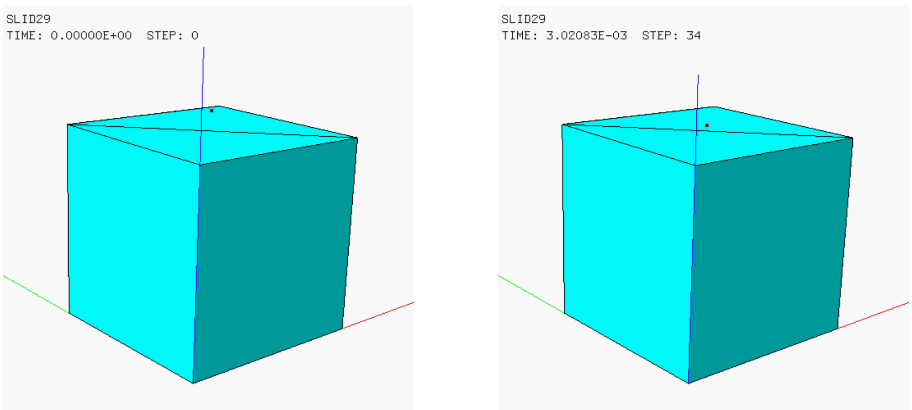
(a) Displacement (b) Velocity

Figure 36: Some results of test SLID26 compared with slid13.

3.1.13 Case SLID29

This test represents the impact of a concentrated mass (PMAT) on a continuum, meshed by two prisms (PR6). It is similar to case SLID06 but the target is now a parallelepiped. The impact occurs at the center of the upper face of the parallelepiped and the solution is expected to be symmetric.

The main purpose of the test is to check in detail the determination of adjacent master faces in 3D continuum for triangular faces, which are correctly detected. Also the occurrence of multiple penetrations is tested, since the projectile hits two master faces simultaneously but this results in a single contact constraint. Some results are presented in Figures 37 and 38. The solution looks symmetric, within the limits of the very coarse discretization.

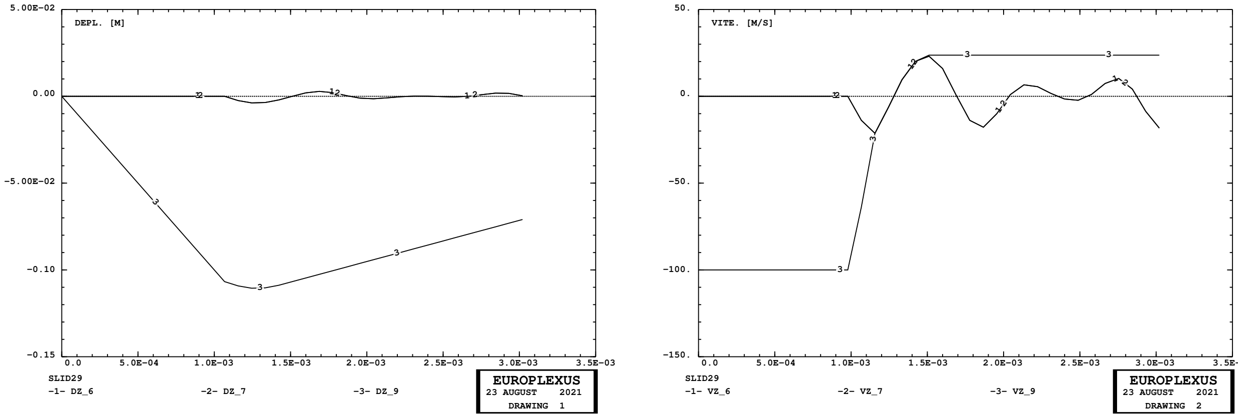


(a) Step 0 (b) Step 34

Figure 37: Initial and final mesh of test SLID29.

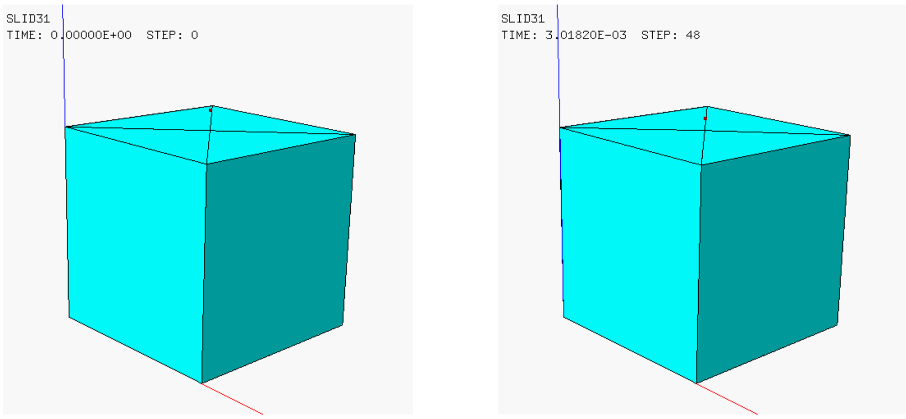
3.1.14 Case SLID31

This test is similar to SLID29 but the target is meshed by four PR6 instead of just two for an even more symmetric configuration. Impact at the center of the upper face causes four simultaneous penetrations into the master faces, which result in a single contact constraint. The solution is fairly symmetric, as shown in Figures 39 and 40.



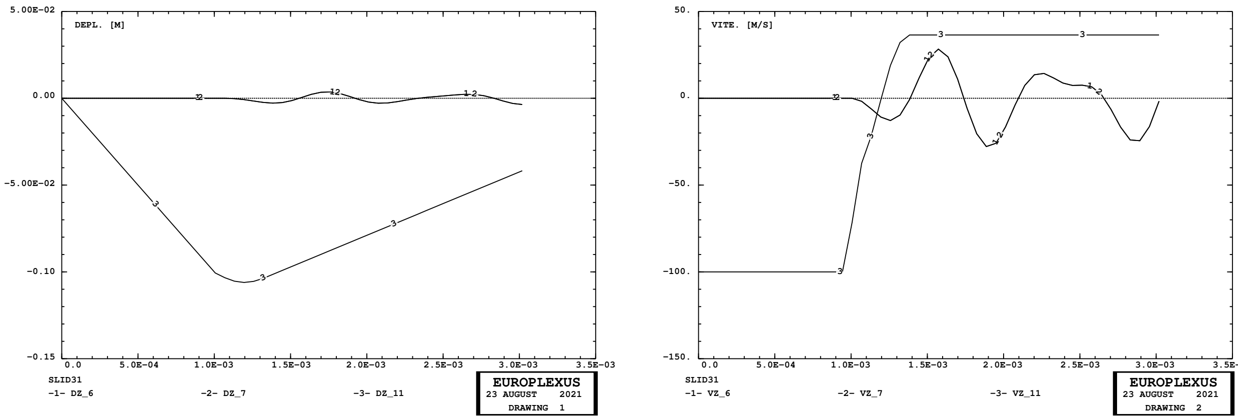
(a) Displacement (b) Velocity

Figure 38: Some results of test SLID29.



(a) Step 0 (b) Step 48

Figure 39: Initial and final mesh of test SLID31.



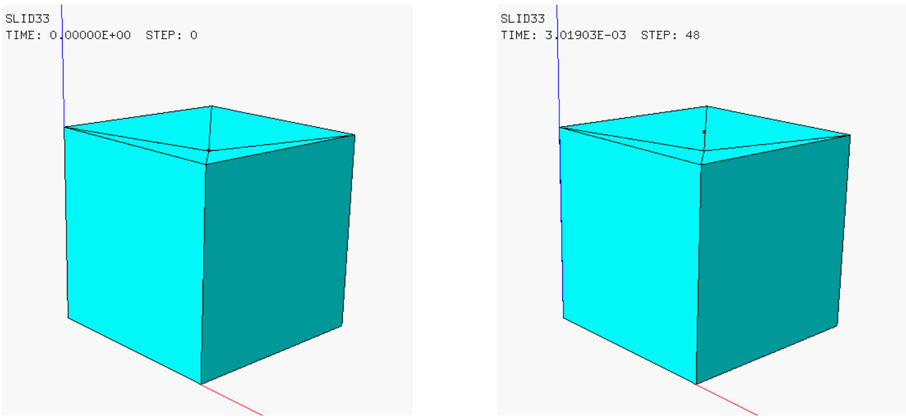
(a) Displacement (b) Velocity

Figure 40: Some results of test SLID31.

3.1.15 Case SLID33

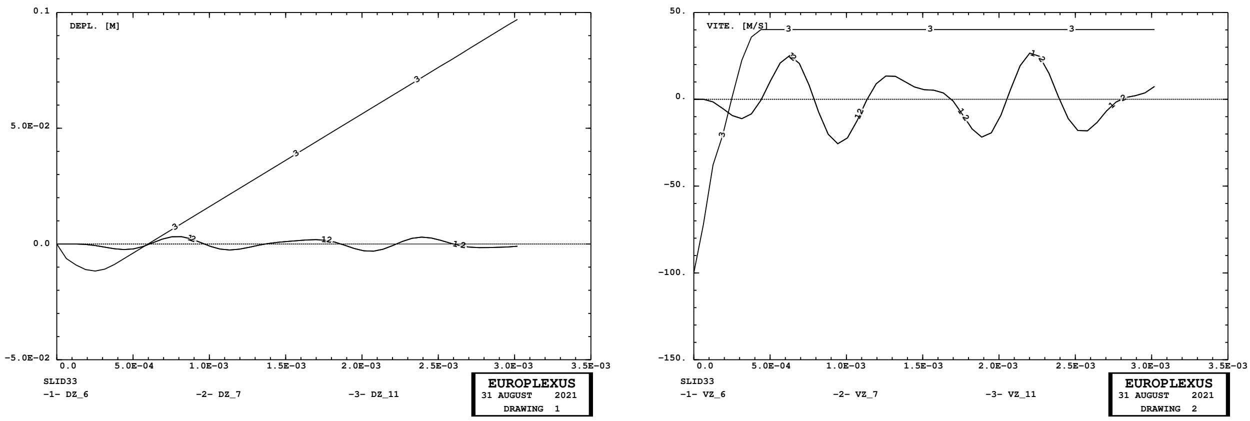
This test is similar to SLID31 but the central nodes 8 and 11 of the target and of the projectile are slightly lowered in order to create an impact on an initially concave (rather than plane) master surface.

Master face protrusions should be automatically activated under these circumstances. Impact at the center of the upper face causes four simultaneous penetrations into the master faces, which result in a single contact constraint. Contact occurs between steps 1 and 10 of the simulation. The solution is fairly symmetric, as shown in Figures 41 and 42.



(a) Step 0 (b) Step 48

Figure 41: Initial and final mesh of test SLID33.



(a) Displacement (b) Velocity

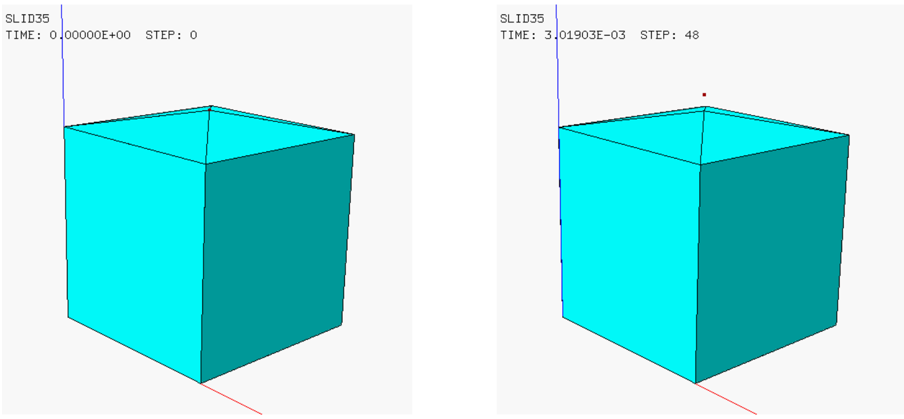
Figure 42: Some results of test SLID33.

3.1.16 Case SLID34

This test is identical to SLID33 but the element topology is modified so as to check the penetration into triangular faces in a different configuration. As expected, the solution is identical to that of case SLID33 and is not shown for brevity.

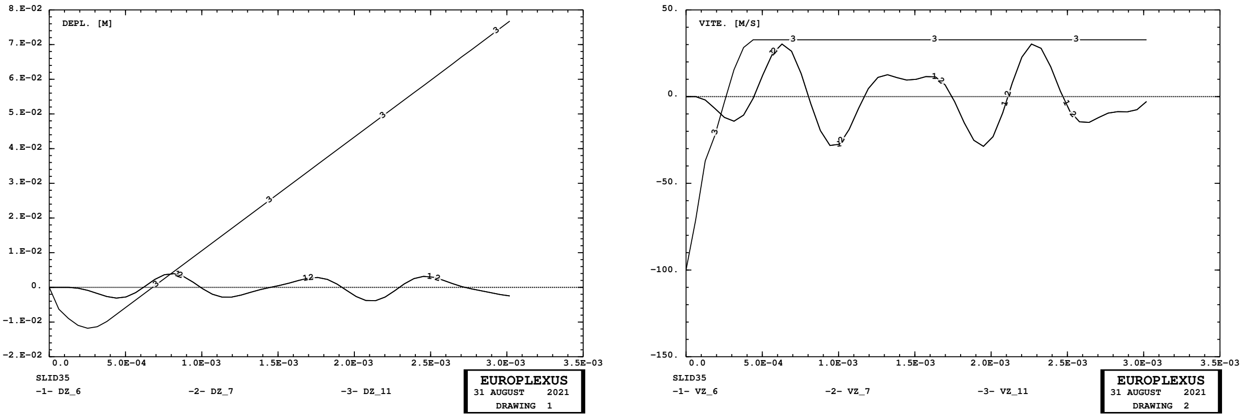
3.1.17 Case SLID35

This test is similar to SLID31 but the central nodes 8 and 11 of the target and of the projectile are slightly raised in order to create an impact on an initially convex (rather than plane) master surface. Master face protrusions should not be automatically activated under these circumstances. Impact at the center of the upper face causes four simultaneous penetrations into the master faces, which result in a single contact constraint. Contact occurs between steps 1 and 11 of the simulation. The solution is fairly symmetric, as shown in Figures 43 and 44.



(a) Step 0 (b) Step 48

Figure 43: Initial and final mesh of test SLID35.



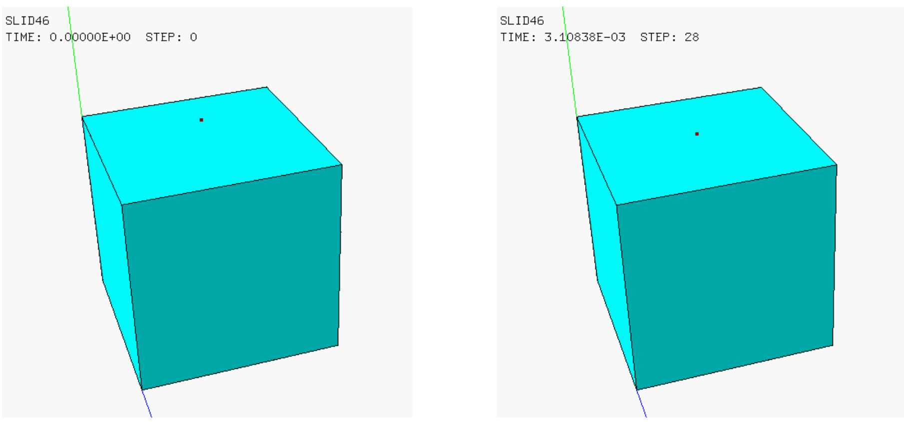
(a) Displacement (b) Velocity

Figure 44: Some results of test SLID35.

3.1.18 Case SLID46

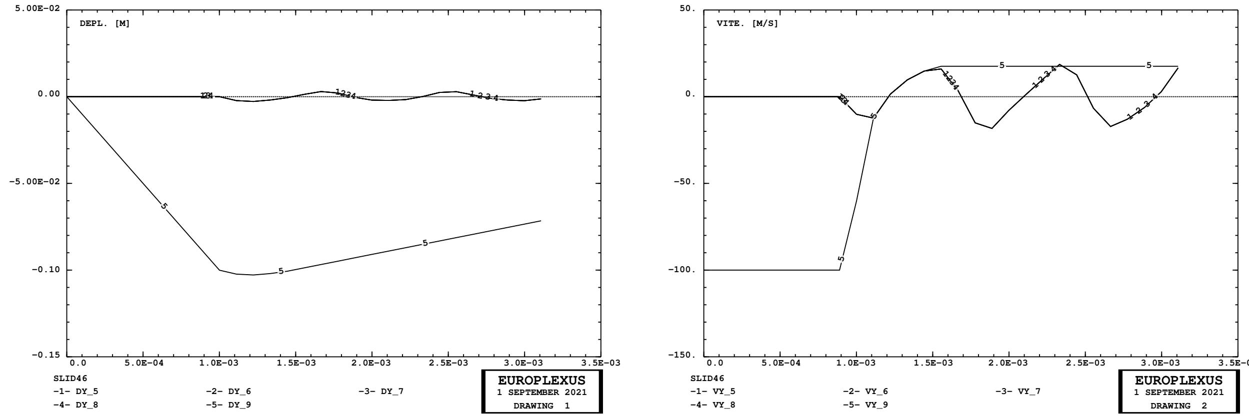
This test is the 3D version of test SLID03. A material point impacts a continuum meshed by a single hexahedron. The impact occurs on a quadrangular master face.

The solution is fairly symmetric, as shown in Figures 45 and 46.



(a) Step 0 (b) Step 28

Figure 45: Initial and final mesh of test SLID46.



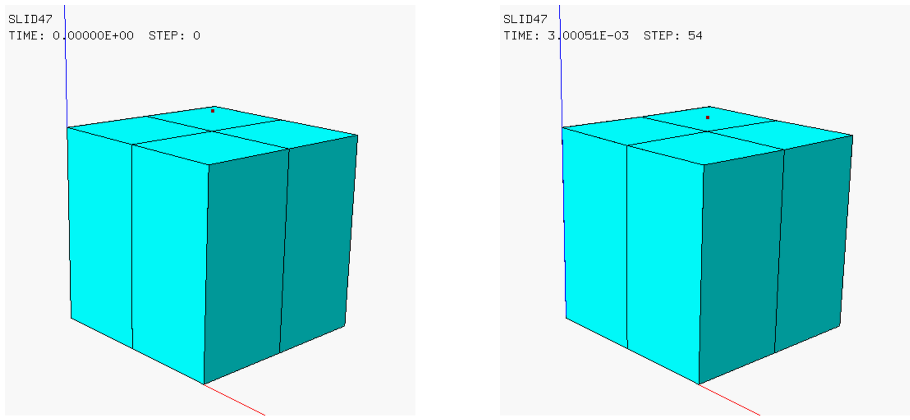
(a) Displacement (b) Velocity

Figure 46: Some results of test SLID46.

3.1.19 Case SLID47

This test is similar to SLID03 but the continuum is meshed by four hexahedra. The impact occurs on four quadrangular faces simultaneously. The master surface is initially planar but it becomes slightly curved as the impact proceeds.

The solution is fairly symmetric, as shown in Figures 47 and 48.



(a) Step 0 (b) Step 54

Figure 47: Initial and final mesh of test SLID47.

3.1.20 Case SLID49

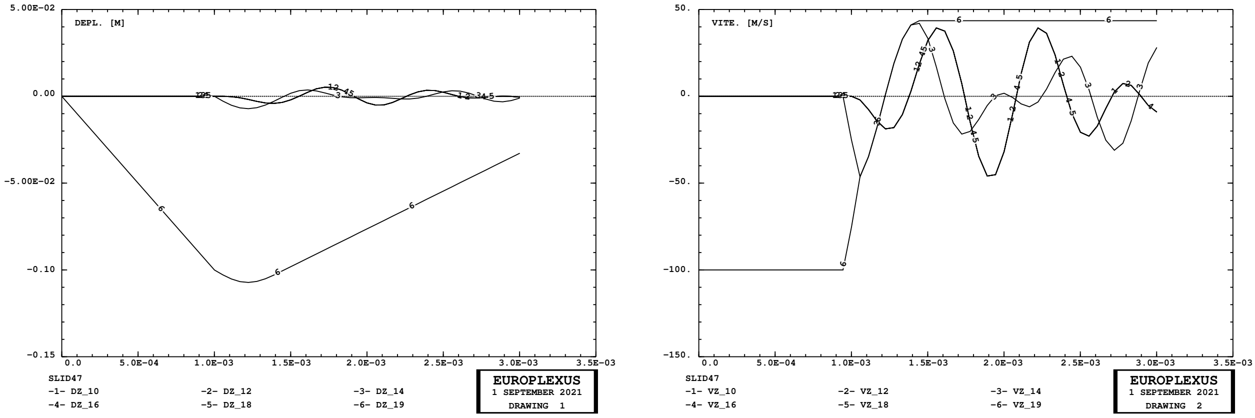
This test is similar to SLID47 but the central node of the target and the penetrator node are slightly raised so that impact occurs on a convex master surface, with the implications that this has on the use of protrusions.

The solution is fairly symmetric, as shown in Figures 49 and 50.

3.1.21 Case SLID50

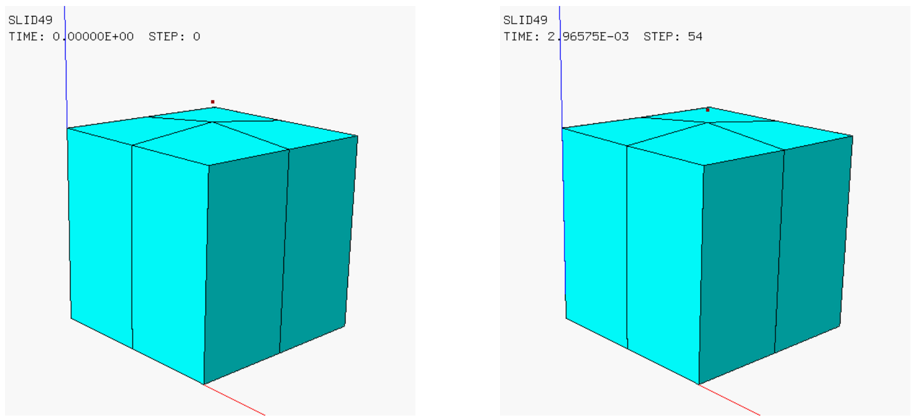
This test is similar to SLID47 but the central node of the target and the penetrator node are slightly lowered so that impact occurs on a concave master surface, with the implications that this has on the use of protrusions.

The solution is fairly symmetric, as shown in Figures 51 and 52.



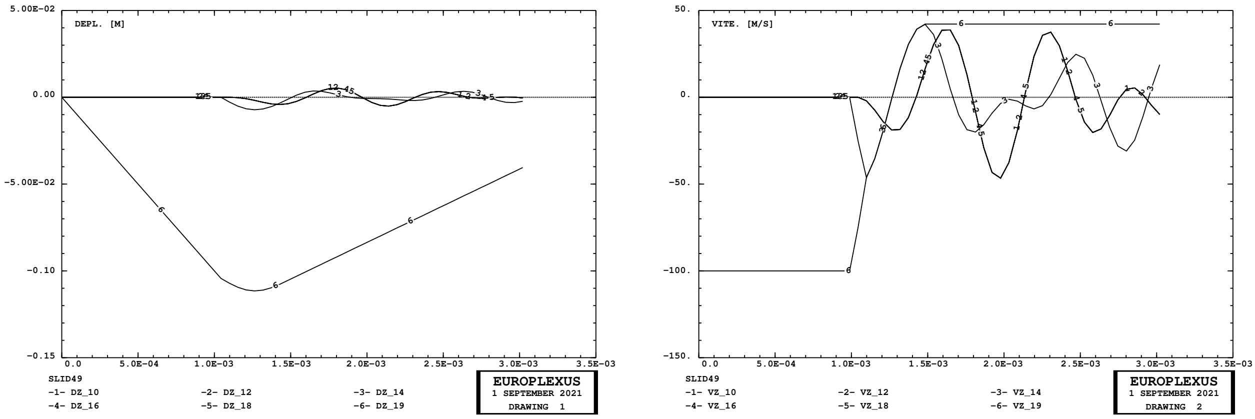
(a) Displacement (b) Velocity

Figure 48: Some results of test SLID47.



(a) Step 0 (b) Step 55

Figure 49: Initial and final mesh of test SLID49.

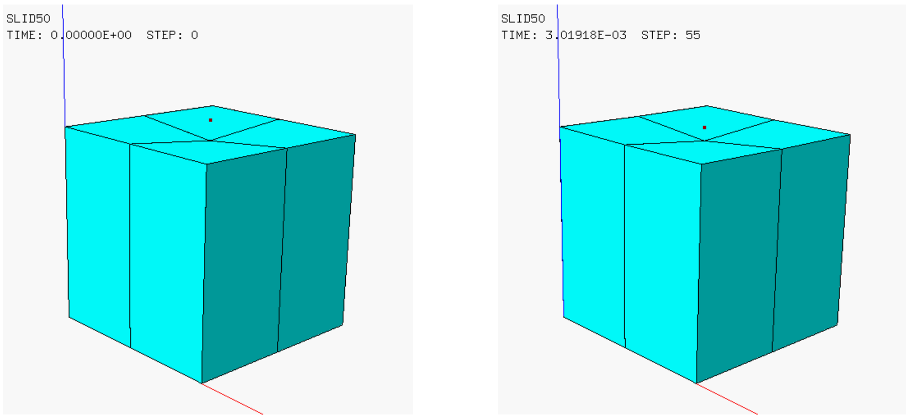


(a) Displacement (b) Velocity

Figure 50: Some results of test SLID49.

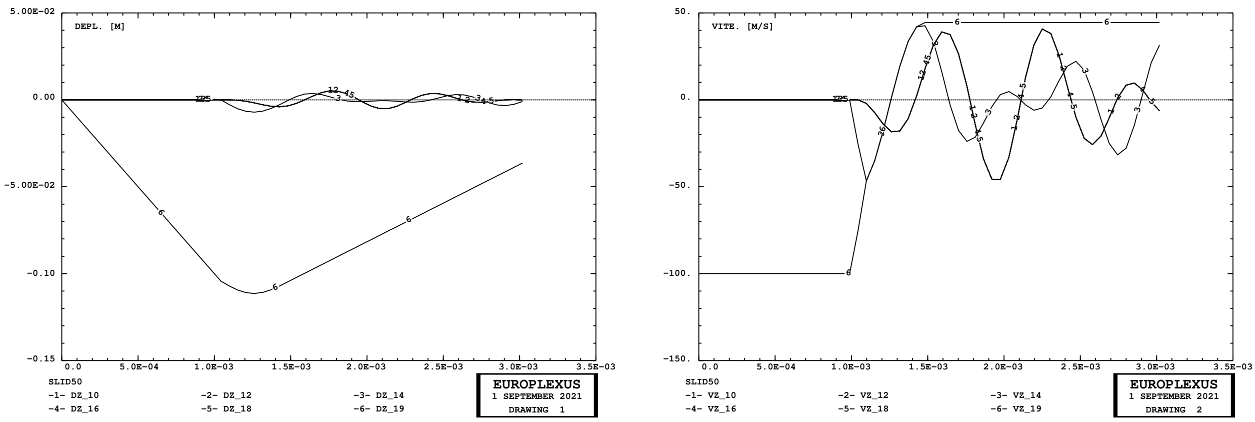
3.1.22 Case SLID53

This test is similar to SLID47 but we model only 1/2 of the problem by imposing a symmetry plane with `CONT SPLA`. It should be noted that, since the projectile is represented by a material point



(a) Step 0 (b) Step 55

Figure 51: Initial and final mesh of test SLID50.



(a) Displacement (b) Velocity

Figure 52: Some results of test SLID50.

(PMAT) and is not discretized, its mass must scaled down to respect the symmetry. In this case, only half of the real projectile mass should be assigned to the material point.

Another subtle point is that, in order for the contact algorithm to work properly together with the symmetry, the node of the material point (PMAT) must be subjected to the symmetry, as well as the nodes of the continuum (target).

The solution is identical to that with the full model, and is shown in Figures 53 and 54.

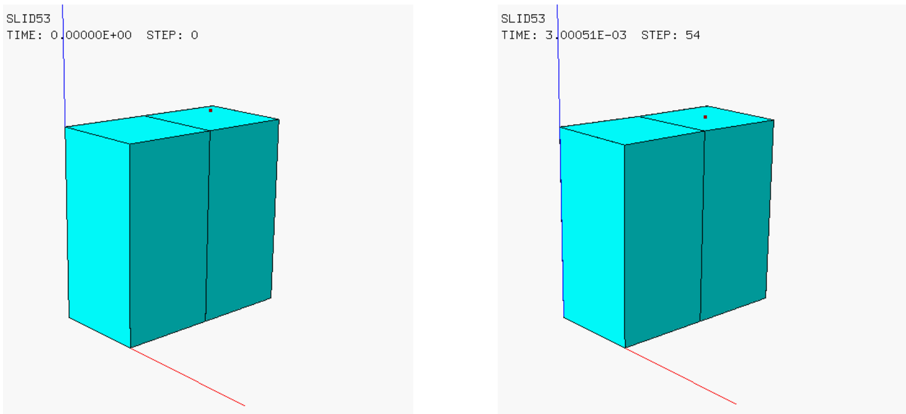
3.1.23 Case SLID54

This test is similar to SLID47 but we model only 1/4 of the problem by imposing two symmetry planes with `CONT SPLA`. In this case, only one fourth of the real projectile mass should be assigned to the material point.

The solution is identical to that with the full model, and is shown in Figures 55 and 56.

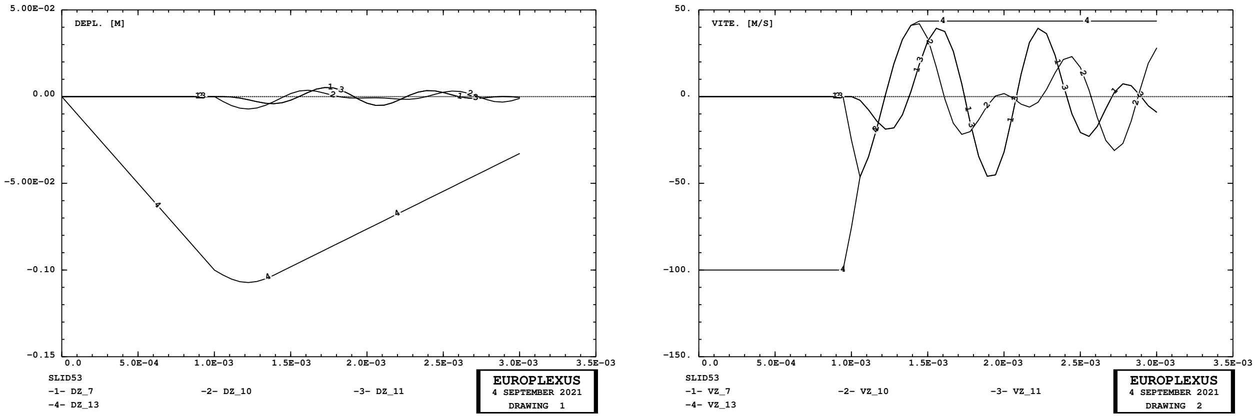
3.2 Basic continuum tests with friction

We now perform some basic continuum tests to check out the friction. The calculations performed are summarized in Table 5.



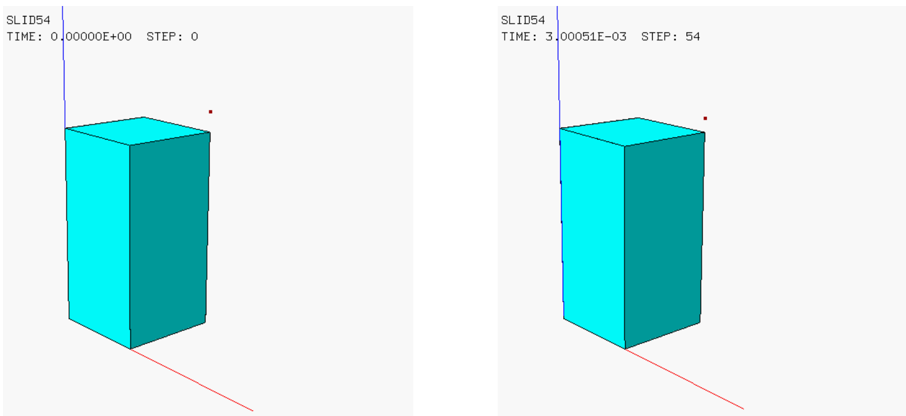
(a) Step 0 (b) Step 54

Figure 53: Initial and final mesh of test SLID53.



(a) Displacement (b) Velocity

Figure 54: Some results of test SLID53.

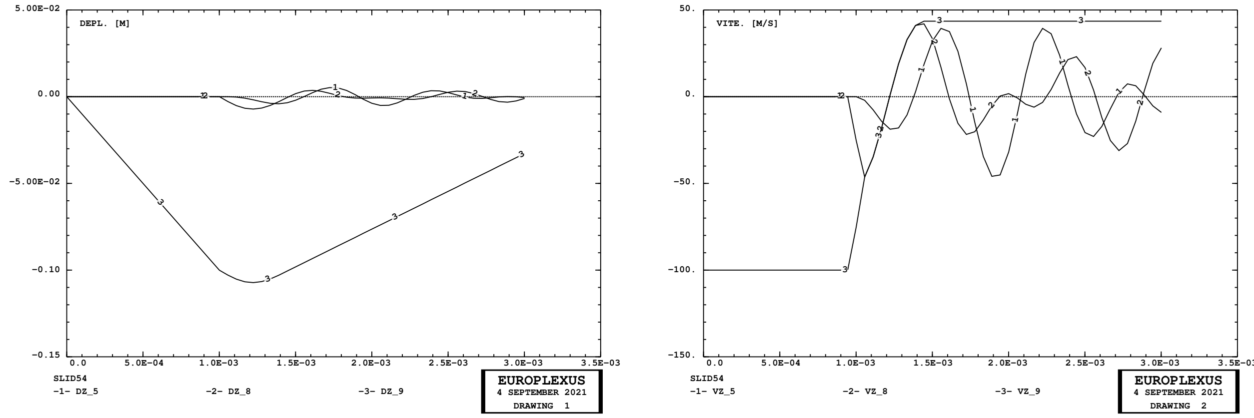


(a) Step 0 (b) Step 54

Figure 55: Initial and final mesh of test SLID54.

3.2.1 Case SLID16

This test is similar to case SLID03 (in 2D space) studied in the previous Section. We add a horizontal velocity component in order to study the sliding of the material point along the target during the impact. In this case no friction is specified and the solution will be used as a reference to investigate



(a) Displacement (b) Velocity

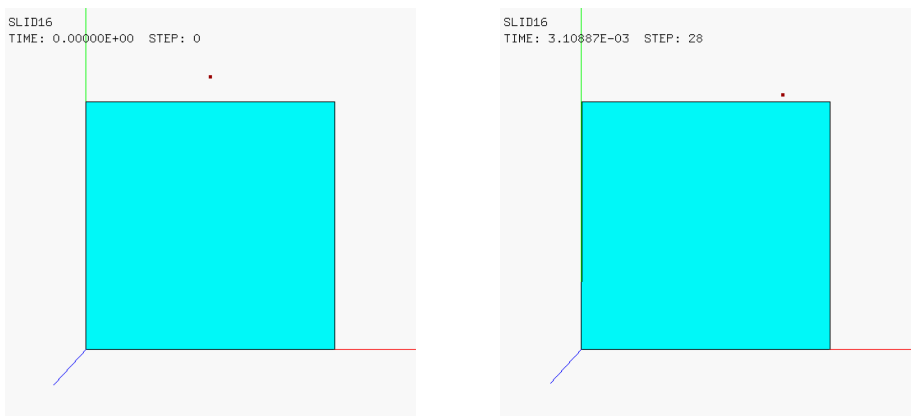
Figure 56: Some results of test SLID54.

Input file	Mesh	Description	t_{fin} (ms)	Steps	CPU (s)
SLID16	1 Q42L 1 PMAT	2D sliding of mass on a continuum	3.0	28	0.2
SLID17	1 Q42L 1 PMAT	Idem 16 but with friction	3.0	28	0.2
SLID40	1 PR6 1 PMAT	Idem 06 (no friction) but add horizontal velocity	3.0	34	0.2
SLID41	1 PR6 1 PMAT	Idem 40 but with friction	3.0	34	0.2

Table 5: Basic continuum numerical examples with friction.

the effects of friction in a subsequent simulation.

Figure 57 shows the initial and final mesh. Contact starts at step 9 ($t = 1$ ms) and terminates at step 13 ($t = 1.44$ ms), when rebound starts (exactly like in case SLID03). Figure 58 shows the computed horizontal displacements and velocities of characteristic points.



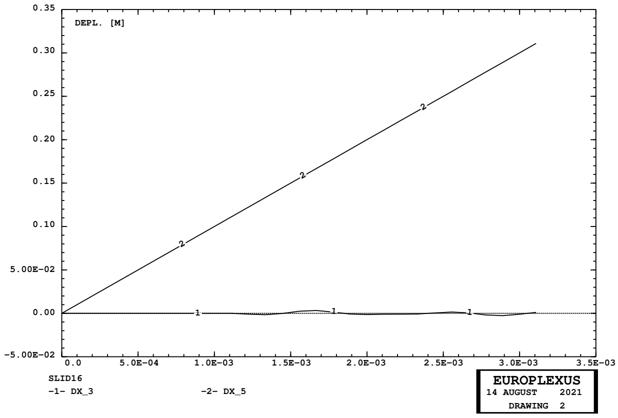
(a) Step 0 (b) Step 28

Figure 57: Initial and final mesh of test SLID16.

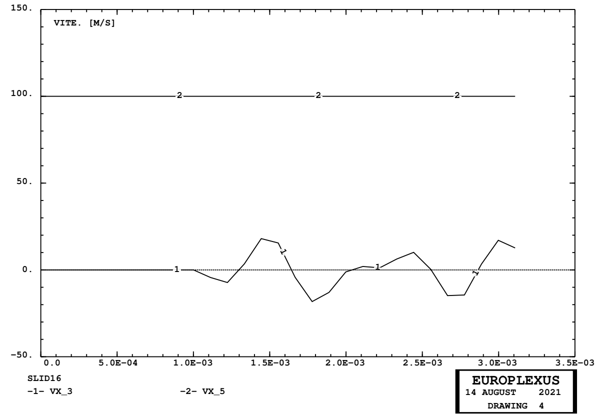
Note that, as expected in the absence of friction, the horizontal displacement of the projectile is linear in time and its horizontal velocity is constant. The small oscillatory horizontal displacements in the target are due to the Poisson effect.

3.2.2 Case SLID17

This test is similar to case SLID16 but we add friction:



(a) Horizontal displacement

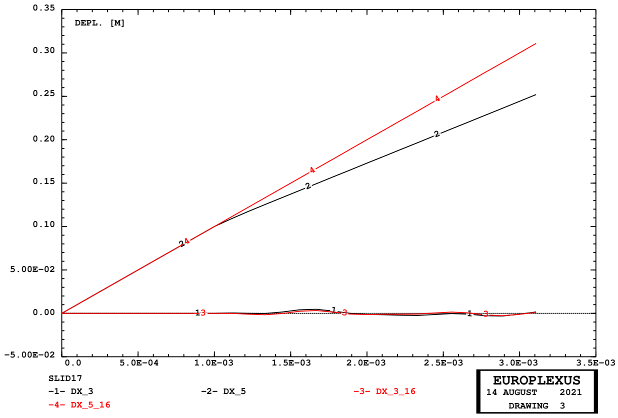


(b) Horizontal velocity

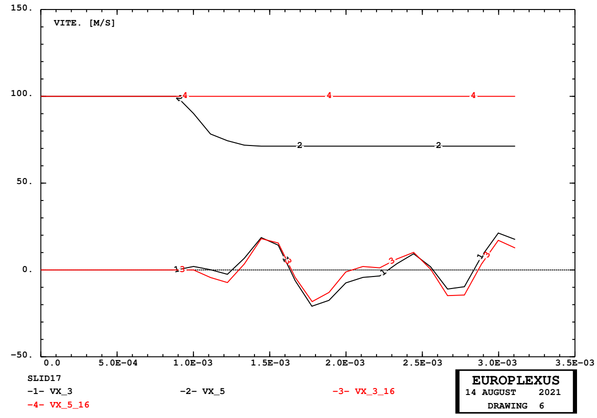
Figure 58: Some results of test SLID16.

```
LINK COUP ! SPLT NONE
     BLOQ 12 LECT bloc TERM
     SLID 1 SURF FROT MUST 0.25 MUDY 0.25 GAMM 0.1
                EMAS LECT targ TERM
                NMAS LECT 3 4 TERM
                NSLA LECT 5 TERM
INIT VITE 2 -100 LECT proj TERM
          1  100 LECT proj TERM
```

Figure 59 compares this solution (black curves) with the previous one (red curves), that had no friction. As expected, after impact the horizontal displacement and velocity are smaller in the case with friction.



(a) Horizontal displacement



(b) Horizontal velocity

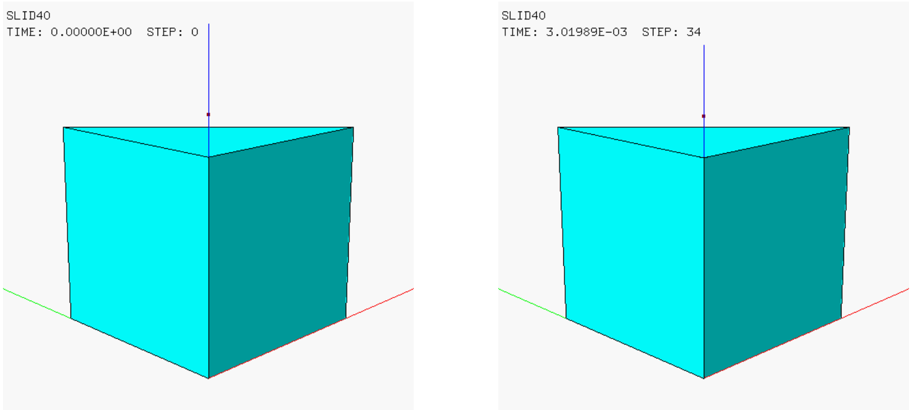
Figure 59: Some results of test SLID17 compared with SLID16.

3.2.3 Case SLID40

This test is similar to case SLID06 (in 3D space) studied in the previous Section. We add a horizontal velocity component in order to study the sliding of the material point along the target during the impact. In this case no friction is specified and the solution will be used as a reference to investigate the effects of friction in a subsequent simulation.

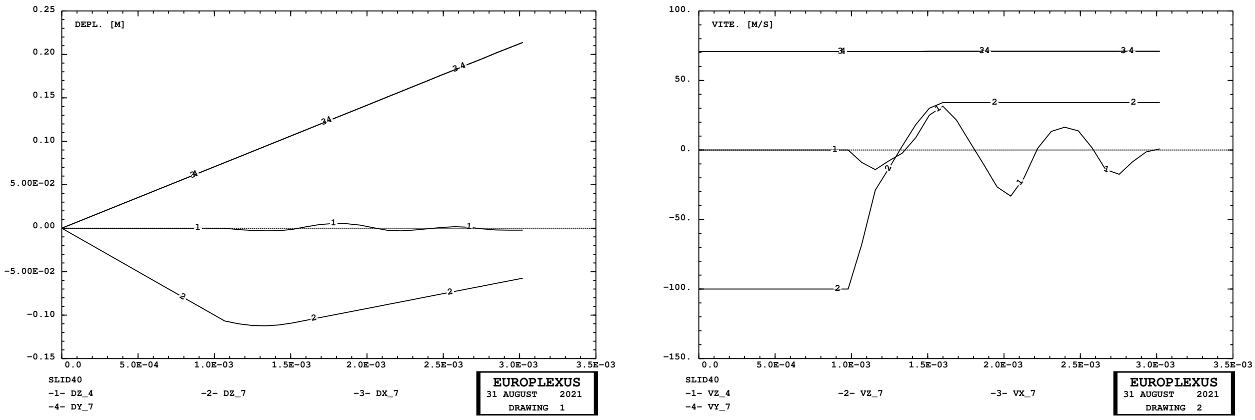
Figure 60 shows the initial and final mesh. Contact starts at step 12 ($t = 1.1$ ms) and terminates at step 20 ($t = 1.8$ ms), when rebound starts. (exactly like in case SLID06). Figure 61 shows the computed displacements and velocities of characteristic points.

Note that, as expected in the absence of friction, the horizontal displacement of the projectile is linear in time and its horizontal velocity is constant.



(a) Step 0 (b) Step 34

Figure 60: Initial and final mesh of test SLID40.

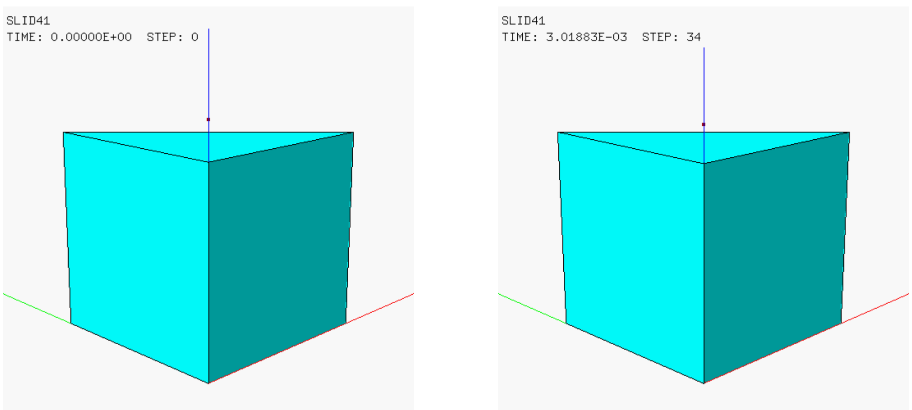


(a) Displacements (b) Velocities

Figure 61: Some results of test SLID40.

3.2.4 Case SLID41

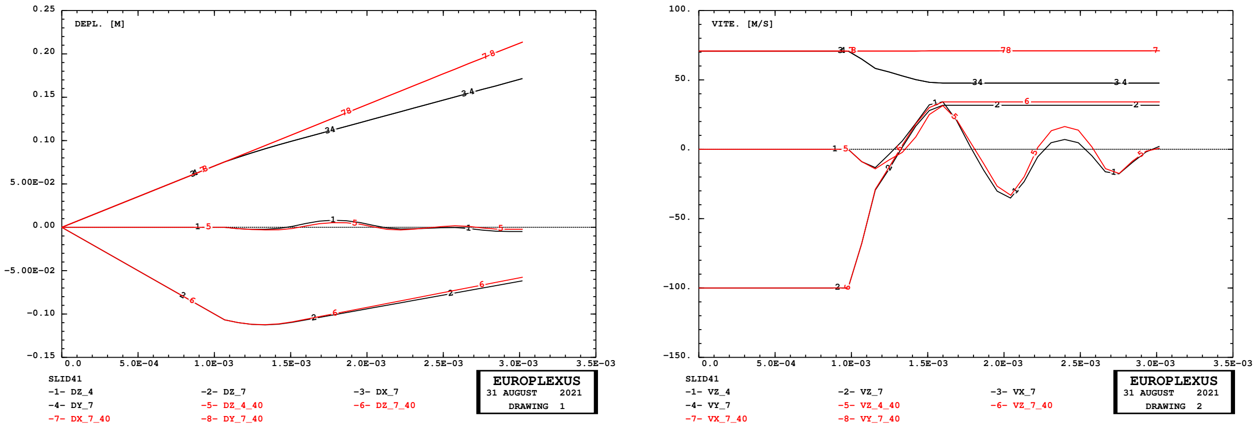
This test is similar to case SLID40 but we add friction. Figure 62 shows the initial and final mesh. Contact starts at step 12 ($t = 1.1$ ms) and terminates at step 20 ($t = 1.8$ ms), when rebound starts. (exactly like in case SLID40).



(a) Step 0 (b) Step 34

Figure 62: Initial and final mesh of test SLID41.

Figure 63 compares the computed displacements and velocities of characteristic points (in black) with those of the solution without friction (in red). Note how the horizontal velocity and displacement are reduced by the effect of friction.



(a) Displacements

(b) Velocities

Figure 63: Some results of test SLID41 compared with SLID40.

3.3 Basic shell tests without friction

We now perform some basic shell tests without friction. The calculations performed are summarized in Table 6.

Input file	Mesh	Description	t_{fin} (ms)	Steps	CPU (s)
SLID20	3 ED01 1 PMAT	2D sliding of mass on a shell	20.0	157	0.4
SLID21	1 Q42L 1 PMAT	2D sliding of mass on a square continuum	3.0	28	0.2
SLID22	4 ED01 1 PMAT	2D sliding of mass on a square shell	3.0	24	0.1
SLID23	4 ED01 1 PMAT	2D sliding of mass on a convex shell	20.0	154	0.4
SLID24	4 ED01 1 PMAT	2D sliding of mass on a concave shell	20.0	154	0.4
SLID25	4 ED01 1 PMAT	2D sliding of mass on a convex shell	20.0	77	0.2
SLID27	2 ED01 1 PMAT	Idem 23 but 1/2 model with symmetry	20.0	154	0.4
SLID28	2 ED01 1 PMAT	Idem 24 but 1/2 model with symmetry	20.0	154	0.4
SLID30	2 T3GS 1 PMAT	3D sliding of mass on a shell	3.0	34	0.2
SLID32	4 T3GS 1 PMAT	Same as 30 but 4 T3GS and blocked contour	3.0	47	0.2
SLID36	4 T3GS 1 PMAT	Idem 32 but concave master surface	3.0	46	0.2
SLID37	4 T3GS 1 PMAT	Idem 32 but convex master surface	3.0	47	0.2
SLID48	4 Q4GS 1 PMAT	Same as 32 but 4 Q4GS instead of T3GS	3.0	47	0.3
SLID51	4 Q4GS 1 PMAT	Idem 48 but convex master surface	3.0	47	0.2
SLID52	4 Q4GS 1 PMAT	Idem 48 but concave master surface	3.0	47	0.2
SLID55	2 Q4GS 1 PMAT	Same as 48 but with a symmetry plane	3.0	47	0.2
SLID56	1 Q4GS 1 PMAT	Same as 48 but with two symmetry planes	3.0	47	0.1

Table 6: Basic shell numerical examples without friction.

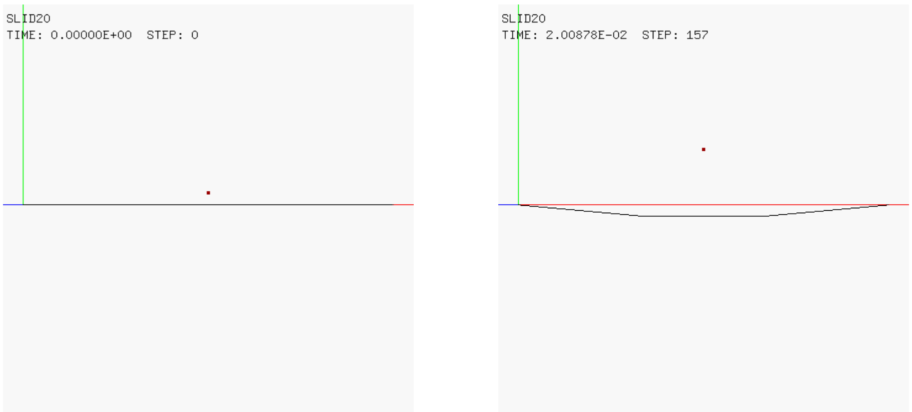
3.3.1 Case SLID20

This test models the impact of a material point on a beam/shell in 2D. The shell is modelled by three elements of type ED01. The impact occurs at the shell center, i.e. in the middle of the central element.

The contact-related input data reads:

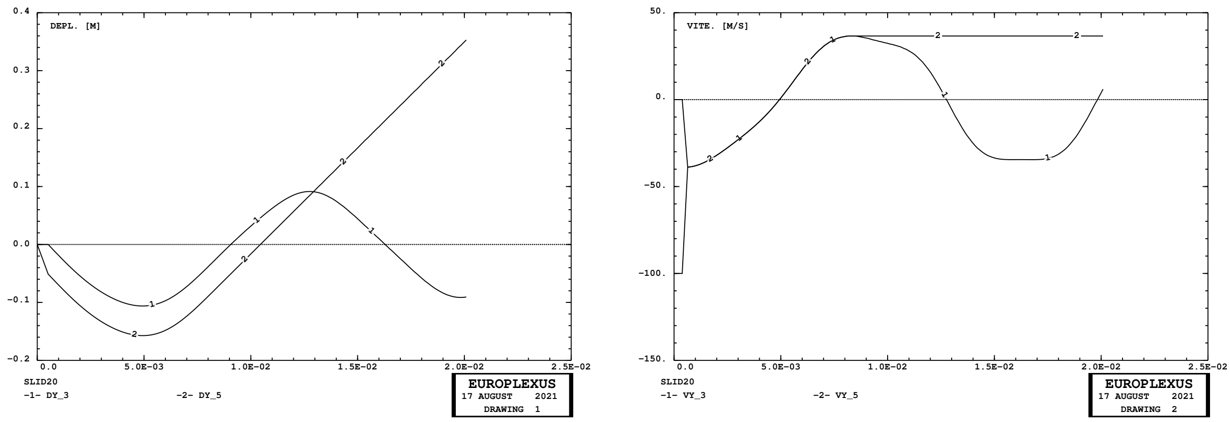
```
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                  NMAS LECT 1 2 3 4 TERM
                  NSLA LECT 5 TERM
INIT VITE 2 -100 LECT proj TERM
```

Figure 64 shows the initial and final mesh. Figure 65 shows the computed vertical displacements and velocities of characteristic points. Contact lasts between steps 4 ($t = 0.51$ ms) and 73 ($t = 9.34$ ms), then rebound occurs and the shell continues to oscillate elastically.



(a) Step 0 (b) Step 157

Figure 64: Initial and final mesh of test SLID20.



(a) Displacement (b) Velocity

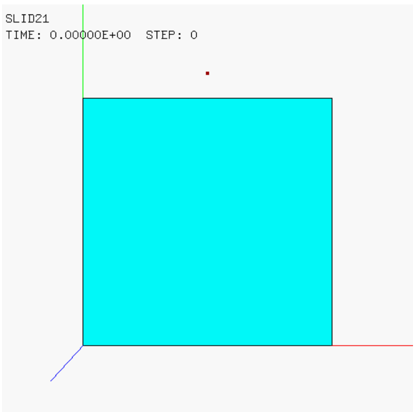
Figure 65: Some results of test SLID20.

3.3.2 Cases SLID21 and SLID22

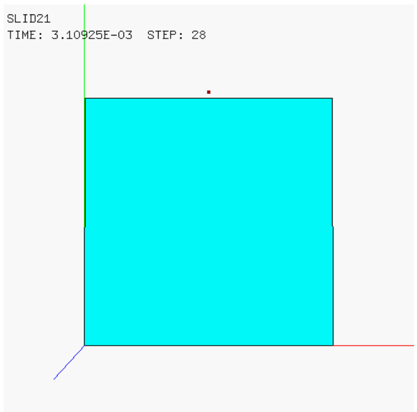
These tests aim at checking the set-up of *closed* master surfaces. The target is a square, which in case SLID21 is meshed by a single continuum quadrangle while in case SLID22 is meshed by four shells of type ED01. In both cases the entire perimeter of the target is declared as a master surface. Contact occurs in the middle of the upper master face.

Figure 66 shows the initial and final mesh for case SLID21. Figure 67 shows the computed vertical displacements and velocities of characteristic points. Contact lasts between steps 9 ($t = 1.00$ ms) and 13 ($t = 1.44$ ms), then rebound occurs and the target continues to oscillate elastically.

Figure 68 shows the initial and final mesh for case SLID22. Figure 69 shows the computed vertical displacements and velocities of characteristic points. Contact lasts between steps 9 ($t = 0.51$ ms) and 11 ($t = 1.40$ ms), then rebound occurs and the target continues to oscillate elastically.

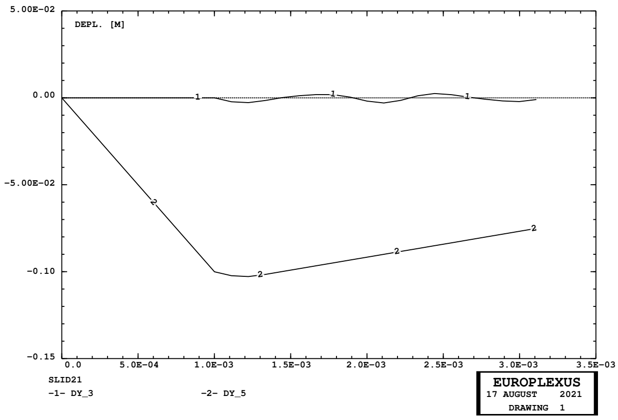


(a) Step 0

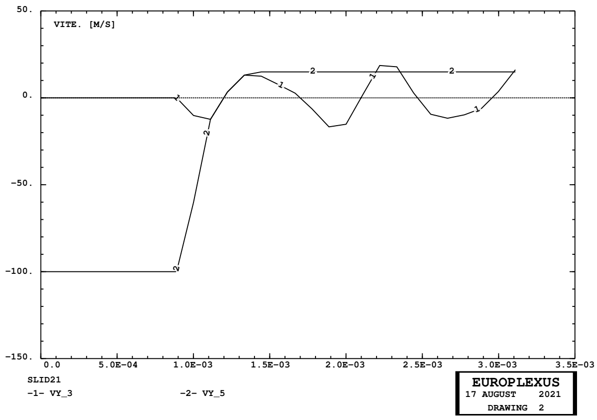


(b) Step 28

Figure 66: Initial and final mesh of test SLID21.

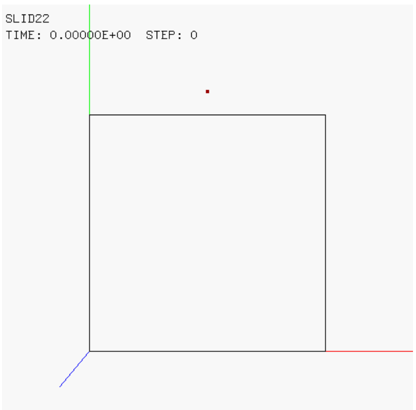


(a) Displacement

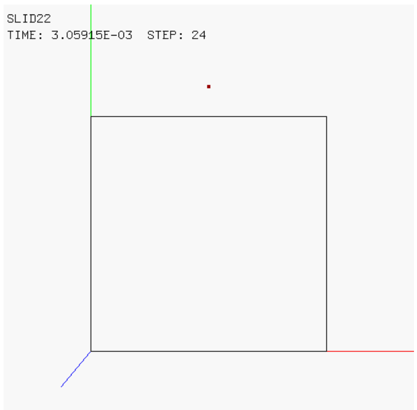


(b) Velocity

Figure 67: Some results of test SLID21.



(a) Step 0



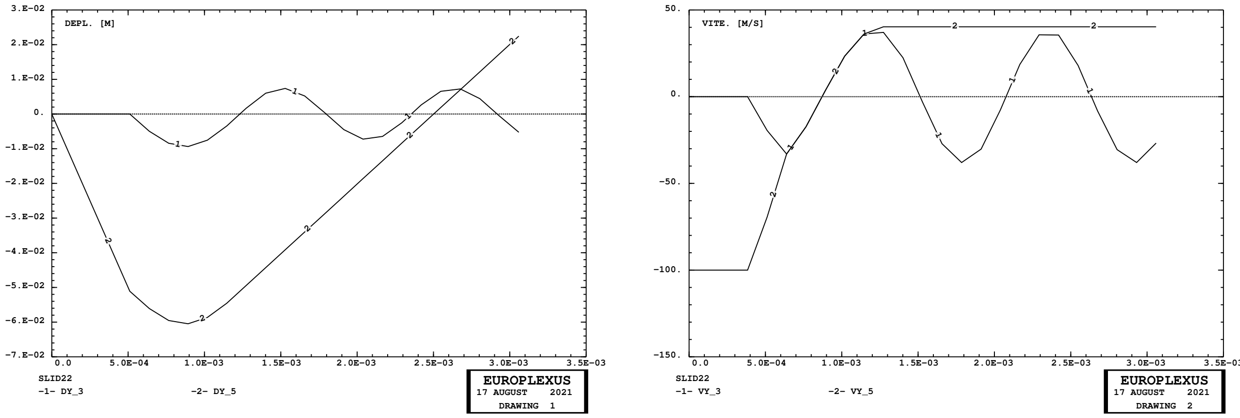
(b) Step 24

Figure 68: Initial and final mesh of test SLID22.

3.3.3 Cases SLID23, SLID24 and SLID25

These tests aim at checking penetration in convex or concave shells. A material point penetrates the shell near a node that is common to two adjacent master faces.

In test SLID23 the shell (meshed by four ED01 elements) appears as convex to the approaching



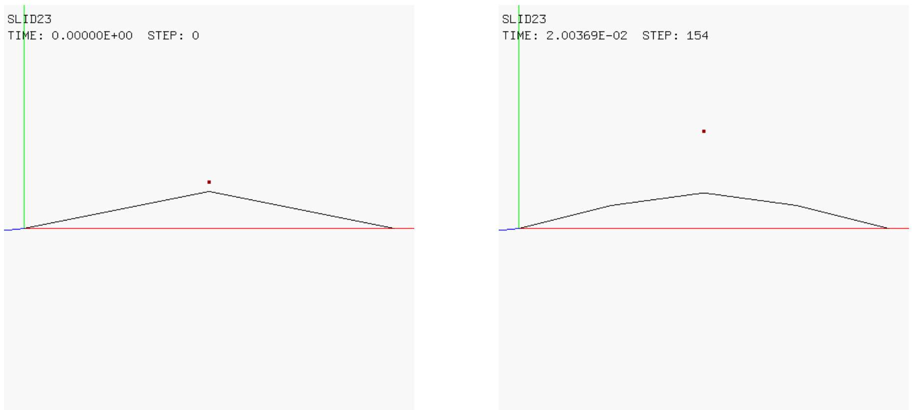
(a) Displacement (b) Velocity

Figure 69: Some results of test SLID22.

penetrator (slave node), while in test SLID24 the penetrator arrives from the other side so the shell appears as concave. Case SLID25 is similar to SLID24 but uses a simpler shell mesh consisting of only two elements.

In all cases two simultaneous penetrations are expected to occur. The code should impose just one contact link, along the average normal of the two penetrations that in these cases should be perfectly vertical due to symmetry of the problem. Therefore it is expected that the projectile bounces back with a perfectly vertical motion.

The results confirm these expectations. Figure 70 shows the initial and final mesh for case SLID23. Figure 71 shows the computed vertical displacements and velocities of characteristic points. Contact lasts between steps 4 ($t = 0.52$ ms) and 45 ($t = 5.84$ ms), then rebound occurs and the target continues to oscillate elastically.



(a) Step 0 (b) Step 154

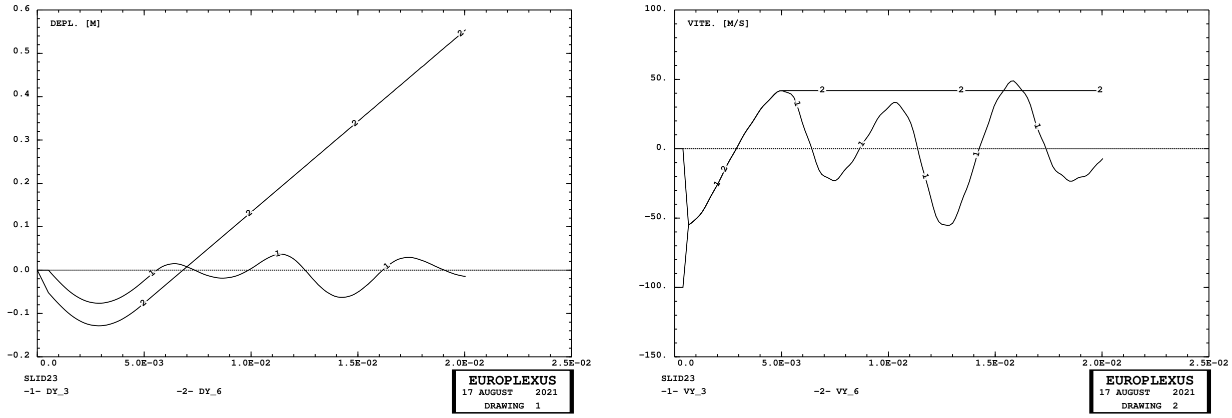
Figure 70: Initial and final mesh of test SLID23.

Figures 72 and 73 show the same results for test SLID24, while Figures 74 and 75 the same results for test SLID25.

3.3.4 Cases SLID27 and SLID28

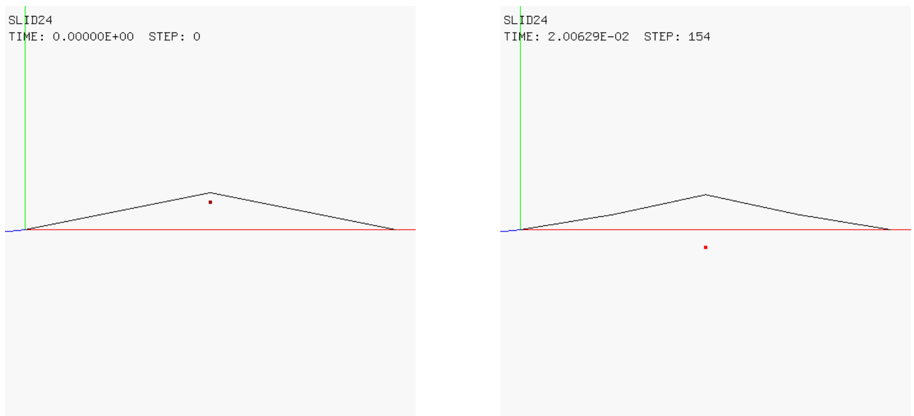
These tests are repetitions of cases SLID23 and SLID24, respectively, by modeling only 1/2 of the problem and using symmetry.

The results are very similar, but not identical, to the reference solutions, see Figures 76 and 77.



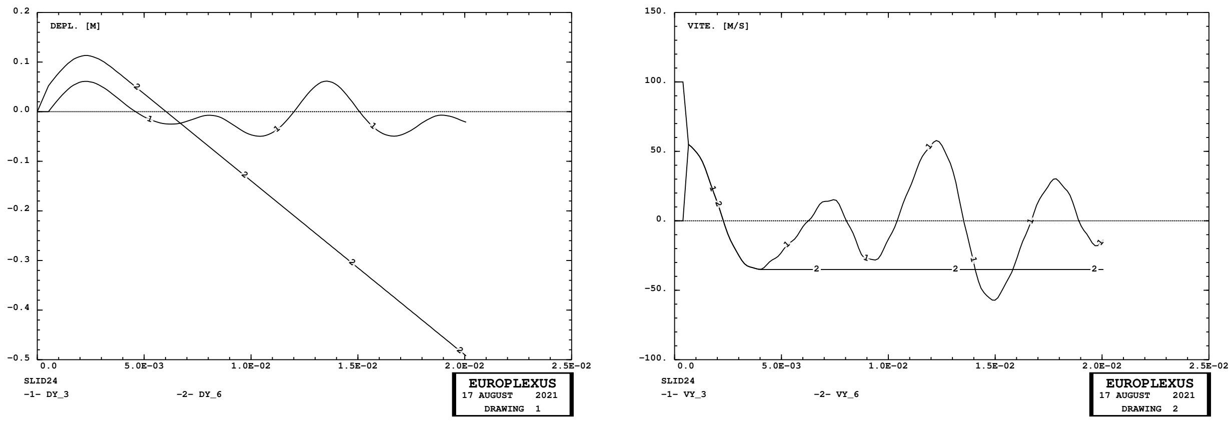
(a) Displacement (b) Velocity

Figure 71: Some results of test SLID23.



(a) Step 0 (b) Step 154

Figure 72: Initial and final mesh of test SLID24.

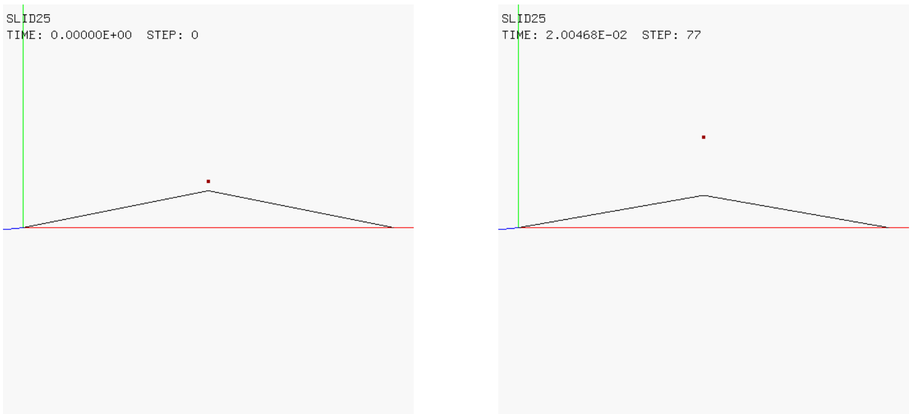


(a) Displacement (b) Velocity

Figure 73: Some results of test SLID24.

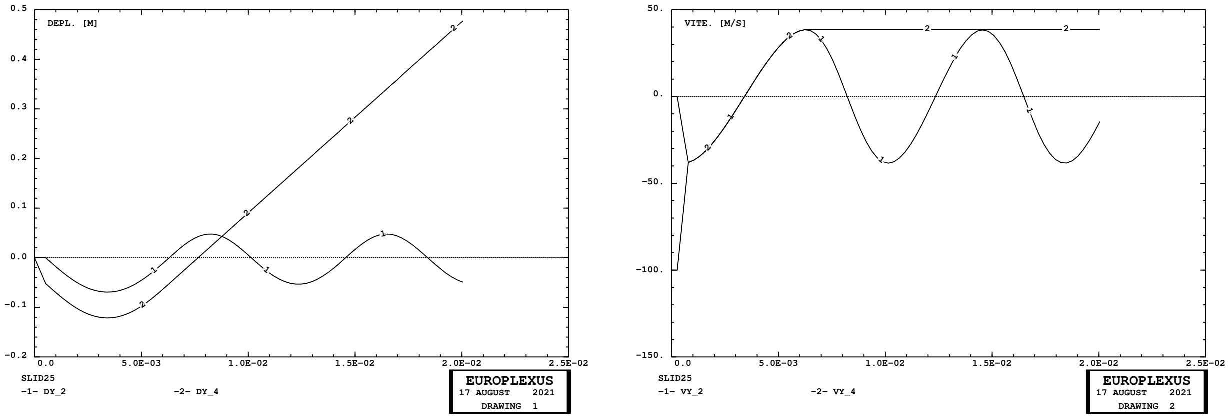
3.3.5 Case SLID30

This test represents the impact of a concentrated mass (PMAT) on a square shell, meshed by two triangles (T3GS). Since the target (shell) is not blocked, it is pushed away by the projectile. Impact



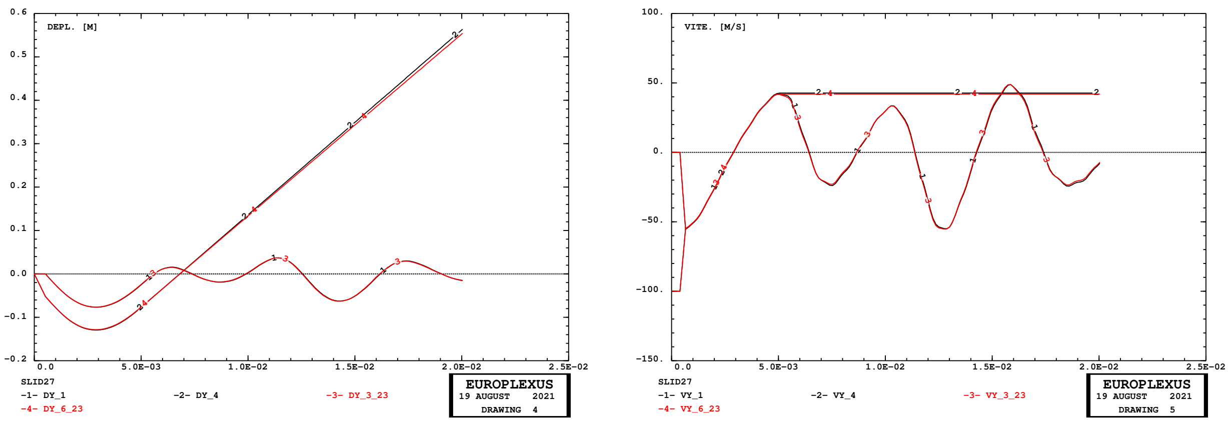
(a) Step 0 (b) Step 77

Figure 74: Initial and final mesh of test SLID25.



(a) Displacement (b) Velocity

Figure 75: Some results of test SLID25.

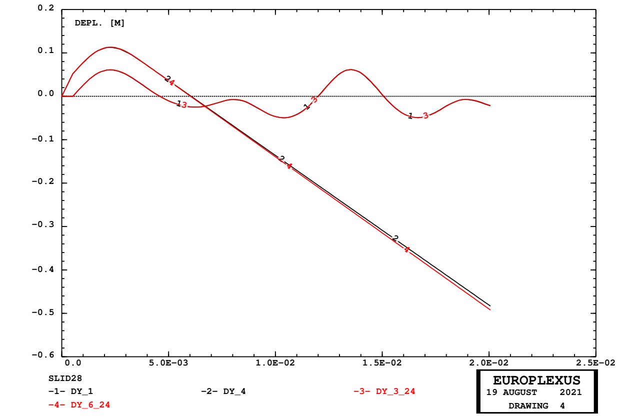


(a) Displacement (b) Velocity

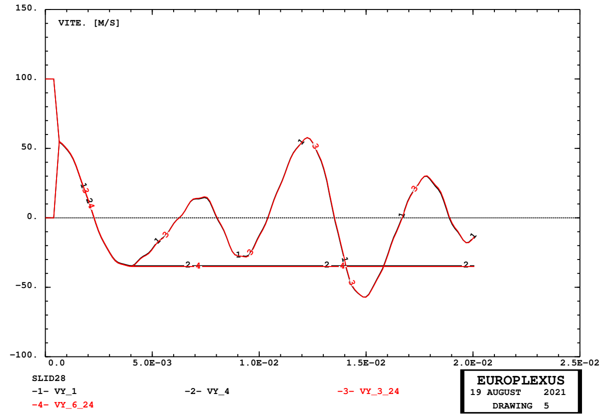
Figure 76: Some results of test SLID27 compared with SLID23.

occurs at the shell (quadrangle) center and therefore simultaneously on the two triangular master faces.

The main scope of the test is to verify the calculation of adjacent master faces in 3D (triangular) shells, which is correct. Some results are shown in Figures 78 and 79 and the solution is actually



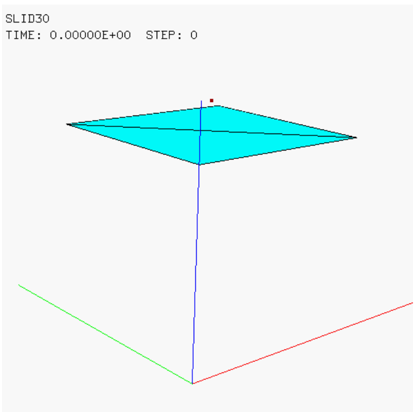
(a) Displacement



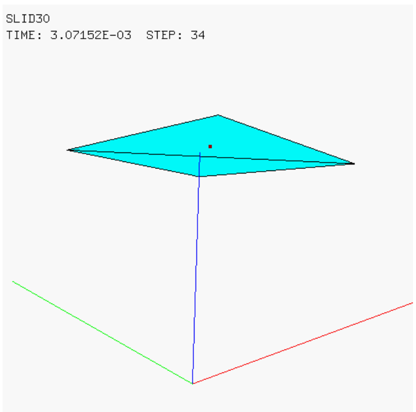
(b) Velocity

Figure 77: Some results of test SLID28 compared with SLID24.

symmetric within the limits of the very coarse discretization.

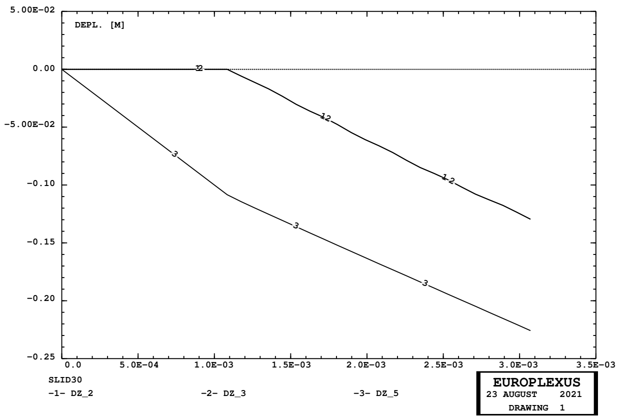


(a) Step 0

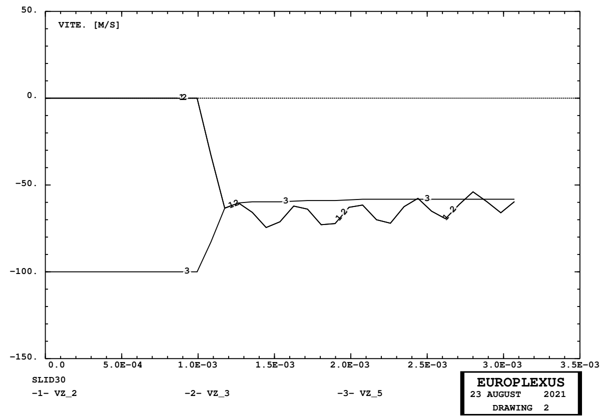


(b) Step 34

Figure 78: Initial and final mesh of test SLID30.



(a) Displacement

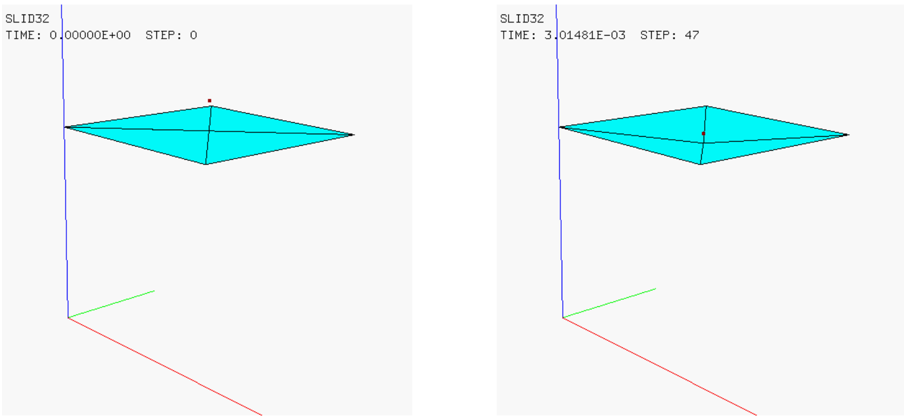


(b) Velocity

Figure 79: Some results of test SLID30.

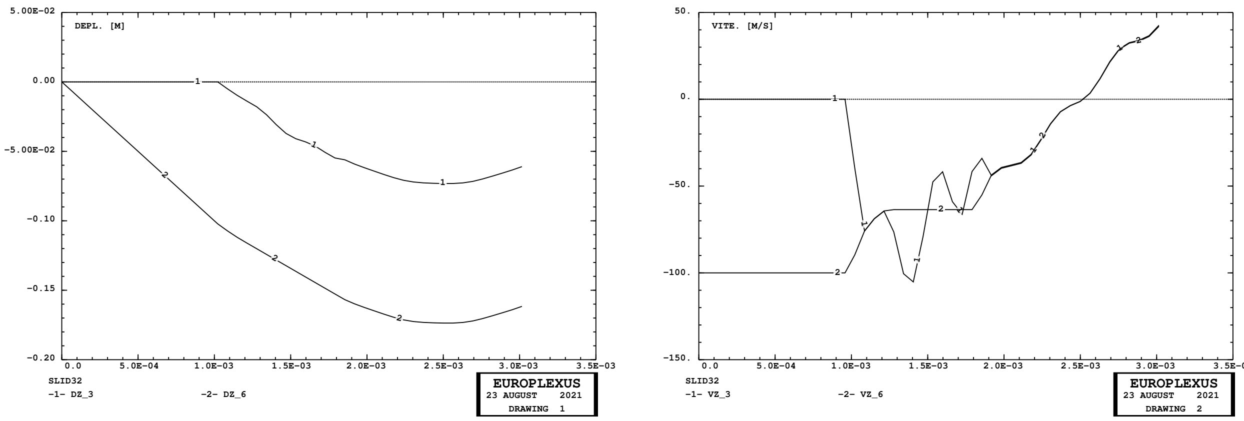
3.3.6 Case SLID32

This test is similar to SLID32 but the target is meshed by four T3GS instead of just two for an even more symmetric configuration. Another difference is that the shell contour is now completely blocked in translation. Impact at the center of the quadrangular shell causes four simultaneous penetrations into the master faces, which result in a single contact constraint. The solution is fairly symmetric, as shown in Figures 80 and 81.



(a) Step 0 (b) Step 47

Figure 80: Initial and final mesh of test SLID32.



(a) Displacement (b) Velocity

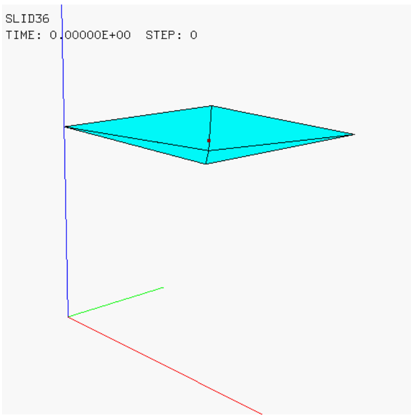
Figure 81: Some results of test SLID32.

3.3.7 Case SLID36

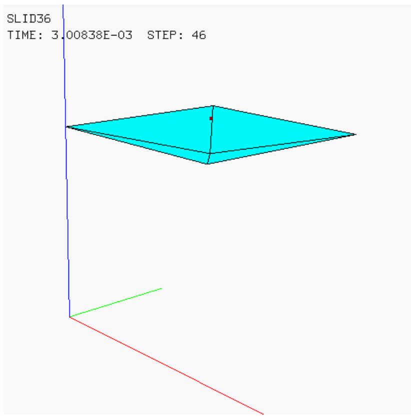
This test is similar to SLID32 but the central nodes 3 and 6 of the target and of the projectile are slightly lowered in order to create an impact on an initially concave (rather than plane) master surface. Master face protrusions (for shells) should not be automatically activated under these circumstances. Impact at the center of the upper face causes four simultaneous penetrations into the master faces, which result in a single contact constraint. Contact occurs between steps 1 and 26 of the simulation. The solution is fairly symmetric, as shown in Figures 82 and 83.

3.3.8 Case SLID37

This test is similar to SLID32 but the central nodes 3 and 6 of the target and of the projectile are slightly raised in order to create an impact on an initially convex (rather than plane) master surface.

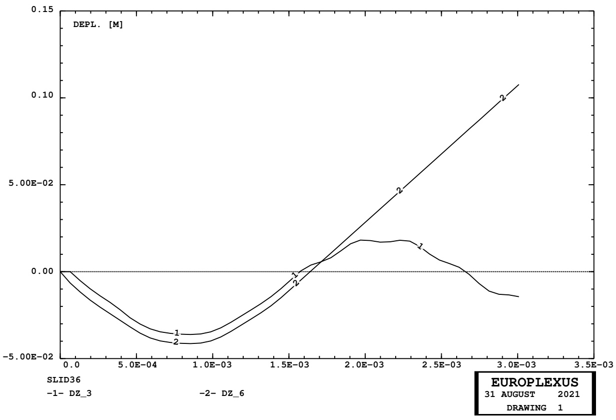


(a) Step 0

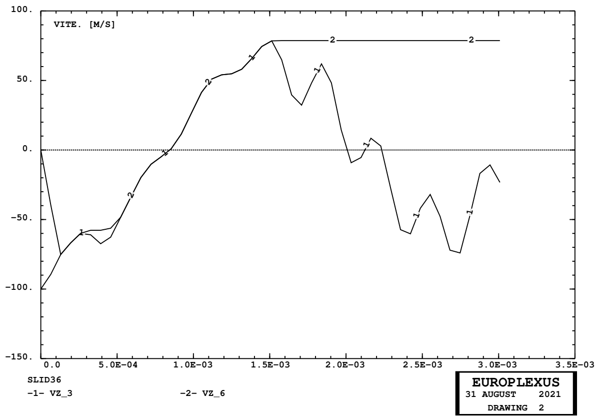


(b) Step 46

Figure 82: Initial and final mesh of test SLID36.



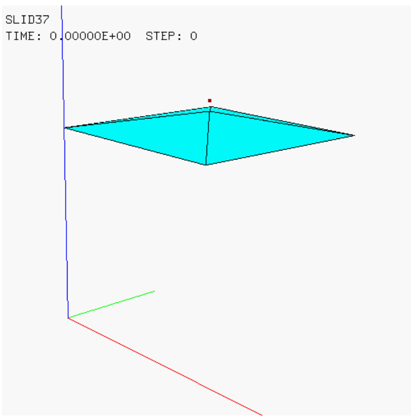
(a) Displacement



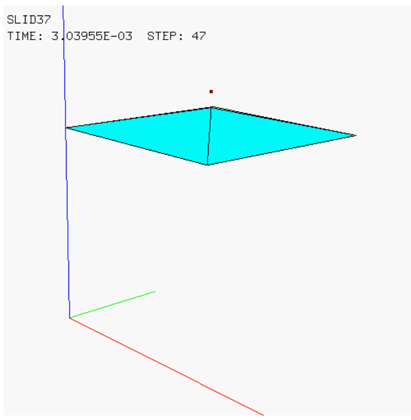
(b) Velocity

Figure 83: Some results of test SLID36.

Master face protrusions (for shells) should be automatically activated under these circumstances. Impact at the center of the upper face causes four simultaneous penetrations into the master faces, which result in a single contact constraint. Contact occurs between steps 18 and 26 of the simulation. The solution is fairly symmetric, as shown in Figures 84 and 85.

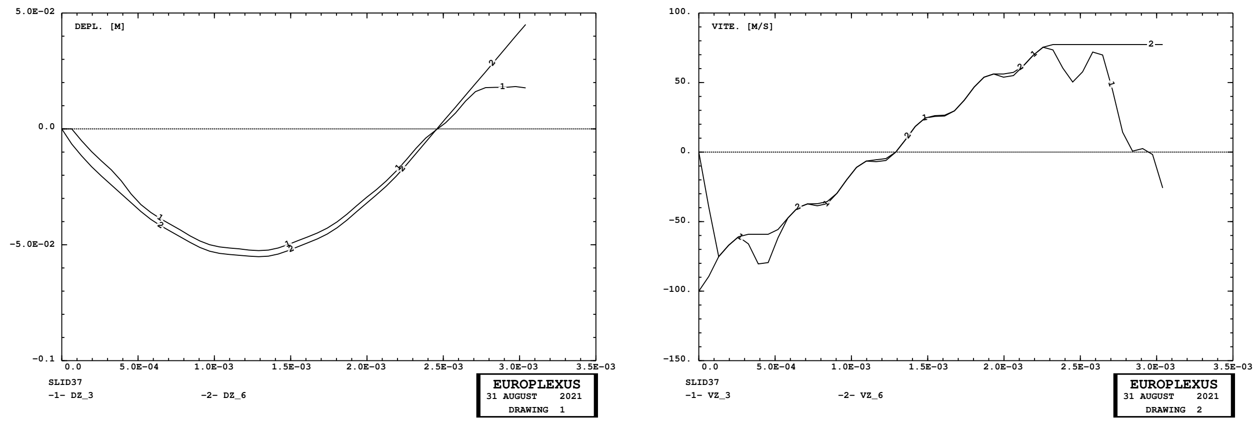


(a) Step 0



(b) Step 47

Figure 84: Initial and final mesh of test SLID37.

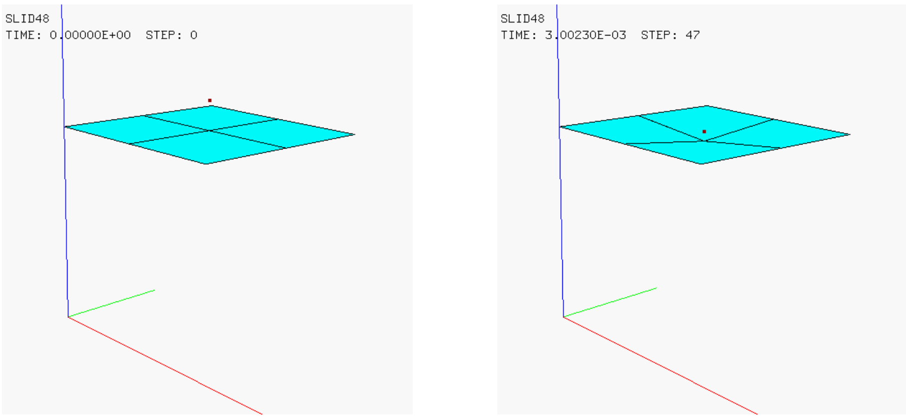


(a) Displacement (b) Velocity

Figure 85: Some results of test SLID37.

3.3.9 Case SLID48

This test is similar to SLID32 but the mesh is made of four Q4GS (quadrangular faces) instead of T3GS (triangular faces). The solution is fairly symmetric, as shown in Figures 86 and 87. The master surface is initially flat but it becomes slightly concave during the impact. Contact occurs on four master faces simultaneously.



(a) Step 0 (b) Step 47

Figure 86: Initial and final mesh of test SLID48.

3.3.10 Case SLID51

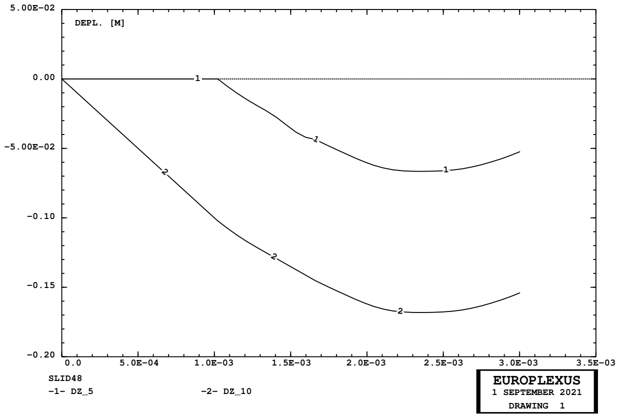
This test is similar to SLID48 but the central node of the target and the penetrator node are slightly raised so that impact occurs on a convex master surface, with the implications that this has on the use of protrusions.

The solution is fairly symmetric, as shown in Figures 88 and 89.

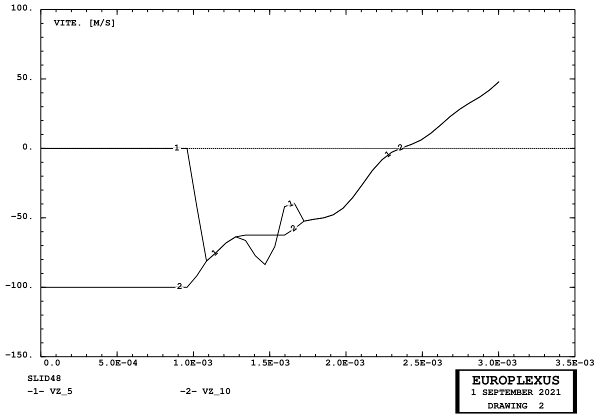
3.3.11 Case SLID52

This test is similar to SLID48 but the central node of the target and the penetrator node are slightly lowered so that impact occurs on a concave master surface, with the implications that this has on the use of protrusions.

The solution is fairly symmetric, as shown in Figures 90 and 91.

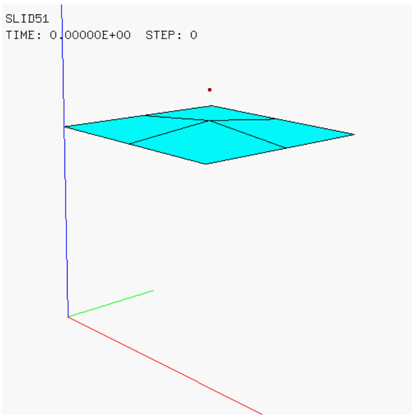


(a) Displacement

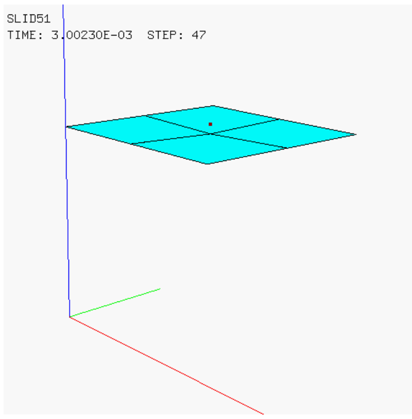


(b) Velocity

Figure 87: Some results of test SLID48.

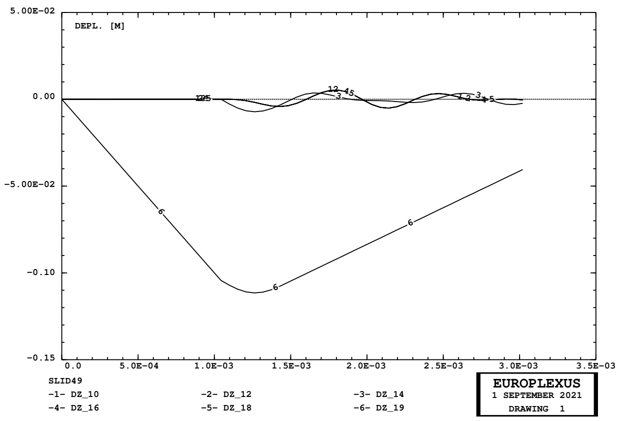


(a) Step 0

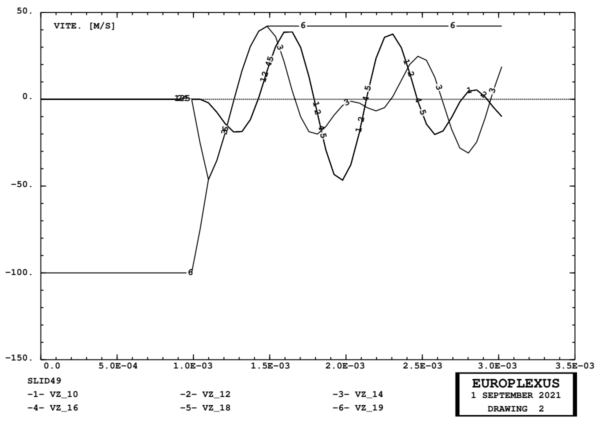


(b) Step 47

Figure 88: Initial and final mesh of test SLID51.



(a) Displacement

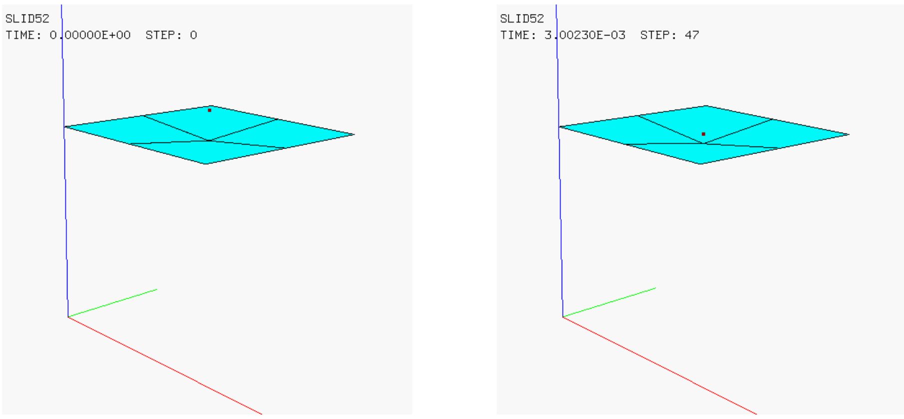


(b) Velocity

Figure 89: Some results of test SLID51.

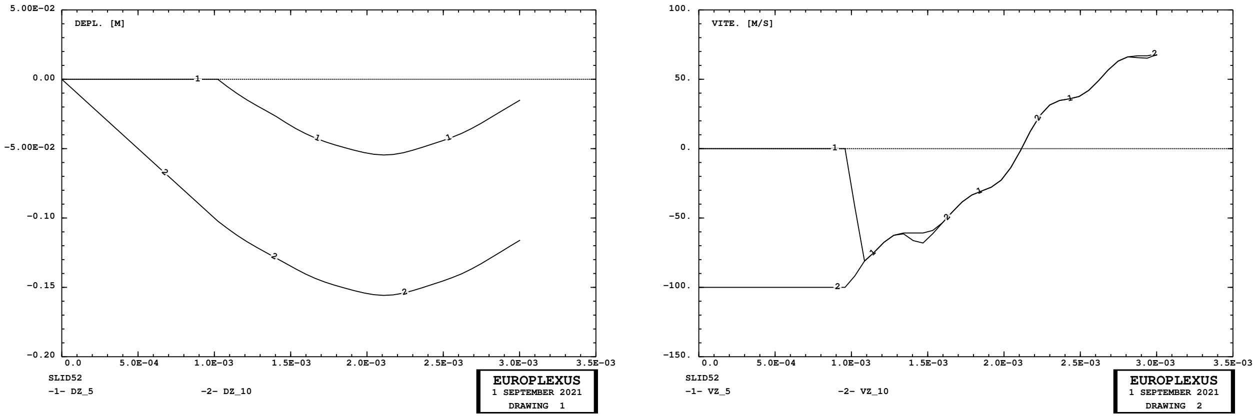
3.3.12 Case SLID55

This test is similar to SLID48 but we model only 1/2 of the problem by imposing a symmetry plane with `CONT SPLA`.



(a) Step 0 (b) Step 47

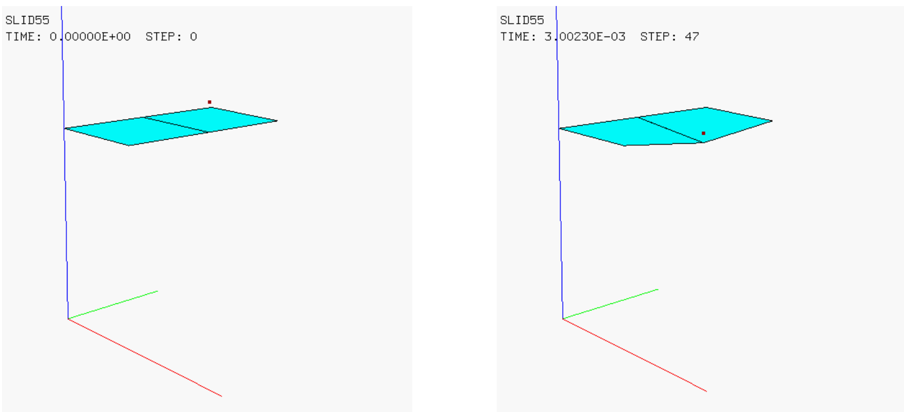
Figure 90: Initial and final mesh of test SLID52.



(a) Displacement (b) Velocity

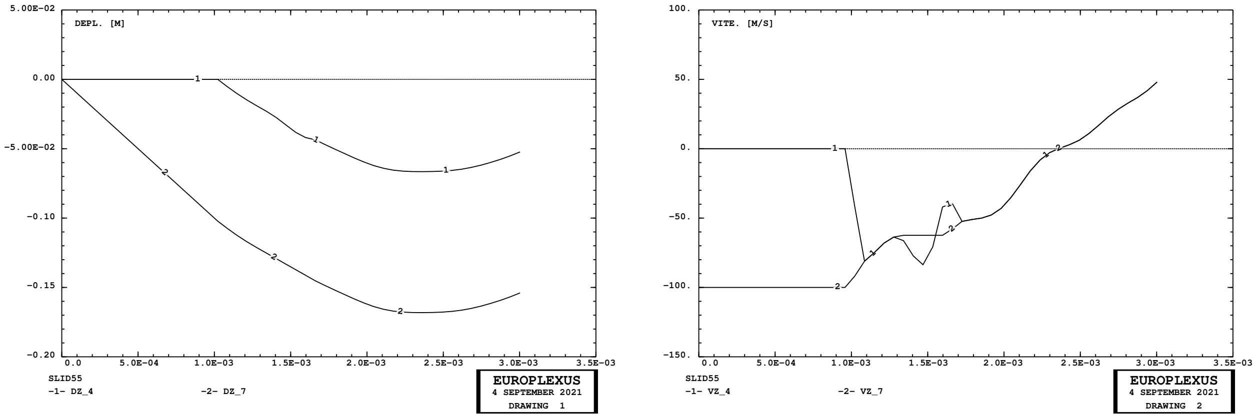
Figure 91: Some results of test SLID52.

The solution is identical to that with the full model, and is shown in Figures 92 and 93.



(a) Step 0 (b) Step 47

Figure 92: Initial and final mesh of test SLID55.



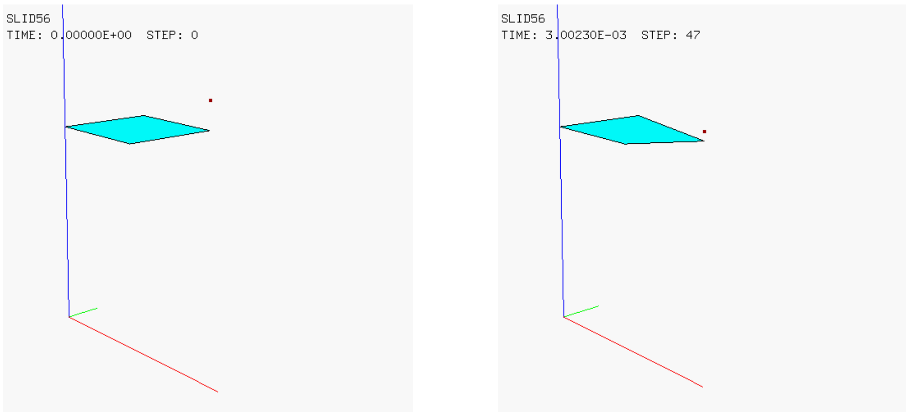
(a) Displacement (b) Velocity

Figure 93: Some results of test SLID55.

3.3.13 Case SLID56

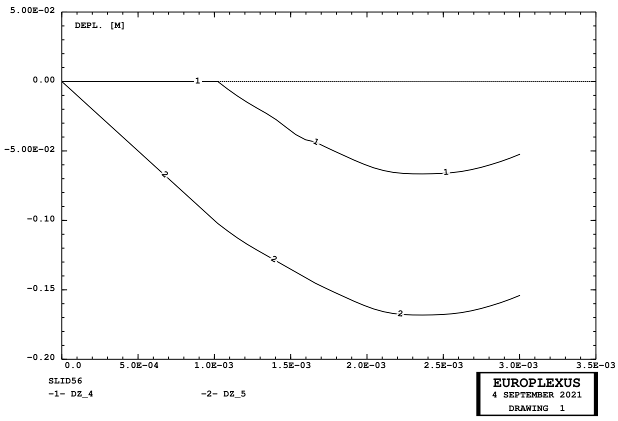
This test is similar to SLID48 but we model only 1/4 of the problem by imposing two symmetry planes with `CONT SPLA`.

The solution is identical to that with the full model, and is shown in Figures 94 and 95.

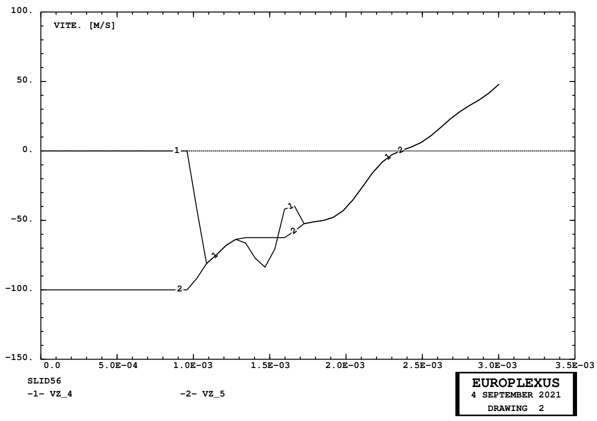


(a) Step 0 (b) Step 47

Figure 94: Initial and final mesh of test SLID56.



(a) Displacement



(b) Velocity

Figure 95: Some results of test SLID56.

4 Application — The sliding disk problem

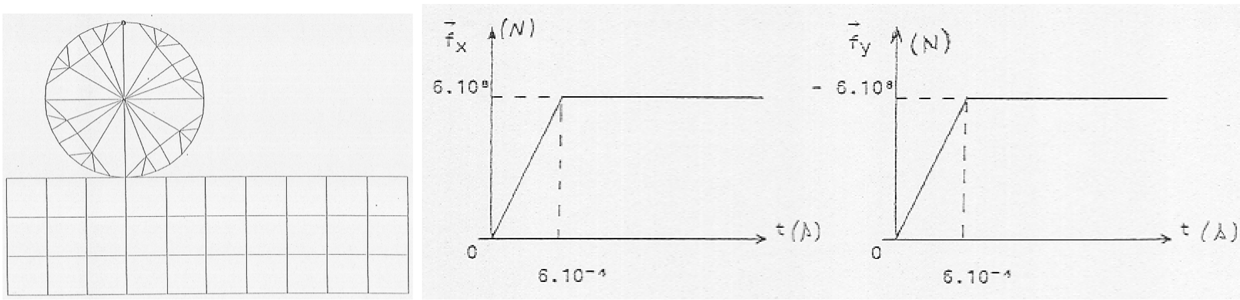
We now consider a slightly more complicated problem, the sliding of a disk along a solid plane, taken from reference [8] and solved more than 30 years ago with the PLEXUS code (ancestor of EPX) using the GLIS model. The problem has also been revisited more recently in reference [26].

The tests (the first one in 2D, the second one in 3D) represent the sliding, without or with friction, of a solid circular disk along a plane. The Cast3m mesh generation files are not available, so the meshes have been tentatively reconstructed from the data (some of which appear to be slightly inconsistent) and from the pictures contained in the report. Fortunately, the EPX files were listed in the report. They have been slightly adapted to conform to current EPX syntax.

4.1 Problem definition in 2D and original solutions from [8]

In the 2D problem the disk (projectile) has a radius $R = 2$ m, with 32 elements along the circumference, meshed by CAR4 and TRIA elements. The plane (target) is represented by a rectangle of length $L = 10$ m and height $h = 3$ m. It is meshed by 10×3 regular square elements (CAR4) of side 1 m. The disk is placed initially in contact with the plane (zero gap) and at a position of 3 m along the plane, see Figure 96(a). The lower base of the target is blocked in both directions. The initial velocity is zero everywhere. A plane strain (DPLA) formulation is assumed.

The material is assumed linear elastic (LINE) for both bodies, with $\rho = 7800$ kg/m^3, $E = 2 \times 10^{11}$ Pa, $\nu = 0$. There are two time-dependent forces applied to the centre of the disk: a horizontal force of nominal value $F_X = 6 \times 10^8$ N and a vertical force of nominal value $F_Y = -6 \times 10^8$ N. Both forces start from zero at the initial time $t_0 = 0$, grow up linearly until they reach the nominal value at $t_m = 0.6$ ms and then remain constant until the final time $t_f = 60$ ms, as shown in Figure 96(b).



(a) Initial mesh

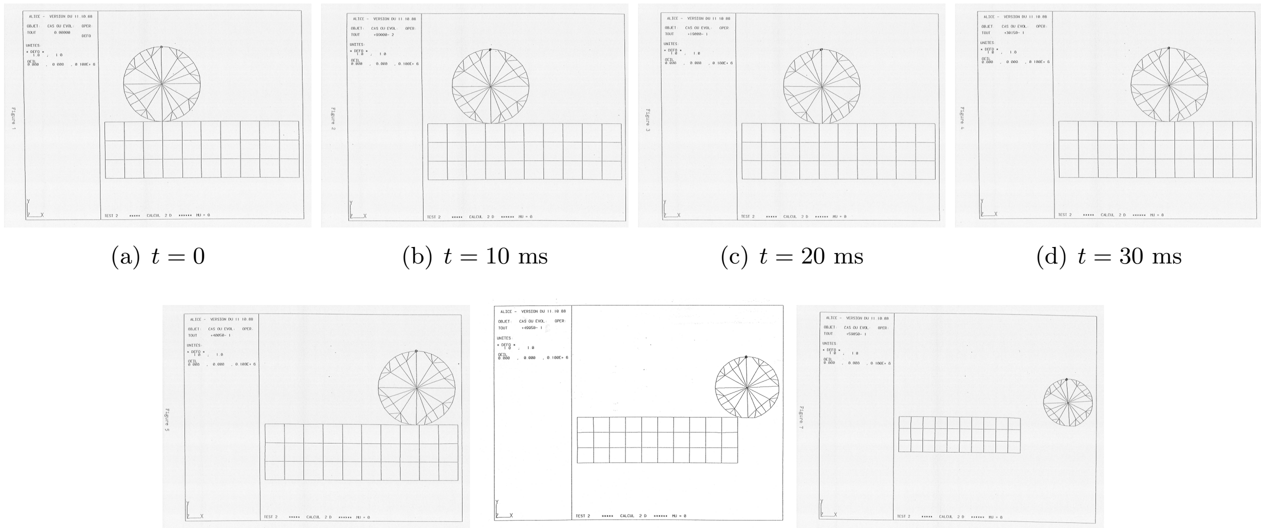
(b) Applied forces

Figure 96: Sliding disk problem in 2D (from [8])

The calculation is performed with a constant step $\Delta t = 5$ μs, requiring 12 000 steps until t_f. A first simulation is performed without friction. In the second simulation friction is assumed with $\mu_s = \mu_k = 0.25$ and $\gamma = 0$ (according to the problem description in the report [8]). In the input file listed in the same report we find $\gamma = 0.1$ instead. However, this discrepancy is irrelevant since when $\mu_s = \mu_k$ the expression describing the friction coefficient as a function of the relative velocity gives a constant friction coefficient ($\mu = 0.25$ here), irrespective of the actual value chosen for γ.

Figure 97 shows the original result obtained in the case without friction, while Figure 98 shows the original result obtained in the case with friction. In each image a small hand-made dot marks the position of the point initially located at the topmost position of the disk, in order to be able to appreciate the rotation of the disk (when present).

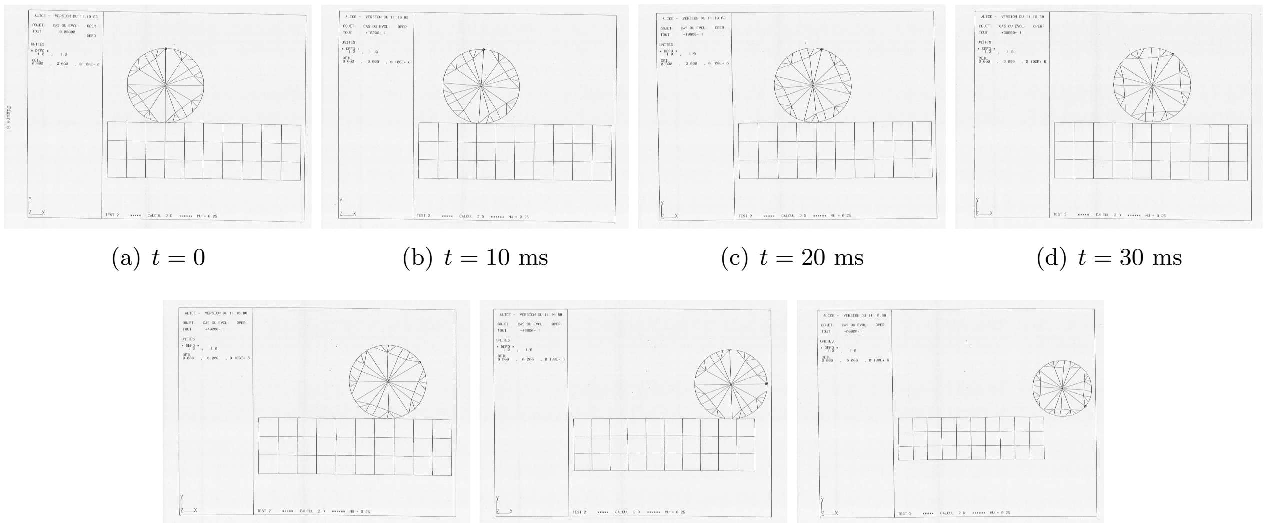
It can be seen that in the first solution the disk slides along the plane (almost) without any rotation, while in the second case it rotates (due to friction), although some sliding seems to remain especially in the first part of the motion (perhaps due to the fact that the vertical force is not yet big enough to cause enough friction in the initial period). Also, the overall translation of the disk is larger in the case without friction.



(a) $t = 0$ (b) $t = 10$ ms (c) $t = 20$ ms (d) $t = 30$ ms

(e) $t = 40$ ms (f) $t = 50$ ms (g) $t = 60$ ms

Figure 97: Result of the sliding disk problem in 2D without friction (from [8])



(a) $t = 0$ (b) $t = 10$ ms (c) $t = 20$ ms (d) $t = 30$ ms

(e) $t = 40$ ms (f) $t = 50$ ms (g) $t = 60$ ms

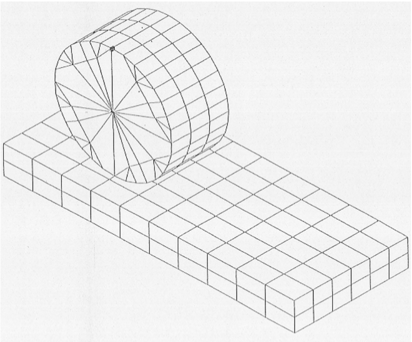
Figure 98: Result of the sliding disk problem in 2D with friction (from [8])

4.2 Problem definition in 3D and original solutions from [8]

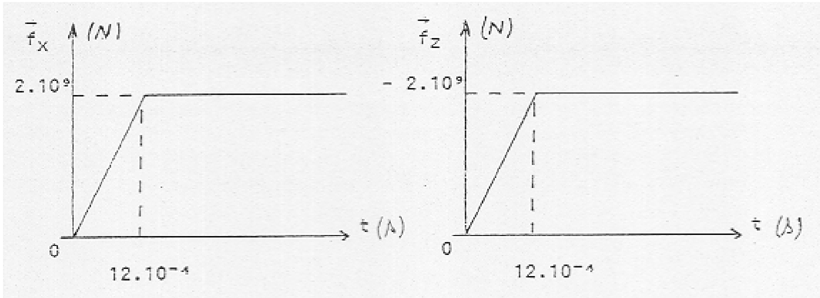
In 3D the problem is set similarly to the 2D case, except for the following details. The disk (projectile) is said (in the text of report [8]) to have a thickness $s = 3$ m, but from the Figures in the same report it appears that the actual thickness is $s = 2$ m (this is the value assumed for the subsequent EPX calculations). The mesh is composed of CUB6 and PRI6 elements. The plane is represented by a parallelepiped of length $L = 10$ m, width $w = 4$ m and height $h = 1$ m (from the Figures, while in the report's text it is erroneously said to have $h = 2$ m). It is meshed exclusively by CUB6 elements ($10 \times 6 \times 2 = 120$ elements), see Figure 99(a).

Like in 2D, the lower base of the target is completely blocked in translation. The forces seem to be applied to the (four) nodes located on the axis of the disk, with each force having a nominal value $F_X = -F_Z = 2 \times 10^9$ Pa, with a time variation similar to that of the 2D case but with $t_m = 1.2$ ms, as shown in Figure 99(b).

The calculation is reportedly performed with a constant step $\Delta t = 20$ μs and until a final time $t_f = 40$ ms, which requires 2000 time steps. A first simulation is performed without friction, see the results in Figure 100. In the second simulation friction is assumed, with the same parameters as in



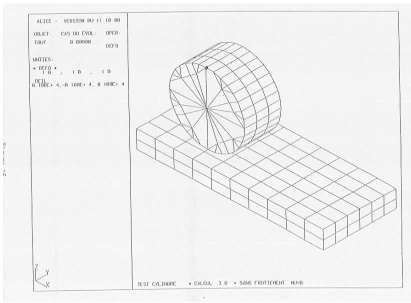
(a) Initial mesh



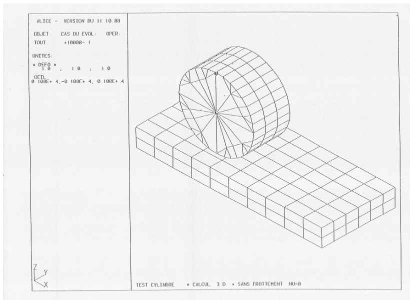
(b) Applied forces

Figure 99: Sliding disk problem in 3D (from [8])

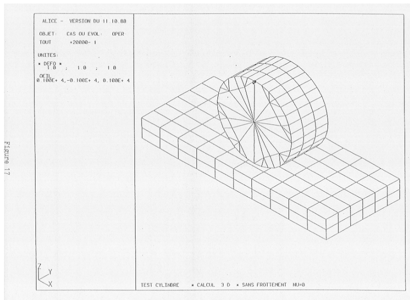
the 2D case, see the results in Figure 101.



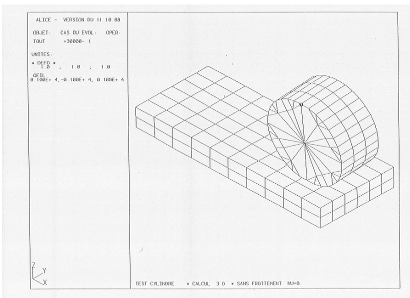
(a) $t = 0$



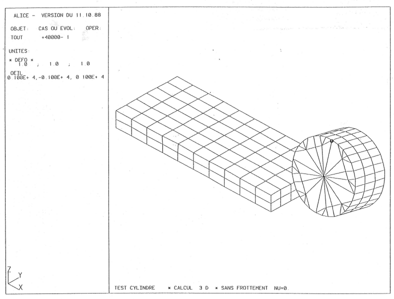
(b) $t = 10$ ms



(c) $t = 20$ ms



(d) $t = 30$ ms



(e) $t = 40$ ms

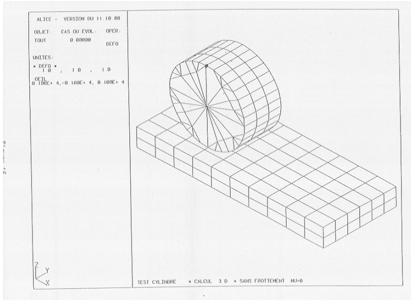
Figure 100: Result of the sliding disk problem in 3D without friction (from [8])

4.3 Solutions in 2D using GLIS

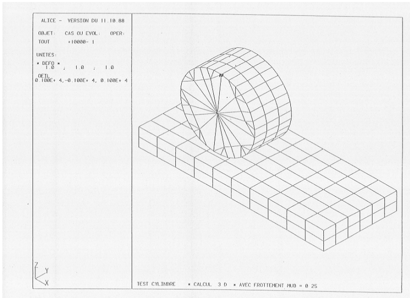
The 2D calculations performed with EPX by using the GLIS contact model (so-called *sliding lines* in 2D) are summarized in Table 7.

Case	Mesh	Description	Final time [ms]	Steps	CPU [s]
FROT23	222 CAR4 1 PMAT	GLIS, no friction	60	30 000	11.8
FROT24	222 CAR4 1 PMAT	GLIS, with friction	60	30 000	11.9

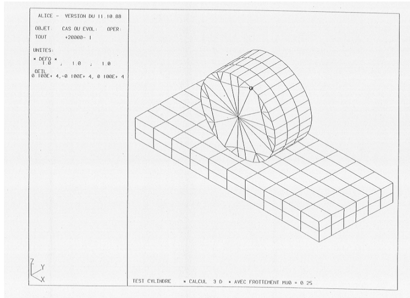
Table 7: Calculations for the sliding disk problem in 2D using GLIS.



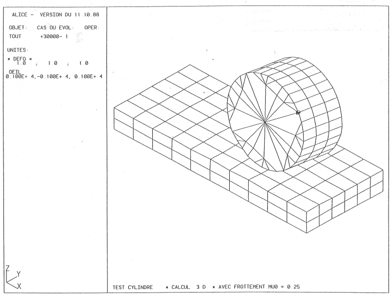
(a) $t = 0$



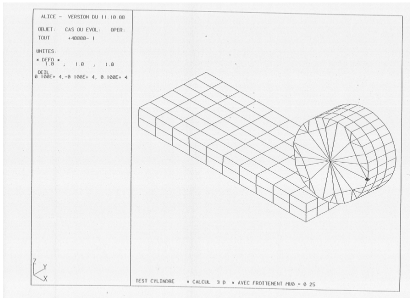
(b) $t = 10$ ms



(c) $t = 20$ ms



(d) $t = 30$ ms



(e) $t = 40$ ms

Figure 101: Result of the sliding disk problem in 3D with friction (from [8])

4.3.1 Case FROT23

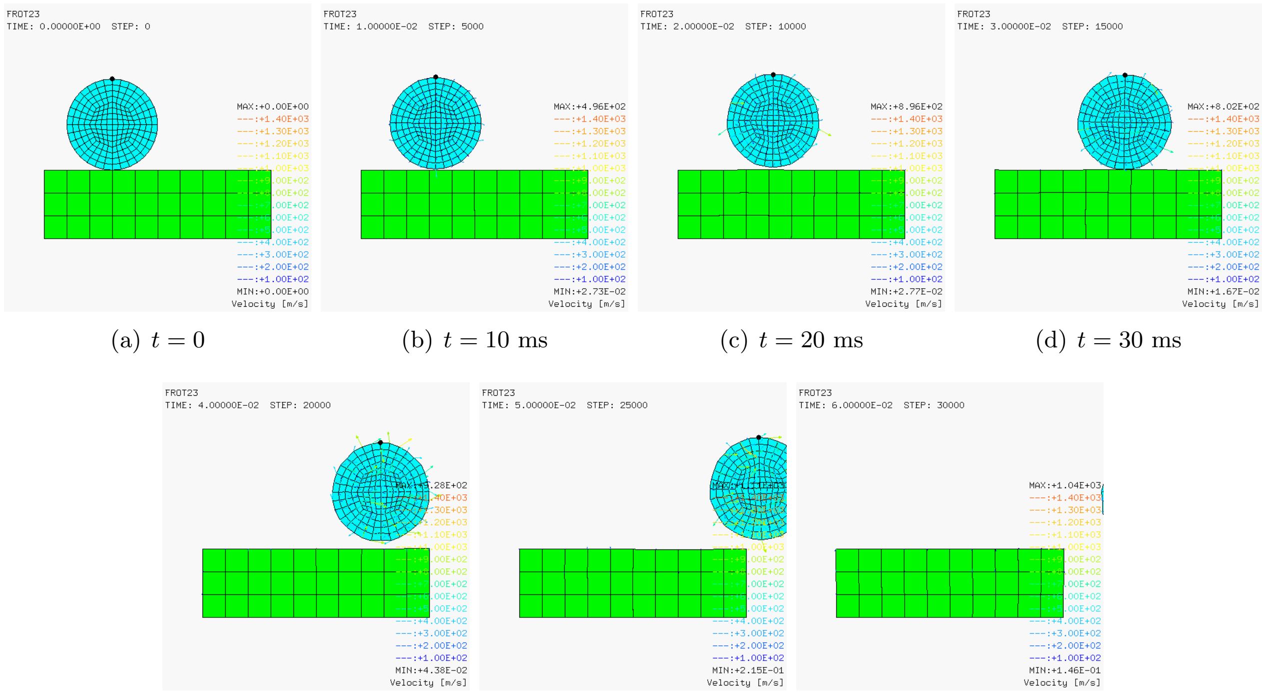
This is an attempt at reproducing with EPX the 2D solution without friction. The mesh is shown in Figure 102(a). Note that the disk has been meshed more regularly than in the original solution, by using exclusively quadrangles. Although the same subdivision of the disk circumference as in the original mesh has been maintained (32 segments), the internal mesh of the disk uses more and smaller elements. The constant time step used in this simulation has therefore been reduced to $\Delta t = 2.0$ μs, resulting in 30 000 steps to reach the final time $t_f = 60$ ms. This is a bit strange since the code reports a stability step of 23 μs. However, attempts at obtaining a solution with either $\Delta t = 20.0$ μs or $\Delta t = 5.0$ μs fail (élément croisé).

Using the `GLIS` model in 2D (*lignes de glissement*) is notoriously difficult in EPX due to its archaic input syntax. The model has apparently not yet been converted to the new links formulation (`LINK COUP`) and so use has to be made of the old `LIAI` directive (which even requires a dimensioning for the sliding lines):

```
DIME GLIS 1 200 TERM
 . . .
!LINK COUP
LIAI
    BLOQ 12 LECT bas TERM
    GLIS 1
        MAIT LECT pb2 TERM
        ESCL LECT pc1 pc2 pc3 pc4 TERM
```

A zero-mass material point (`PMAT`) is attached to the upper point of the disk in order to appreciate the disk rotation. It appears as a small black dot in the pictures, see Figure 102.

Other results of this calculation are presented in Figure 103. The first image shows the vertical position of the lowest point of the disk (i.e., the point initially in contact with the plane). The second image shows the vertical displacements of three points of the disk: the lowest one, the central one and the highest one (marker). There seems to be an excessive vertical deformation of the disk since the displacements are largely different (and there is only very little rotation). The next image shows the horizontal displacements of the same points, which are almost equal (very small rotation). The last picture shows the vertical velocity of the disk centre, and is very noisy.



(a) $t = 0$ (b) $t = 10$ ms (c) $t = 20$ ms (d) $t = 30$ ms

(e) $t = 40$ ms (f) $t = 50$ ms (g) $t = 60$ ms

Figure 102: Result of test FROT23

The solution (especially when looking at an animation) appears much more “bouncy” than the original one, although this might (unlikely) depend on the limited number of frames available in the original report. At certain moments the disk slightly penetrates the plane and at others it detaches considerably.

Overall, there is (almost) no rotation, only translation. Since a relatively large constant horizontal force is applied during the second part of the transient (from t_m to t_f), the disk reaches a large horizontal velocity, of the order of 350 m/s (but with large oscillations) at the end of the transient.

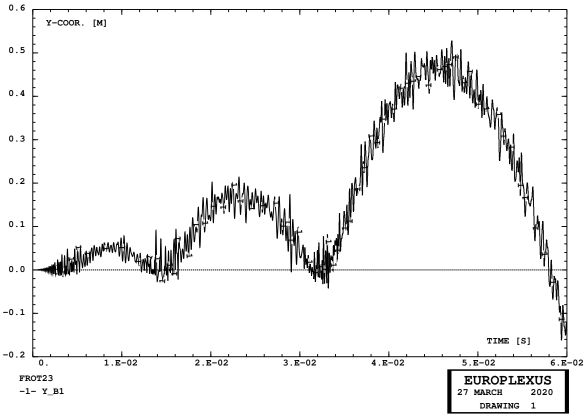
A further simulation FROTN3 has been carried out by adding the option `GLIS NORM ELEM` but the solution obtained is identical (bouncy). It is possible that this option is ignored in the old (`LIAI`-based) implementation of `GLIS`. Overall it is bit unfortunate that it is not possible to reproduce the results of the old report with `GLIS`.

4.3.2 Case FROT24

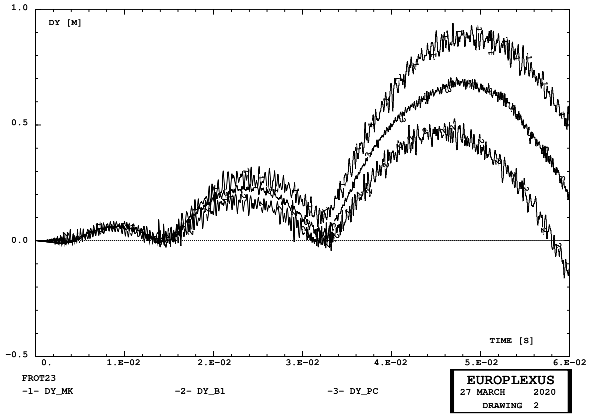
This is a repetition of the previous solution by activating the friction. The friction is tentatively specified as part of the complements of geometry `COMP` directive, as in the original PLEXUS input from reference [8], and not as part of the `GLIS` directive itself (like in 3D tests using `LINK GLIS`).

```
COMP EPAI 0.2 LECT mark TERM ! Only for visualization
     NGRO 1 'b1' LECT circ TERM COND NEAR POIN 3 0
     COUL TURQ LECT circ TERM
          VERT LECT base TERM
          ROUG LECT mark TERM
     FROT 1 MUO 0.25 MU1 0.25 GAMM 0.1
```

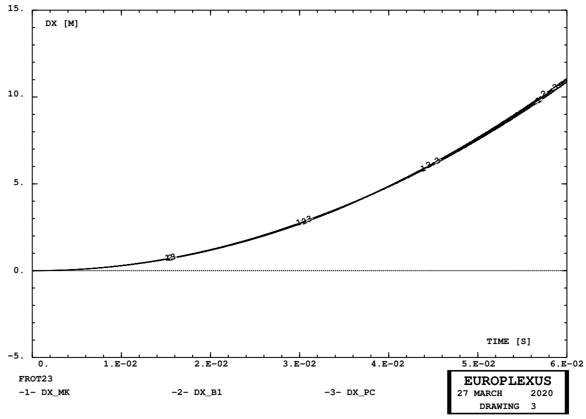
As it appears from the solution, shown in Figure 104, there is a certain rotation of the disk, but much less than in the original solution. For example, at $t = 50$ ms, the disk appears to have rotated about 20 degrees, while it had rotated almost 90 degrees in the original solution. On the contrary, the translation in this solution is larger than in the reference. This may also be an indication that there is less overall contact than in the reference between the disk and the plane (“bouncy” solution). Other results of this calculation are presented in Figure 105.



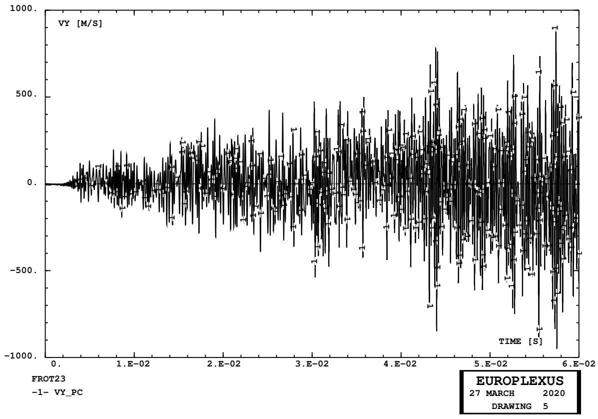
(a) Vertical coordinate



(b) Vertical displacements



(c) Horizontal displacements



(d) Vertical velocity

Figure 103: Further results of case FROT23

Overall, the solutions FROT23 and FROT24 obtained with GLIS in 2D look very poor. However, this might depend on the fact that using the sliding lines model is difficult and requires some insight that is perhaps beyond the limits and scope of the present report.

4.4 Solutions in 2D using SLID

The calculations performed with EPX by using the SLID contact model in 2D are summarized in Table 8.

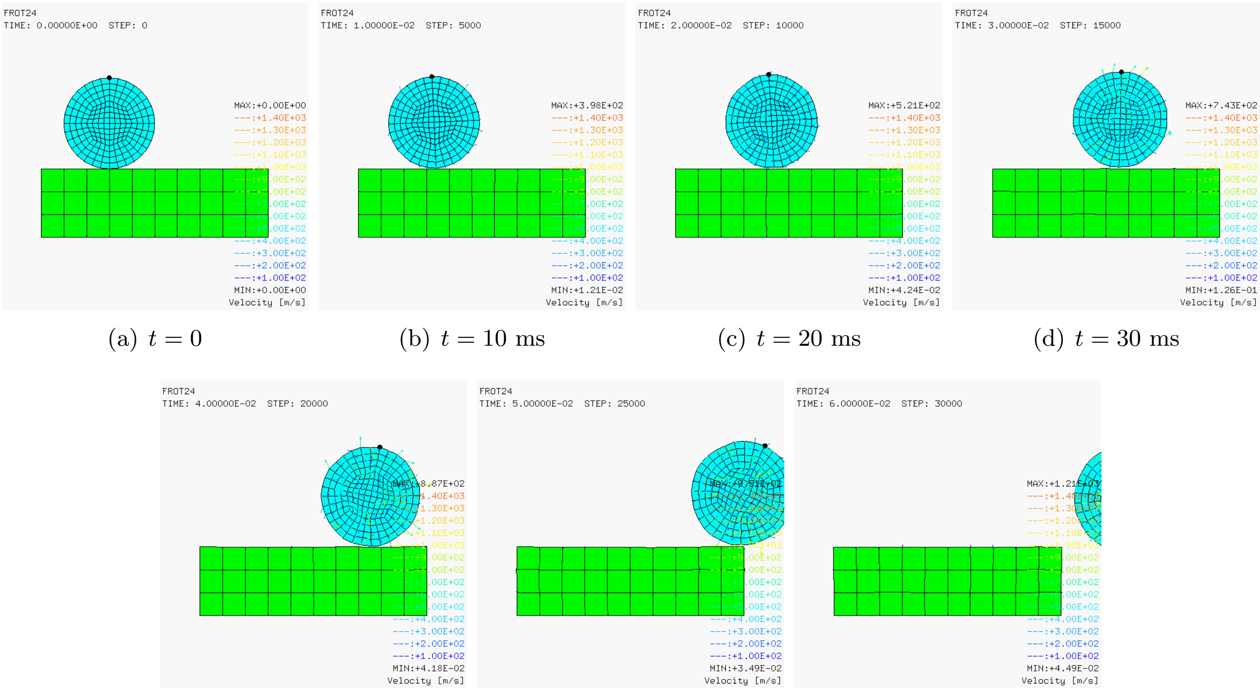
Case	Mesh	Description	Final time [ms]	Steps	CPU [s]
SLID14	222 CAR4 1 PMAT	SLID, no friction	60	30 000	13.3
SLID15	222 CAR4 1 PMAT	Same as 14 but with friction	60	30 000	14.0
SLID18	222 CAR4 1 PMAT	Idem 14 but 2 sliding surfaces	60	30 000	14.1

Table 8: Calculations for the sliding disk problem in 2D using SLID.

4.4.1 Case SLID14

This test is similar to FROT23 (no friction) but uses the SLID contact model (under LINK COUP):

```
LINK COUP
     BLOQ 12 LECT bas TERM
     SLID 1 SURF EMAS LECT base TERM
                 NMAS LECT pb2 TERM
                 NSLA LECT pc1 pc2 pc3 pc4 TERM
```



(a) $t = 0$ (b) $t = 10$ ms (c) $t = 20$ ms (d) $t = 30$ ms

(e) $t = 40$ ms (f) $t = 50$ ms (g) $t = 60$ ms

Figure 104: Result of test FROT24

The solution, presented in Figures 106 and 107, is much smoother and more regular (no spurious bouncing) than case FROT23 and it looks more similar to the original solution with `GLIS` reported in the original report from CEA [8]. The disk slides along the target without any appreciable rotation.

4.4.2 Case SLID15

This test is similar to SLID14 but we add friction:

```
LINK COUP
     BLOQ 12 LECT bas TERM
     SLID 1 SURF FROT MUST 0.25 MUDY 0.25 GAMM 0.1
               EMAS LECT base TERM
               NMAS LECT pb2 TERM
               NSLA LECT pc1 pc2 pc3 pc4 TERM
```

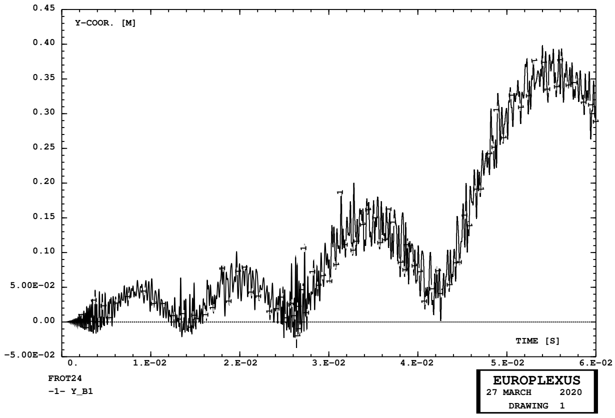
The solution, presented in Figures 108 and 109, is much smoother and more regular (no spurious bouncing) than case FROT24 and it looks more similar to the original solution with `GLIS` reported in the original report from CEA [8]. The disk slides along the target by rotating at the same time, as expected due to the friction.

4.4.3 Case SLID18

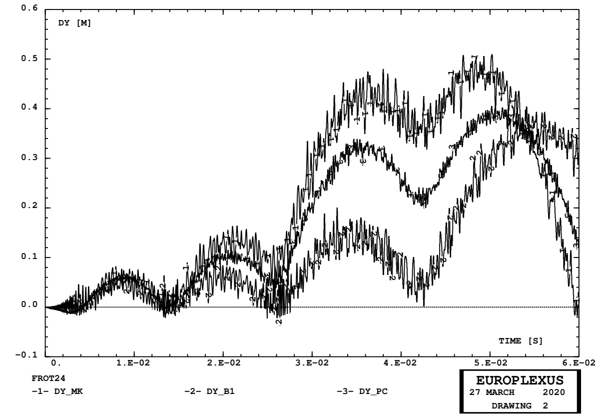
This test is similar to SLID14 but we use two (symmetric) sliding surfaces:

```
LINK COUP
     BLOQ 12 LECT bas TERM
     SLID 2 SURF EMAS LECT base TERM
                 NMAS LECT pb2 TERM
                 NSLA LECT pc1 pc2 pc3 pc4 TERM
            SURF EMAS LECT circ TERM
                 NMAS LECT m2 TERM
                 NSLA LECT s2 TERM
```

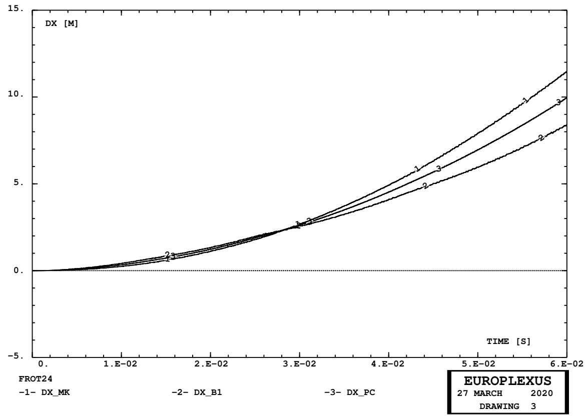
The solution, presented in Figures 110 and 111, is noisy and not as convincing as solution SLID14.



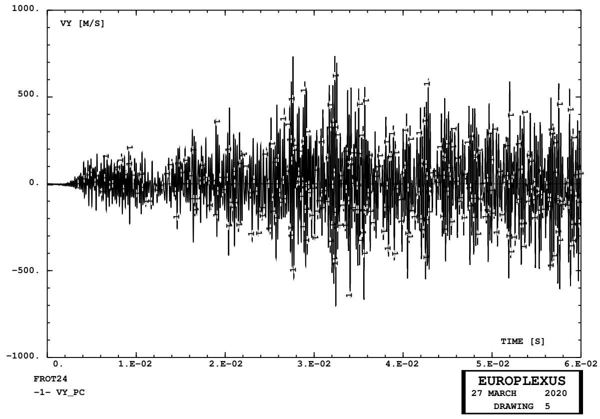
(a) Vertical coordinate



(b) Vertical displacements



(c) Horizontal displacements



(d) Vertical velocity

Figure 105: Further results of case FROT24

4.5 Solutions in 3D using `GLIS`

The 3D calculations performed with EPX by using the `GLIS` contact model (so-called *sliding surfaces* in 3D) are summarized in Table 9.

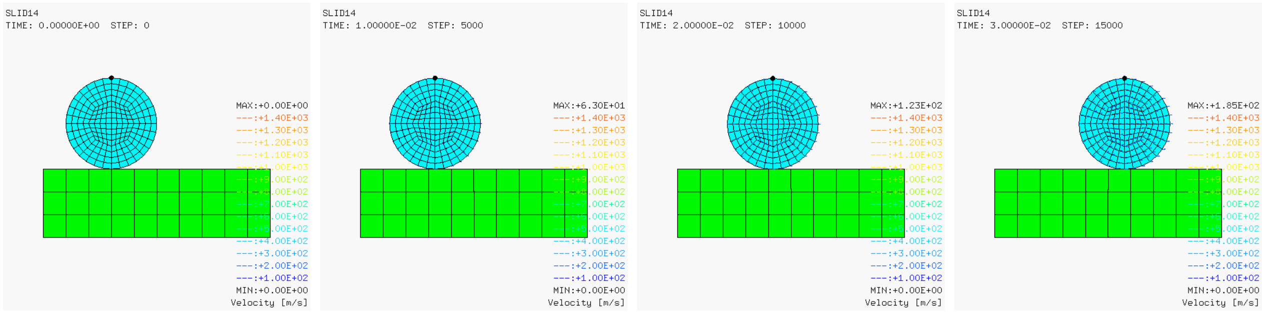
Case	Mesh	Description	Final time [ms]	Steps	CPU [s]
FROT66	696 CUB8 1 PMAT	`GLIS`, no friction	40	2000	23.8
FROT67	696 CUB8 1 PMAT	`GLIS`, with friction	40	2000	23.4

Table 9: Calculations for the sliding disk problem in 3D using `GLIS`.

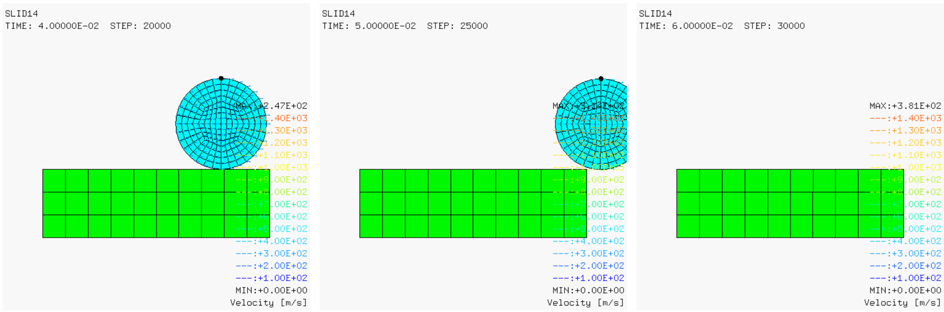
4.5.1 Case FROT66

This is an attempt at reproducing with EPX the 3D simulations from the original CEA report [8]. The problem definition from reference [8] is slightly modified (in particular the applied load distribution) in order to render the solution more regular, see details in reference [24]. The loads declaration is:

```
CHAR 1 FACT 2
    FORC 1  3.33333E8 LECT f1 TERM
    FORC 1  6.66667E8 LECT f2 TERM
    FORC 2 -3.33333E8 LECT f1 TERM
    FORC 2 -6.66667E8 LECT f2 TERM
    TABL 3 0. 0.  12.E-4 1.  6. 1.
```



(a) $t = 0$ (b) $t = 10$ ms (c) $t = 20$ ms (d) $t = 30$ ms



(e) $t = 40$ ms (f) $t = 50$ ms (g) $t = 60$ ms

Figure 106: Result of test SLID14

Some results are presented in Figure 112. The first two pictures show the vertical positions and displacements of some reference nodes, presenting a relatively large rebound which produces the observed "bounciness" of the solution. The last picture shows the horizontal displacements. The solution resembles a parabola, which is the correct answer since the horizontal force is constant (except in the relatively short initial part of the transient where it follows a linear ramp). There is a slight spreading of the result for the three monitored nodes, which corresponds to a slight rotation of the projectile. This should not be present if the target would be perfectly rigid, but it is physically plausible when some deformation occurs in the target, as the projectile moves horizontally.

Figure 113 shows the reaction forces at some selected time steps during the transient solution. Note that the final displacement of the projectile (which is about to exit from the plane) is in relatively good agreement with (only slightly behind) the original solution presented in CEA's report [8].

4.5.2 Case FROT67

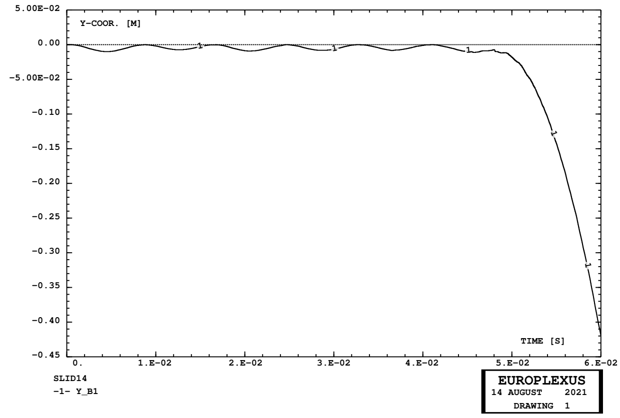
This case is similar to FROT66 but we add friction:

```
LINK COUP
     BLOQ 123 LECT bloc TERM
     GLIS 1 ELIM
          FROT MUST 0.25 MUDY 0.25 GAMM 0.1
          MAIT LECT circ TERM
          ESCL LECT base TERM
```

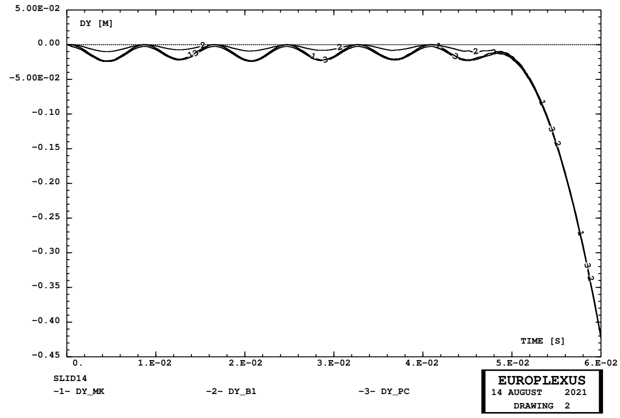
Some results are presented in Figure 114. The first two pictures show the vertical positions and displacements of the nodes (initially) at the bottom of the projectile. The apparent large rebound ($Y \gg 0$) in the first picture is due to the fact that the projectile rotates because of friction, so these nodes are no longer the bottom ones as time goes on.

The last picture shows the horizontal displacements. The spreading of the result for the three monitored nodes corresponds to a large rigid-like rotation of the projectile.

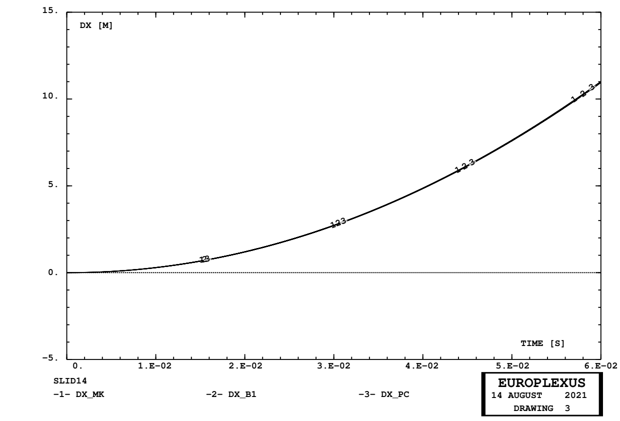
Figure 115 shows the reaction forces at some selected time steps during the transient solution. The horizontal component of such forces seems larger than in the previous solution, due to friction. In fact, the final horizontal displacement of the disk is lower than in the friction-less case. Note the position of the marker node (thick black dot) to appreciate the global rotation.



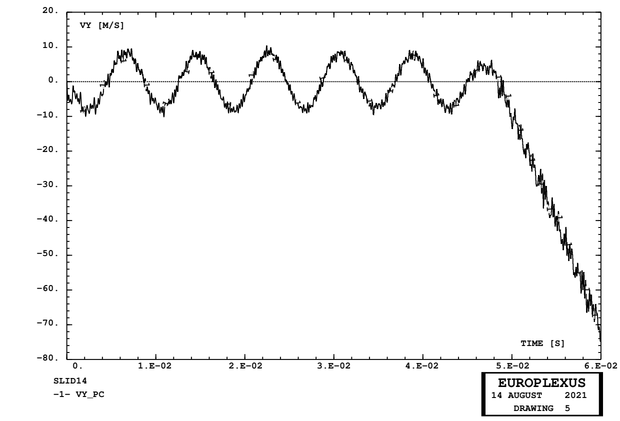
(a) Vertical coordinate



(b) Vertical displacements



(c) Horizontal displacements



(d) Vertical velocity

Figure 107: Further results of case SLID14

4.6 Solutions in 3D using SLID

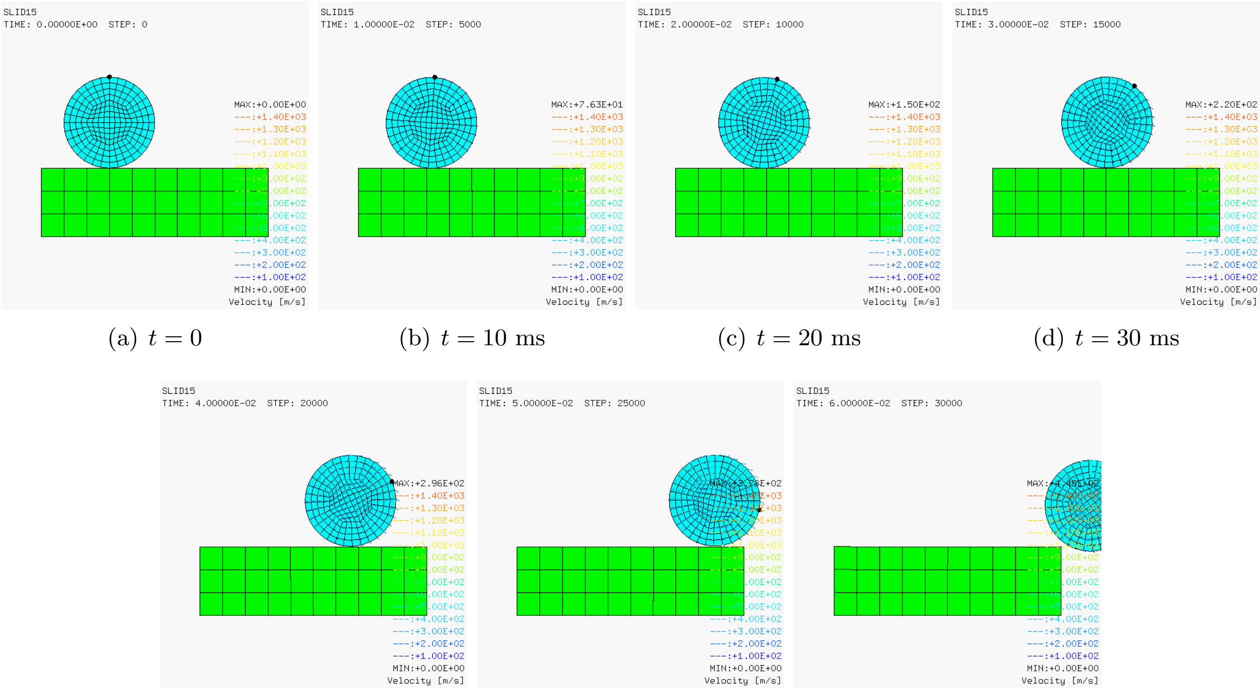
The calculations performed with EPX by using the `SLID` contact model in 3D are summarized in Table 10.

Case	Mesh	Description	Final time [ms]	Steps	CPU [s]
SLID38	8352 TETR 1 PMAT	`SLID`, no friction	40	4 000	26.6
SLID39	16704 TETR 1 PMAT	Idem 38 but PXHEX2T2	40	8 000	123.6
SLID42	8352 TETR 1 PMAT	Idem 38 but with friction	40	4 000	27.5
SLID43	16704 TETR 1 PMAT	Idem 39 but with friction	40	8 000	125.4
SLID59	696 CUB8 1 PMAT	Idem 38 but with hexahedra	40	4 000	10.3
SLID60	696 CUB8 1 PMAT	Idem 59 but with friction	40	4 000	10.6
SLID61	5568 CUB8 1 PMAT	Idem 59 but twice finer mesh	40	8 000	153.3
SLID62	5568 CUB8 1 PMAT	Idem 61 but `PHI 0.2`	40	8 000	156.3
SLID63	696 CUB8 1 PMAT	Idem 59 but swap master/slave	40	4 000	11.0
SLID64	696 CUB8 1 PMAT	Idem 63 but with friction	40	4 000	11.3
SLID65	5568 CUB8 1 PMAT	Idem 63 but twice finer mesh	40	8 000	160.0
SLID66	5568 CUB8 1 PMAT	Idem 65 but with friction	40	8 000	171.9

Table 10: Calculations for the sliding disk problem in 3D using `SLID`.

4.6.1 Case SLID38

This test is similar to FROT66 (no friction) but uses the `SLID` contact model (under `LINK COUP`):



(a) $t = 0$ (b) $t = 10$ ms (c) $t = 20$ ms (d) $t = 30$ ms

(e) $t = 40$ ms (f) $t = 50$ ms (g) $t = 60$ ms

Figure 108: Result of test SLID15

```
LINK COUP
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT em TERM
                 NMAS LECT nm 4 5 TERM
                 NSLA LECT ns TERM
```

The continuum mesh is composed only of tetrahedra, obtained from the hexahedra of test FROT66 by decomposing them through the PXHEX2TE.proc Cast3m procedure, whereby each hexahedron is split into 12 tetrahedra.

The solution, presented in Figures 116 and 117, is smoother and more regular (no spurious bouncing) than case FROT66 and it looks more similar to the original solution with `GLIS` reported in the original report from CEA [8]. The disk slides along the target without any appreciable rotation.

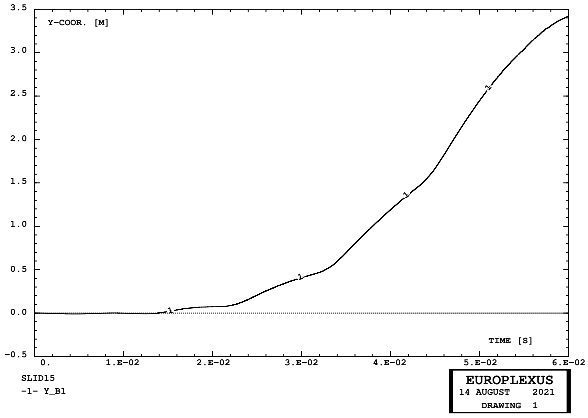
4.6.2 Case SLID39

This test is similar to SLID38 (no friction) but we use a different Cast3m procedure (PXHEX2T2.proc) to generate the tetrahedra, whereby each hexahedron is subdivided into 24 tetrahedra instead of only 12, by adding extra nodes at the centroid of the hexahedron and at the centroid of each one of its faces. Consequently, the mesh is finer and the stability step is halved (and the number of steps is doubled) with respect to the previous solution.

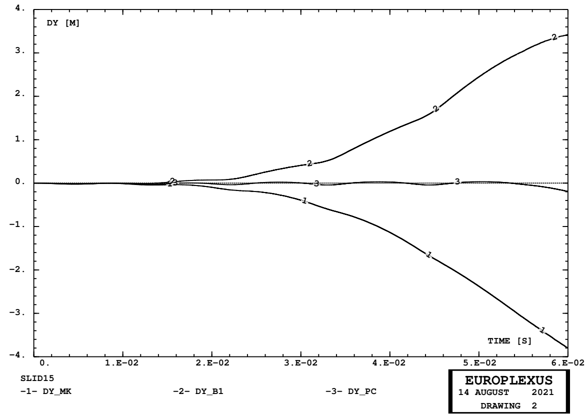
The solution is presented in Figures 118 and 119. It looks quite different from the previous solution as far as the vertical motion of the disk is concerned, and more physical. The bouncings observed in the coarse mesh solution are replaced by a steady indentation with a superposed elastic oscillation, due to better contact resolution. The effect on the horizontal motion is less evident.

4.6.3 Case SLID42

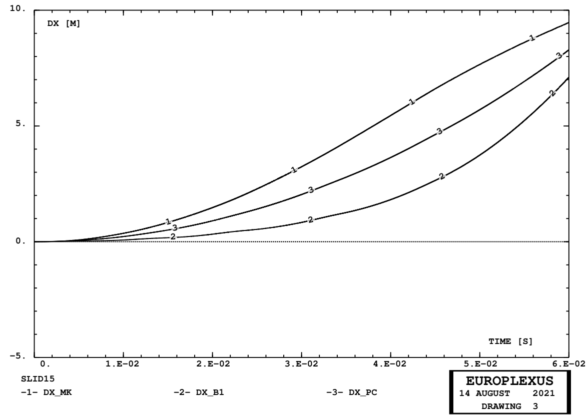
This test is similar to SLID38 (coarse tetrahedra mesh) but we add friction. The solution is presented in Figures 120 and 121. The disk rotates while sliding along the plane, due to friction.



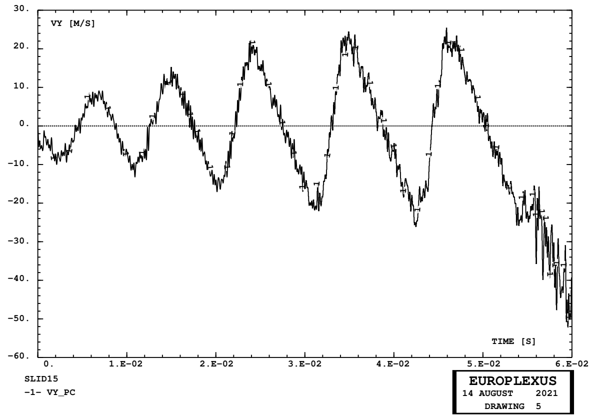
(a) Vertical coordinate



(b) Vertical displacements



(c) Horizontal displacements



(d) Vertical velocity

Figure 109: Further results of case SLID15

4.6.4 Case SLID43

This test is similar to SLID42 (friction) but uses the finer tetrahedron mesh. The solution is presented in Figures 122 and 123. Like in the case without friction, the present solution with fine mesh look smoother and more regular than the previous one with a coarser mesh.

4.6.5 Case SLID59

This test is similar to SLID38 (no friction) but the mesh is composed of hehahedra. The solution is presented in Figures 124 and 125. The solution looks more bouncy than case SLID38.

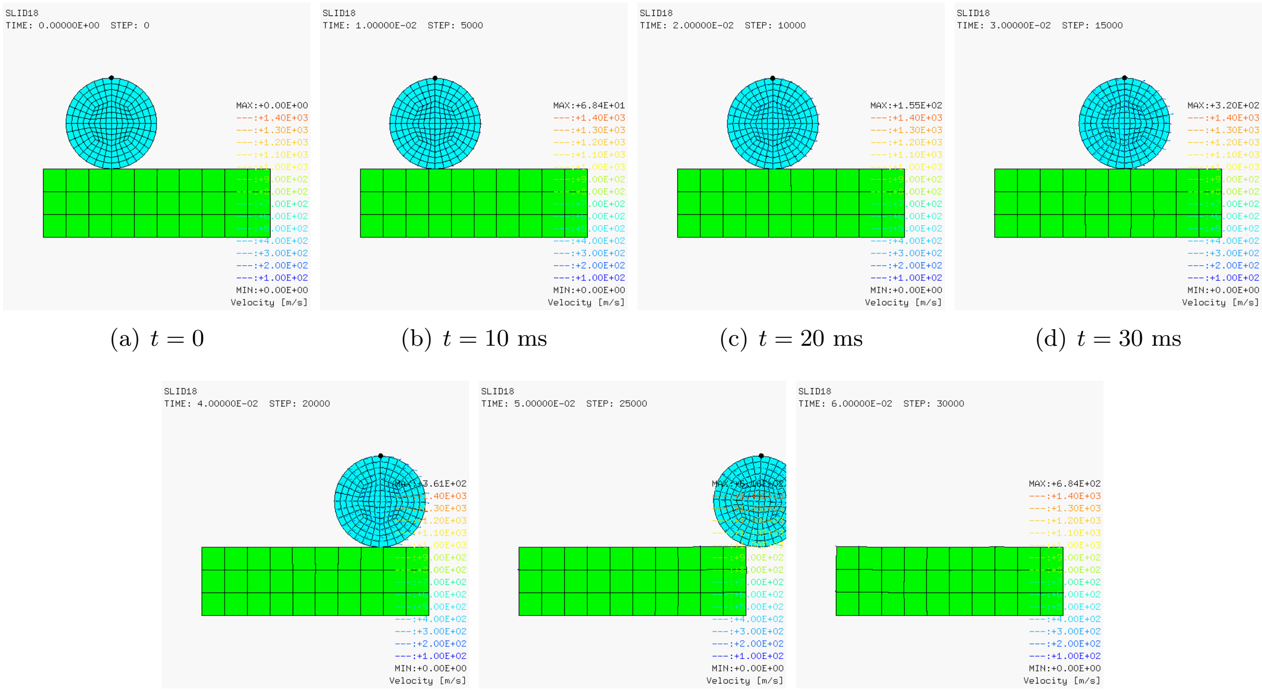
4.6.6 Case SLID60

This test is similar to SLID59 but uses friction. The solution is presented in Figures 126 and 127.

4.6.7 Case SLID61

This test is similar to SLID59 but uses a twice finer mesh made of hexahedra in an attempt to get a more accurate solution. The time increment is halved and the number of time steps is doubled. The solution is presented in Figures 128 and 129.

Unfortunately, the solution looks incorrect. Starting at $t = 15$ ms contact seems to be lost and the disk penetrates into the plane. This might be due to the fact that the thickness of the valid penetration zone becomes smaller and smaller as the elements are refined.



(a) $t = 0$ (b) $t = 10$ ms (c) $t = 20$ ms (d) $t = 30$ ms

(e) $t = 40$ ms (f) $t = 50$ ms (g) $t = 60$ ms

Figure 110: Result of test SLID18

4.6.8 Case SLID62

This test is a repetition of case SLID61 by using a much larger value of the ϕ parameter that governs the thickness of the penetrated zone. A value of $\phi = 0.20$ is chosen instead of the default which is $\phi = 0.05$.

The solution is presented in Figures 130 and 131. Unfortunately, some spurious penetration of the disk into the plane still persists, after $t = 30$ ms.

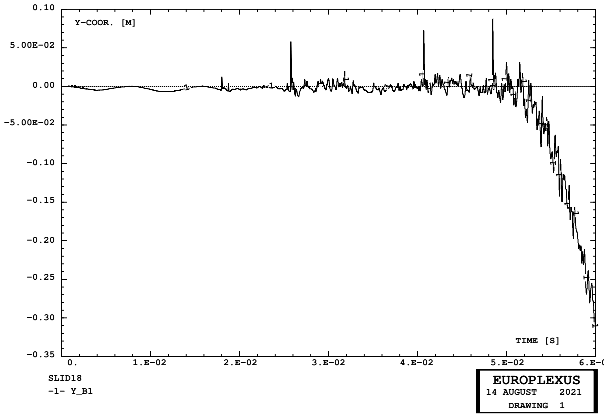
4.6.9 Case SLID63

Inspection of the contact definition reveals that the slave side of the sliding surface (the plane) is meshed more coarsely than the master side (the disk). This choice dates back the original tests in reference [8], but it is against the recommendations of sliding surface algorithms where it is generally assumed that the slave is meshed more finely than the master.

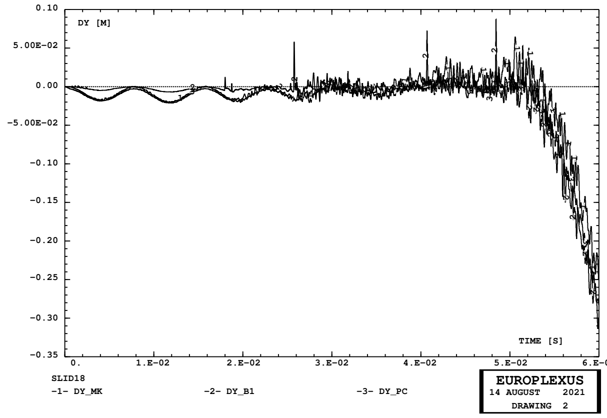
Therefore, we simply swap the definition of master and slave surfaces in an attempt to obtain a better solution, with less spurious penetrations and to avoid the blatantly false results obtained above by refining the computational mesh.

The contact-related input for test SLID63 (derived from SLID59 by swapping the surface definitions) reads:

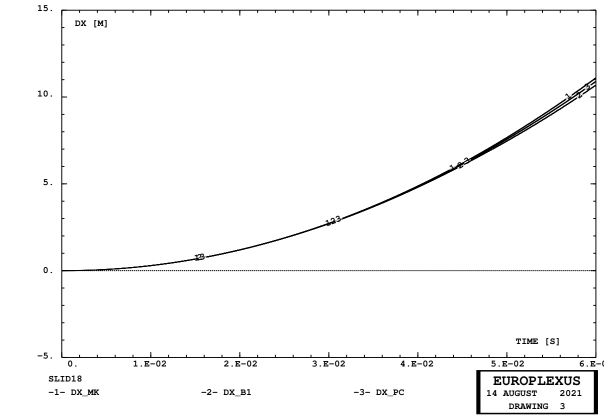
```
COMP NGRO 13 'bloc' LECT base TERM COND Y LT -0.99
             'f1a'  LECT axe TERM COND NEAR POIN 3 2 0
             'f1b'  LECT axe TERM COND NEAR POIN 3 2 2
             'f1'   LECT f1a f1b TERM
             'f2'   LECT axe DIFF f1 TERM
             'b1'   LECT circ TERM COND NEAR POIN 3 0 0
             'b2'   LECT circ TERM COND NEAR POIN 3 0 0.667
             'b3'   LECT circ TERM COND NEAR POIN 3 0 1.333
             'b4'   LECT circ TERM COND NEAR POIN 3 0 2
             'nm'   LECT base TERM COND Y GT -0.01
             'ns1'  LECT circ TERM COND CYLI
                              X1 3 Y1 2 Z1 0
                              X2 3 Y2 2 Z2 2 R 2.1
             'ns2'  LECT circ TERM COND CYLI
                              X1 3 Y1 2 Z1 0
                              X2 3 Y2 2 Z2 2 R 1.9
```



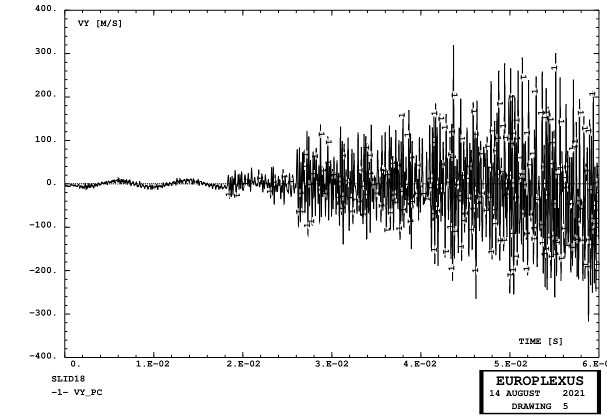
(a) Vertical coordinate



(b) Vertical displacements



(c) Horizontal displacements



(d) Vertical velocity

Figure 111: Further results of case SLID18

```
          'ns'   LECT ns1 DIFF ns2 TERM
     GROU 1  'em'   LECT base TERM COND APPU LARG LECT nm TERM
 . . .
LINK COUP
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT em TERM
                 NMAS LECT nm TERM
                 NSLA LECT ns TERM
```

The solution is presented in Figures 132 and 133. Indeed, the solution looks much better and more regular than SLID59.

4.6.10 Case SLID64

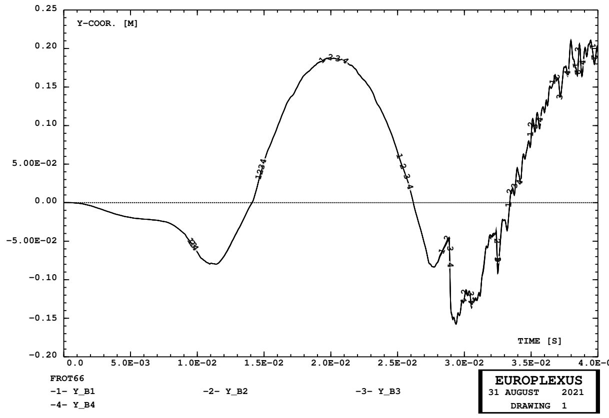
This test is a repetition of case SLID63 (swapped surfaces) by activating the friction.

The solution is presented in Figures 134 and 135. It looks quite regular and better than the solution with the previous definition of the sliding surface.

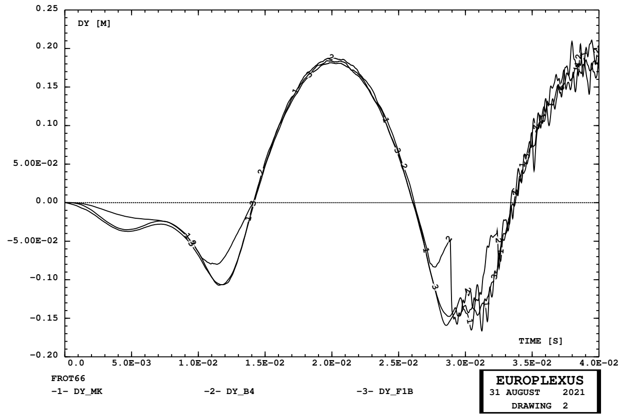
4.6.11 Case SLID65

This test is a repetition of case SLID63 (swapped surfaces) but with a twice finer hexahedra mesh.

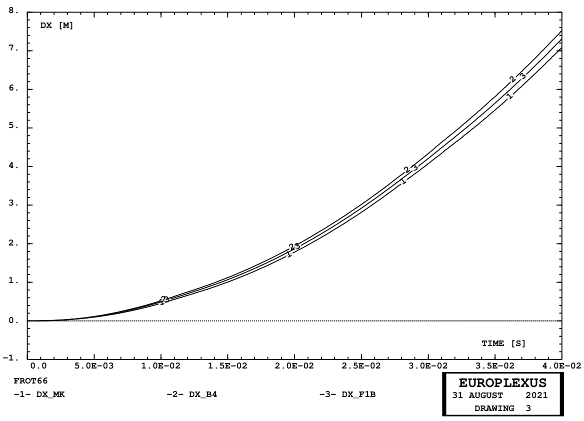
The solution is presented in Figures 136 and 137. It looks quite regular and the spurious penetrations that had been observed when refining the mesh with the previous definition of the sliding surface is avoided.



(a) Vertical coordinates

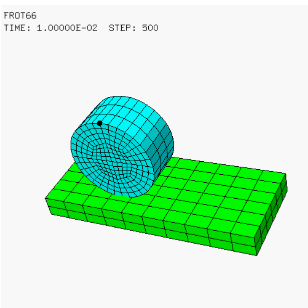


(b) Vertical displacements

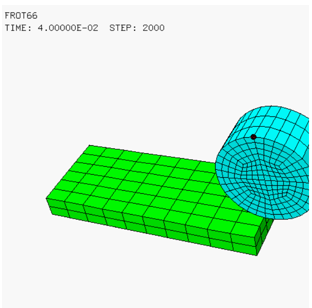


(c) Horizontal displacements

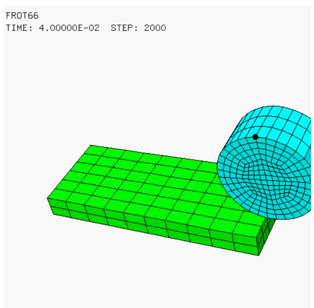
Figure 112: Results of case FROT66



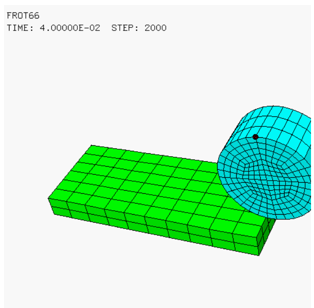
(a) $t = 5$ ms



(b) $t = 20$ ms



(c) $t = 28$ ms



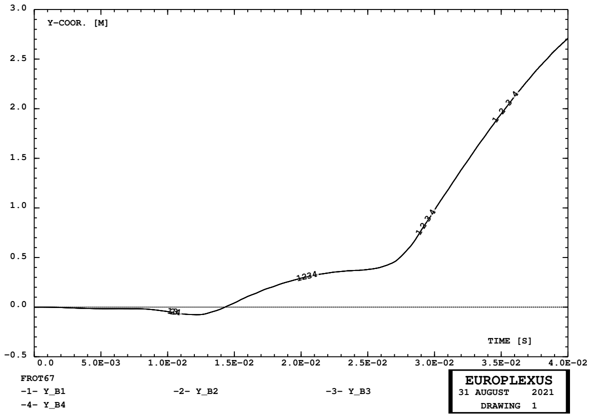
(d) $t = 40$ ms

Figure 113: Further results of case FROT66

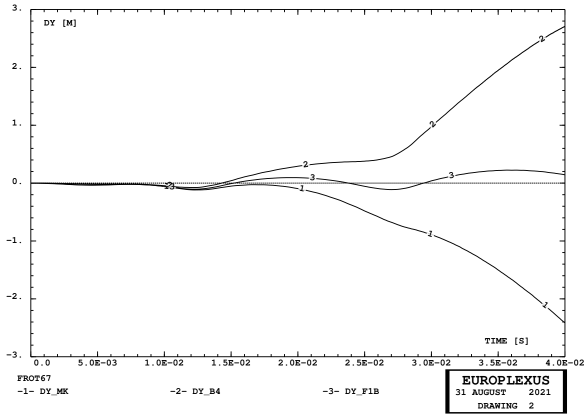
4.6.12 Case SLID66

This test is similar to case SLID63 but with friction.

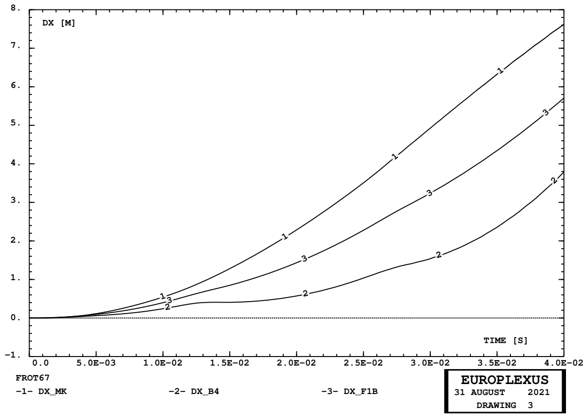
The solution is presented in Figures 138 and 139. It looks quite regular and the spurious penetrations that had been observed when refining the mesh with the previous definition of the sliding surface is avoided.



(a) Vertical coordinates

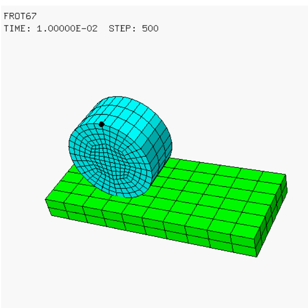


(b) Vertical displacements

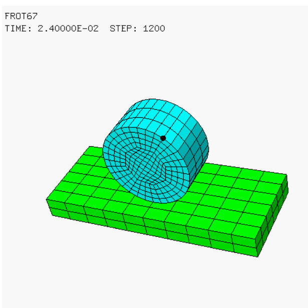


(c) Horizontal displacements

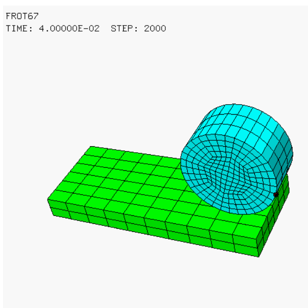
Figure 114: Results of case FROT67



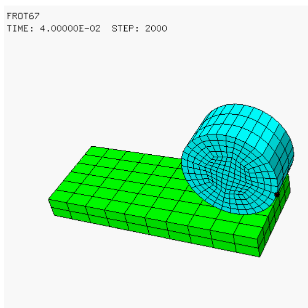
(a) $t = 5$ ms



(b) $t = 12$ ms

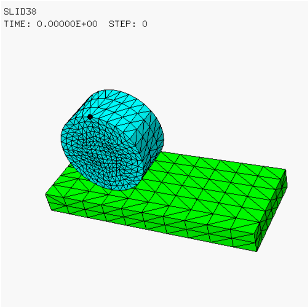


(c) $t = 28$ ms

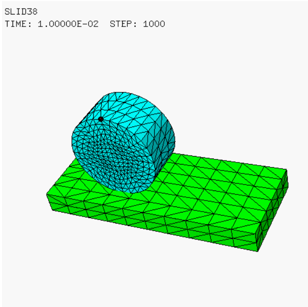


(d) $t = 40$ ms

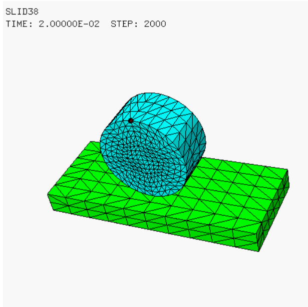
Figure 115: Further results of case FROT67



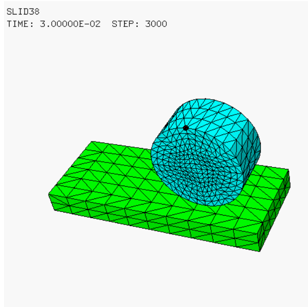
(a) $t = 0$



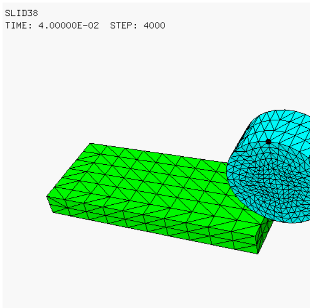
(b) $t = 10$ ms



(c) $t = 20$ ms

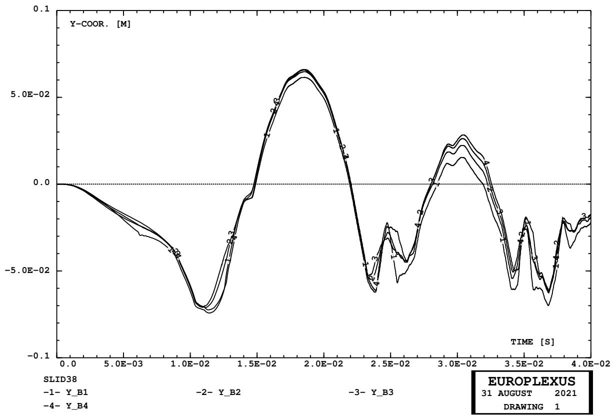


(d) $t = 30$ ms

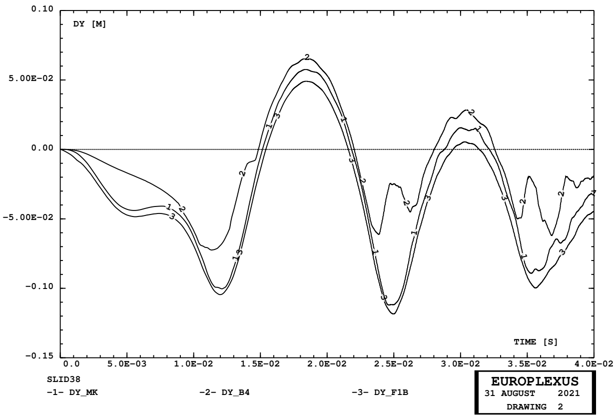


(e) $t = 40$ ms

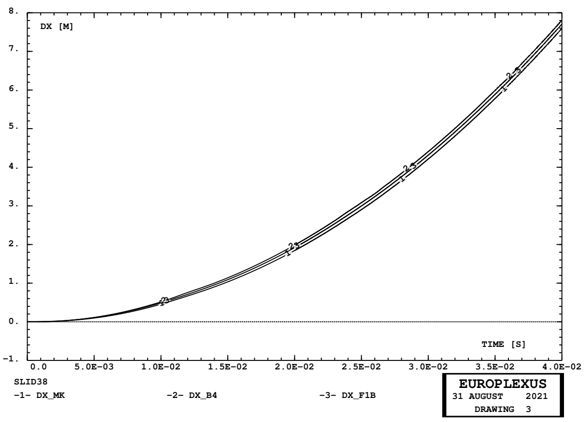
Figure 116: Result of test SLID38



(a) Vertical coordinate

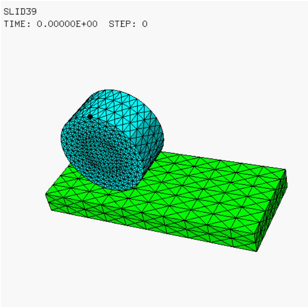


(b) Vertical displacements

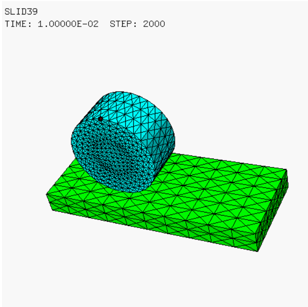


(c) Horizontal displacements

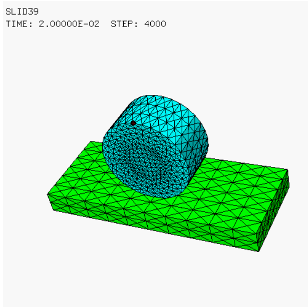
Figure 117: Further results of case SLID38



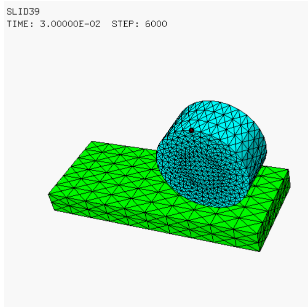
(a) $t = 0$



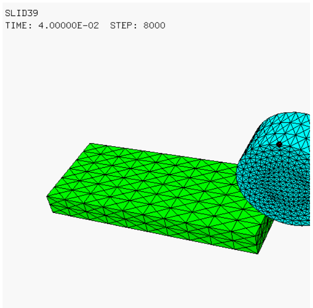
(b) $t = 10$ ms



(c) $t = 20$ ms

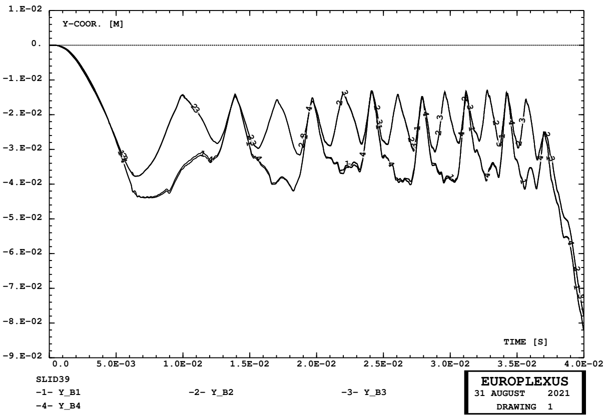


(d) $t = 30$ ms

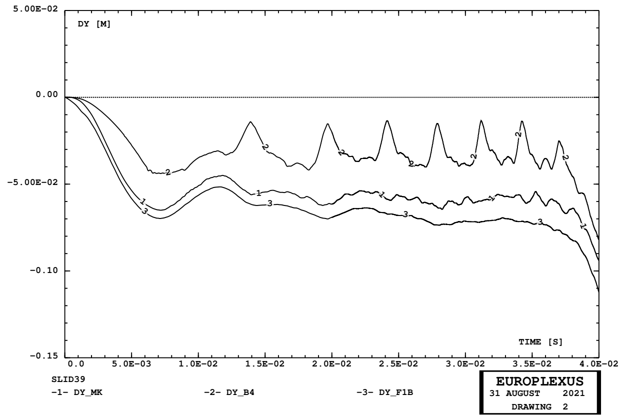


(e) $t = 40$ ms

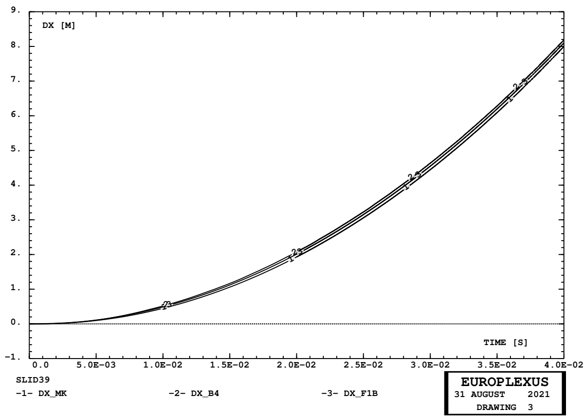
Figure 118: Result of test SLID39



(a) Vertical coordinate

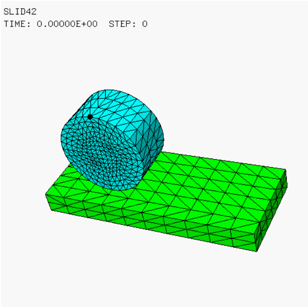


(b) Vertical displacements

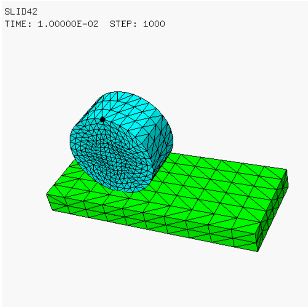


(c) Horizontal displacements

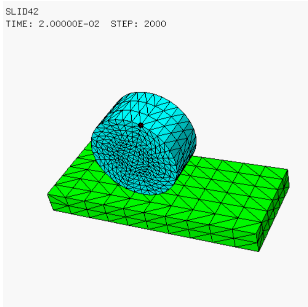
Figure 119: Further results of case SLID39



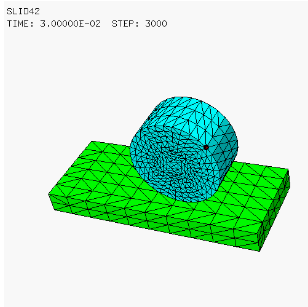
(a) $t = 0$



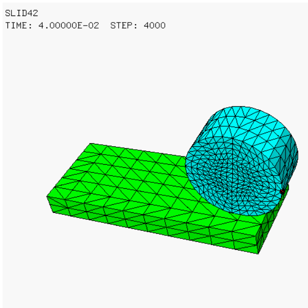
(b) $t = 10$ ms



(c) $t = 20$ ms

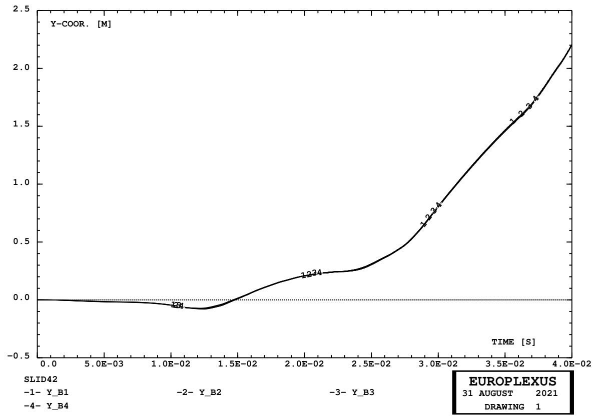


(d) $t = 30$ ms

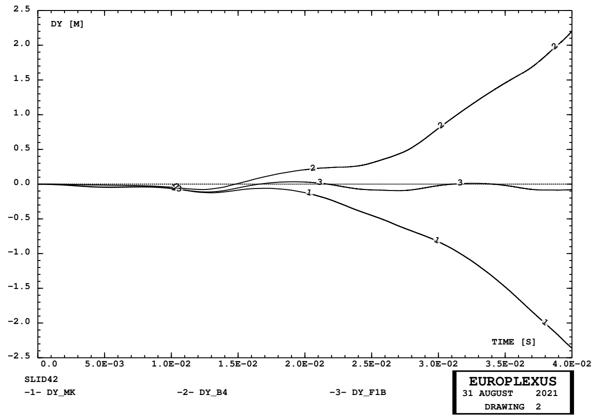


(e) $t = 40$ ms

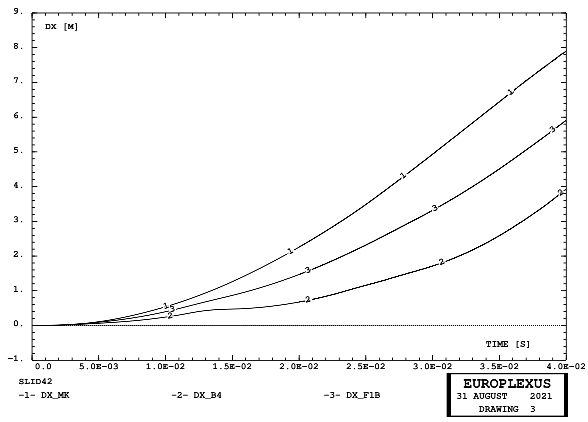
Figure 120: Result of test SLID42



(a) Vertical coordinate

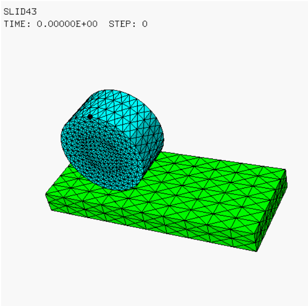


(b) Vertical displacements

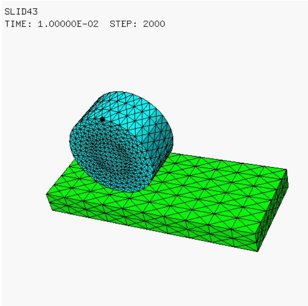


(c) Horizontal displacements

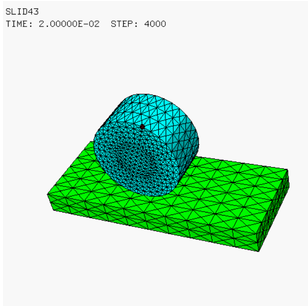
Figure 121: Further results of case SLID42



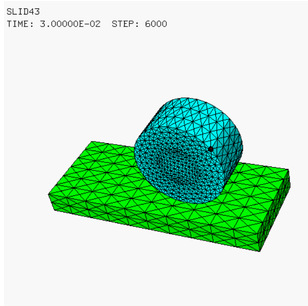
(a) $t = 0$



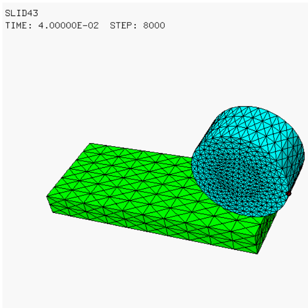
(b) $t = 10$ ms



(c) $t = 20$ ms

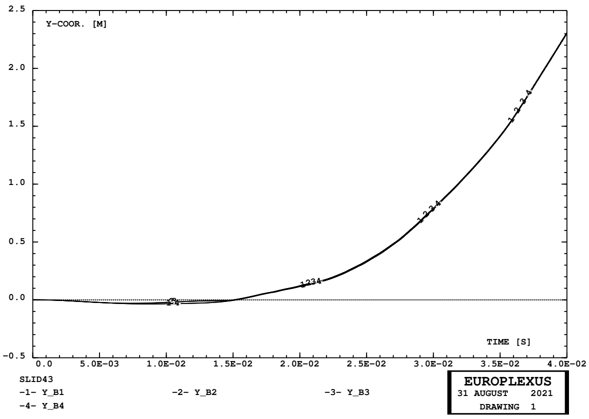


(d) $t = 30$ ms

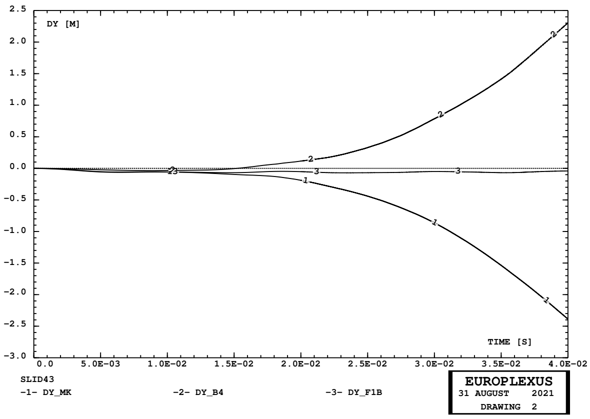


(e) $t = 40$ ms

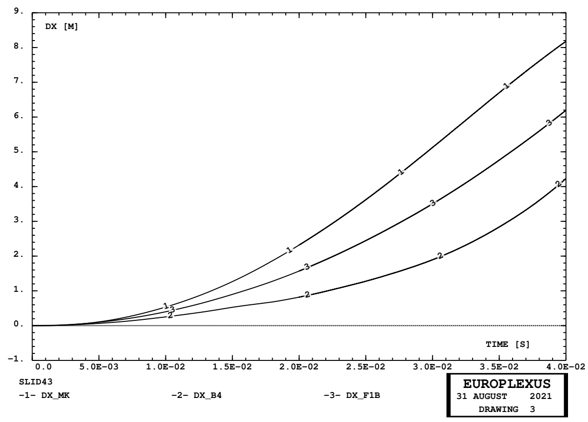
Figure 122: Result of test SLID43



(a) Vertical coordinate

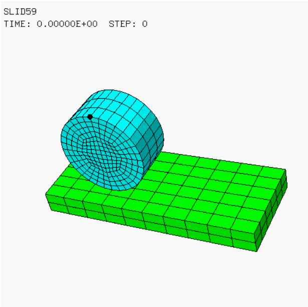


(b) Vertical displacements

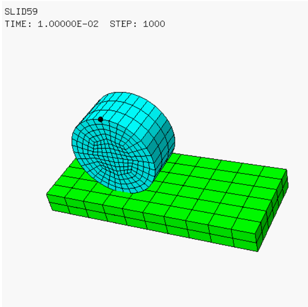


(c) Horizontal displacements

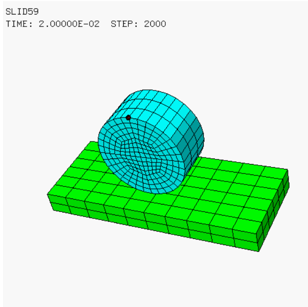
Figure 123: Further results of case SLID43



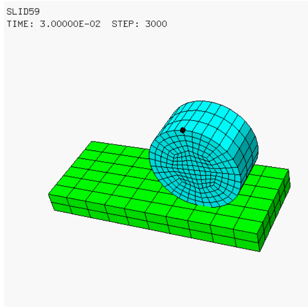
(a) $t = 0$



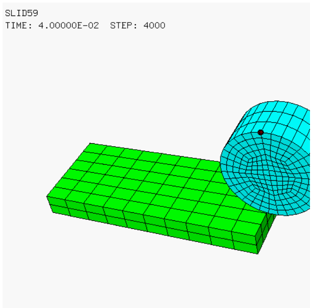
(b) $t = 10$ ms



(c) $t = 20$ ms

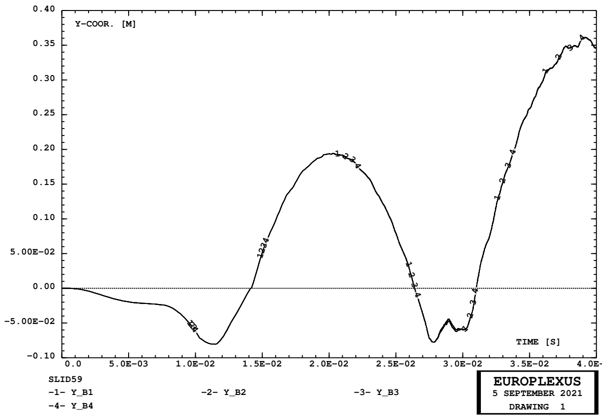


(d) $t = 30$ ms

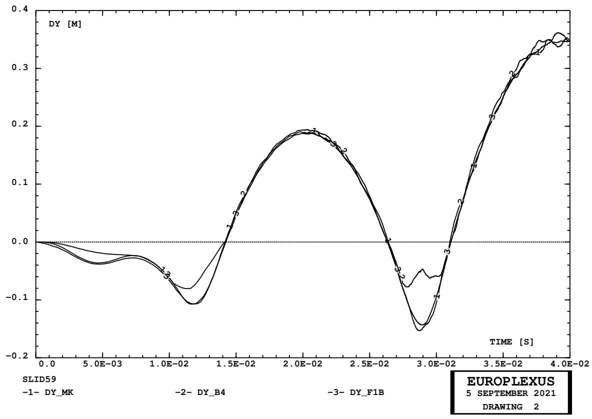


(e) $t = 40$ ms

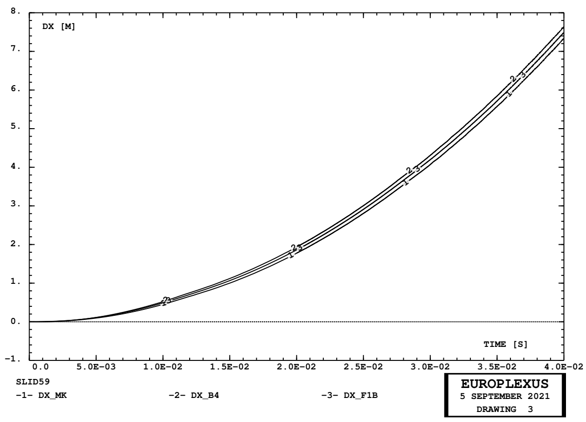
Figure 124: Result of test SLID59



(a) Vertical coordinate

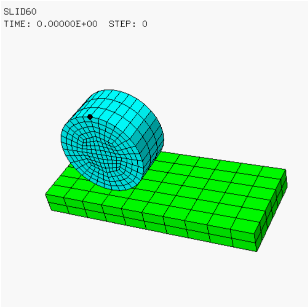


(b) Vertical displacements

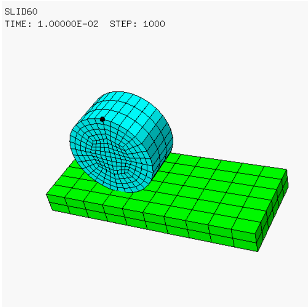


(c) Horizontal displacements

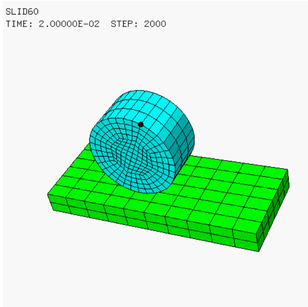
Figure 125: Further results of case SLID59



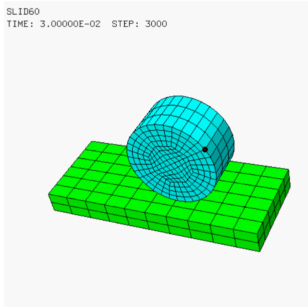
(a) $t = 0$



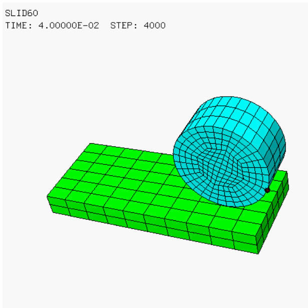
(b) $t = 10$ ms



(c) $t = 20$ ms

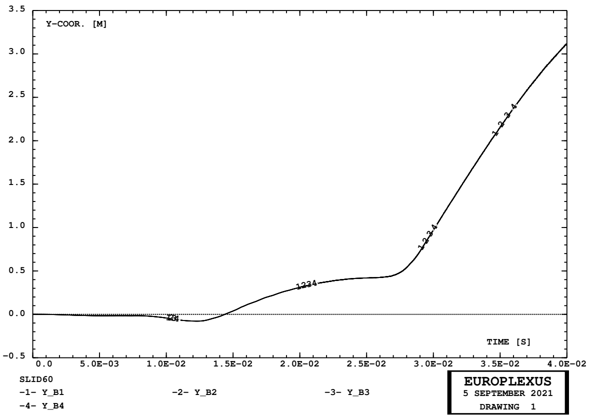


(d) $t = 30$ ms

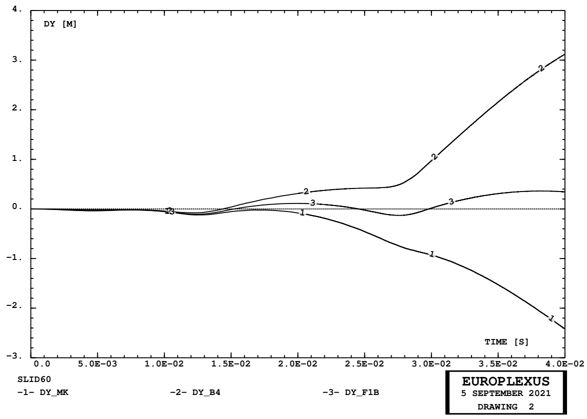


(e) $t = 40$ ms

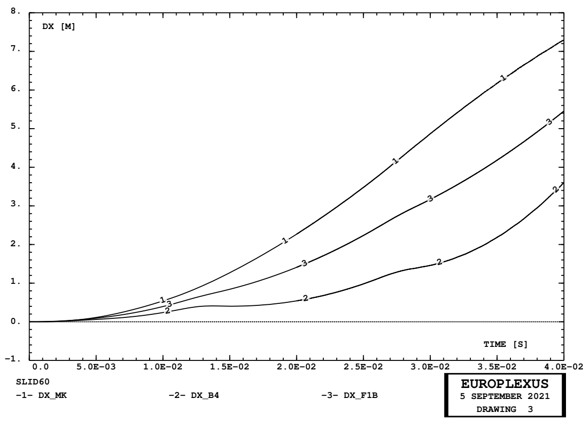
Figure 126: Result of test SLID60



(a) Vertical coordinate

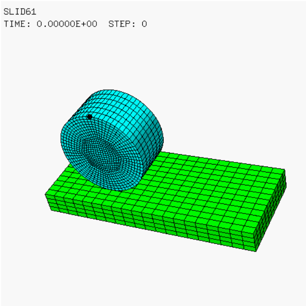


(b) Vertical displacements

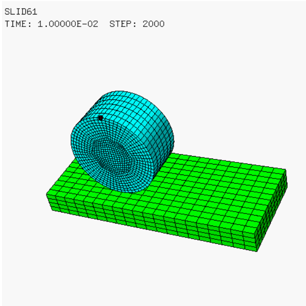


(c) Horizontal displacements

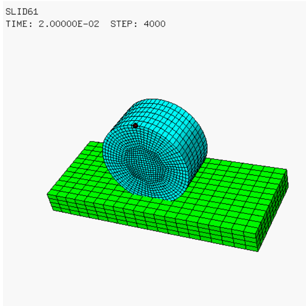
Figure 127: Further results of case SLID60



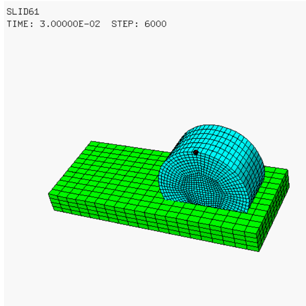
(a) $t = 0$



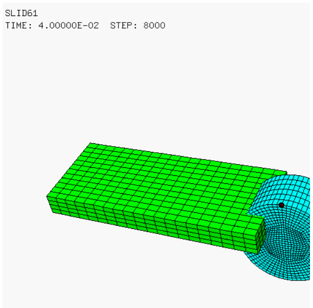
(b) $t = 10$ ms



(c) $t = 20$ ms

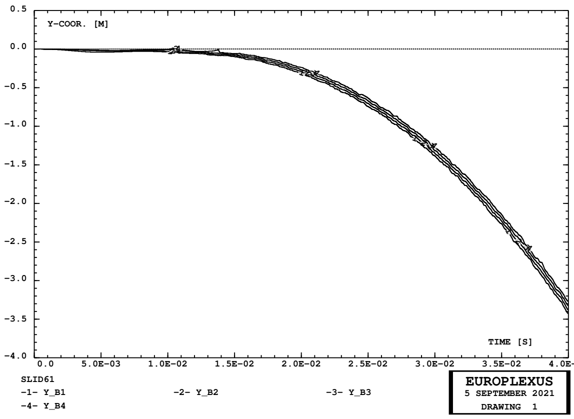


(d) $t = 30$ ms

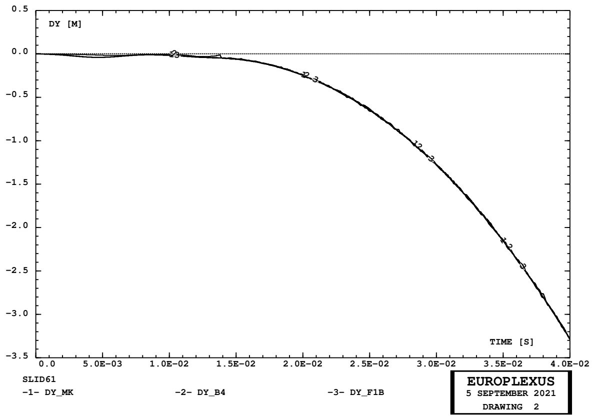


(e) $t = 40$ ms

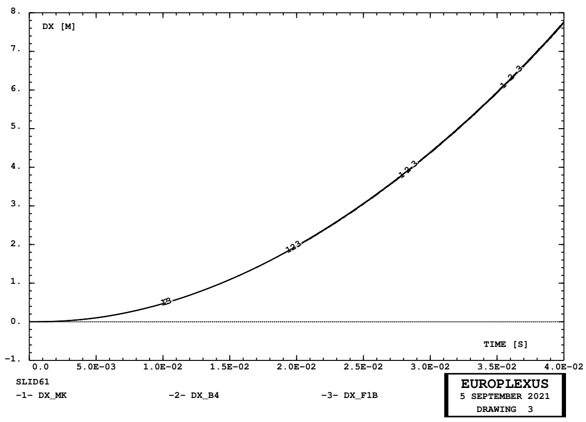
Figure 128: Result of test SLID61



(a) Vertical coordinate

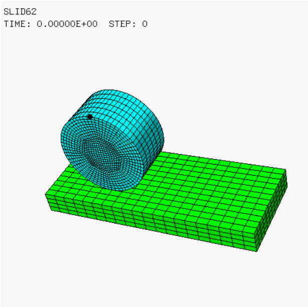


(b) Vertical displacements

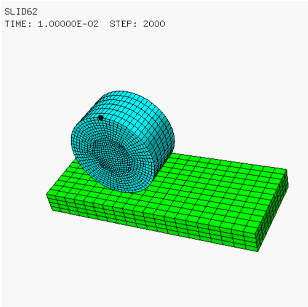


(c) Horizontal displacements

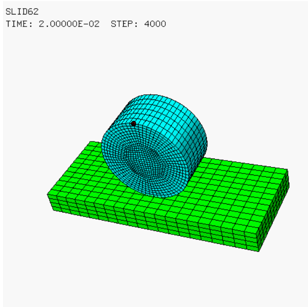
Figure 129: Further results of case SLID61



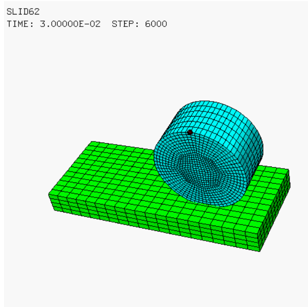
(a) $t = 0$



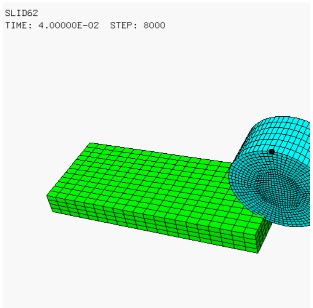
(b) $t = 10$ ms



(c) $t = 20$ ms

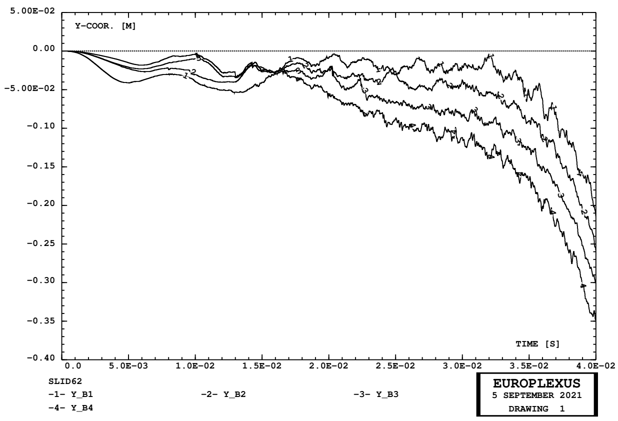


(d) $t = 30$ ms

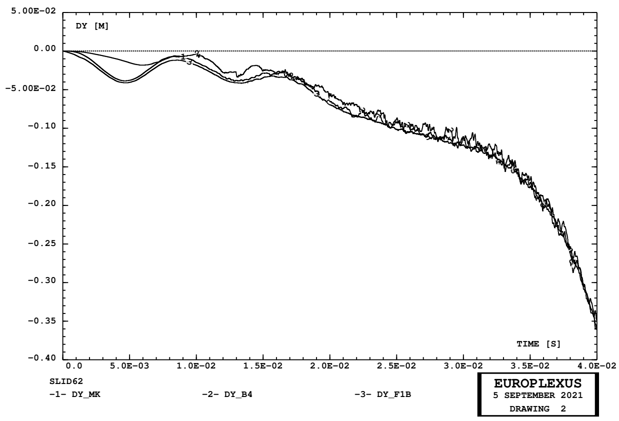


(e) $t = 40$ ms

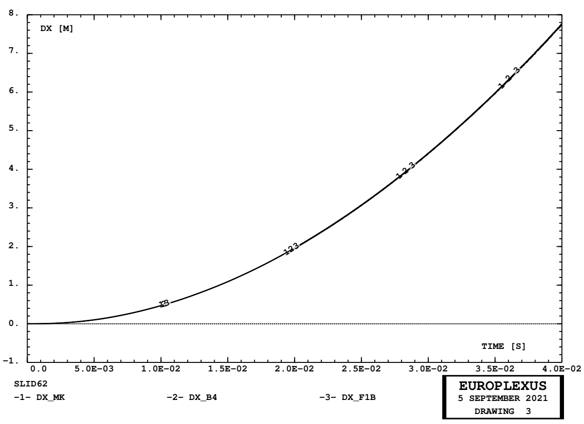
Figure 130: Result of test SLID62



(a) Vertical coordinate

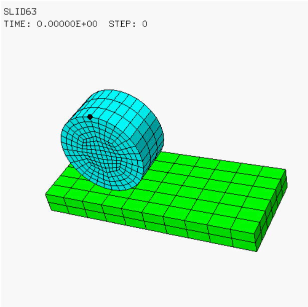


(b) Vertical displacements

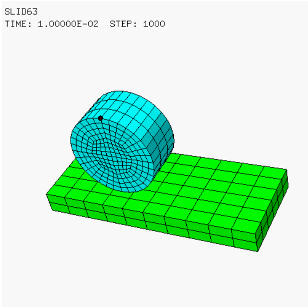


(c) Horizontal displacements

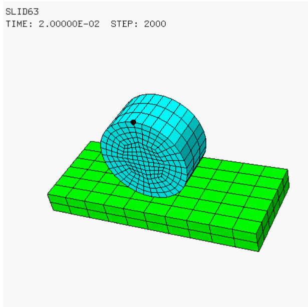
Figure 131: Further results of case SLID62



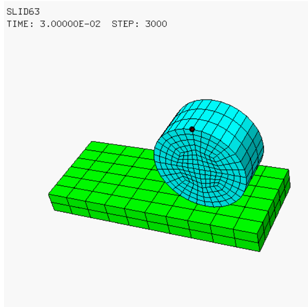
(a) $t = 0$



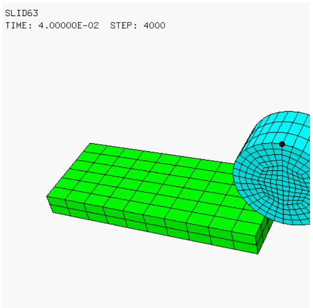
(b) $t = 10$ ms



(c) $t = 20$ ms

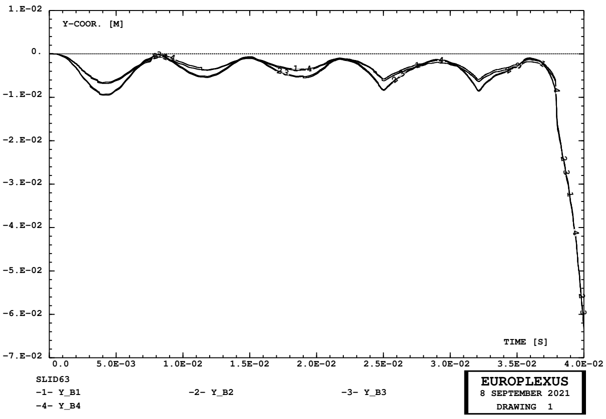


(d) $t = 30$ ms

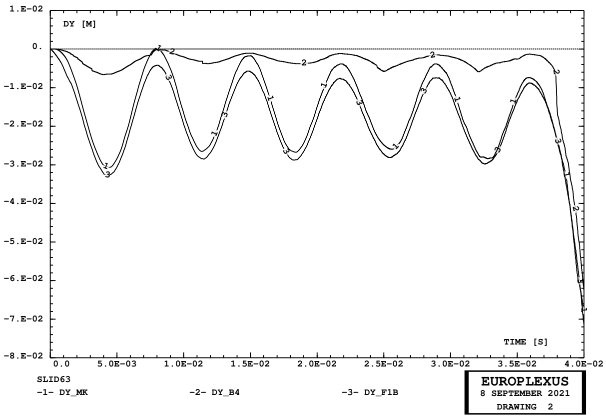


(e) $t = 40$ ms

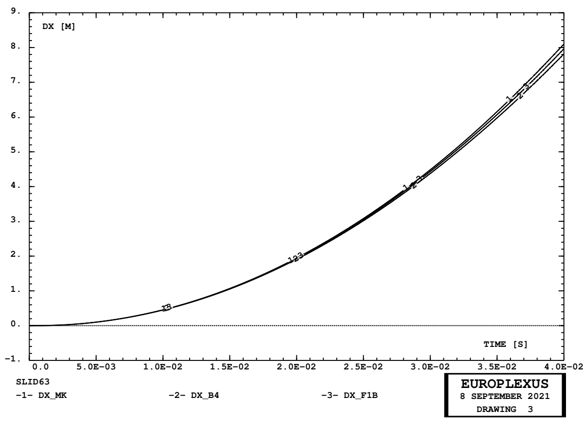
Figure 132: Result of test SLID63



(a) Vertical coordinate

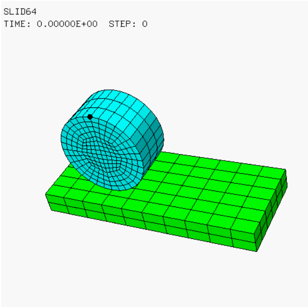


(b) Vertical displacements

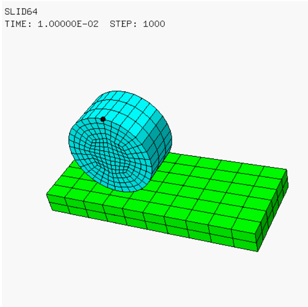


(c) Horizontal displacements

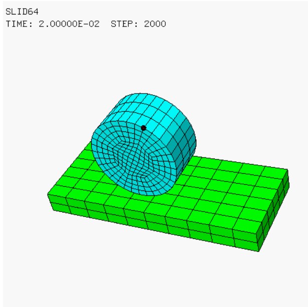
Figure 133: Further results of case SLID63



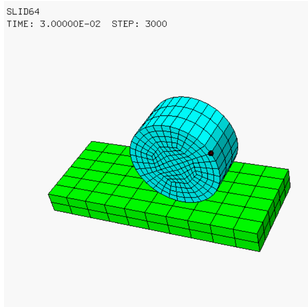
(a) $t = 0$



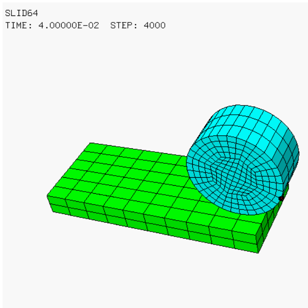
(b) $t = 10$ ms



(c) $t = 20$ ms

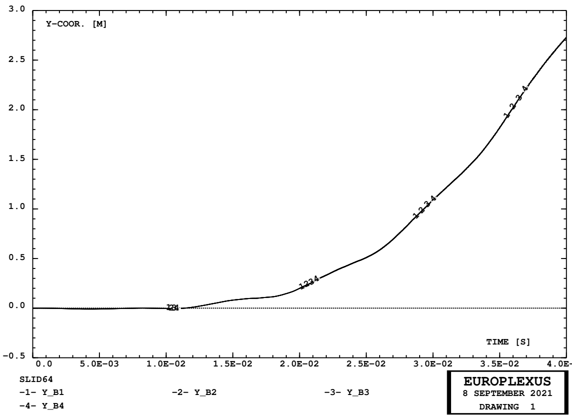


(d) $t = 30$ ms

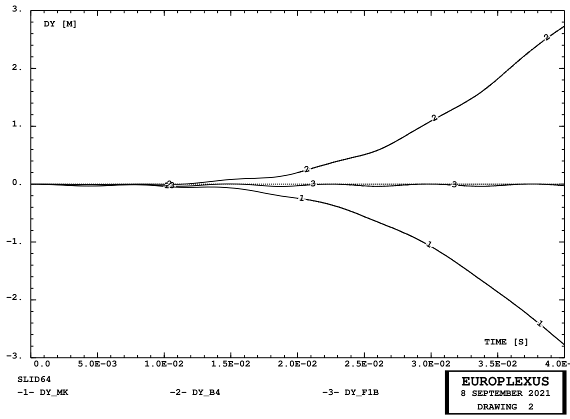


(e) $t = 40$ ms

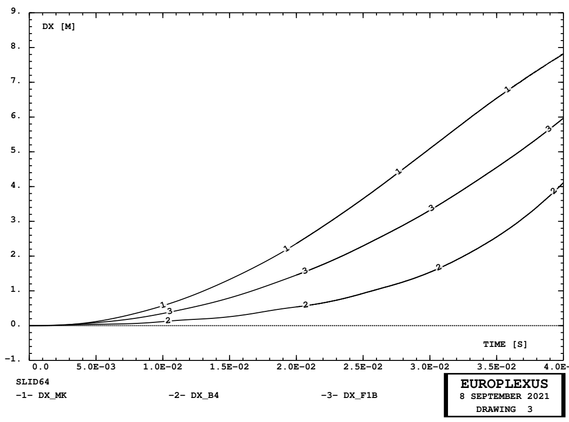
Figure 134: Result of test SLID64



(a) Vertical coordinate

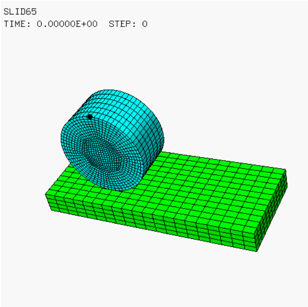


(b) Vertical displacements

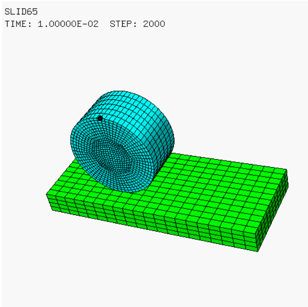


(c) Horizontal displacements

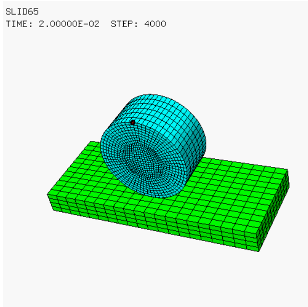
Figure 135: Further results of case SLID64



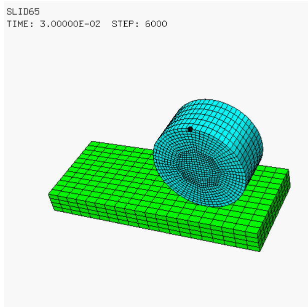
(a) $t = 0$



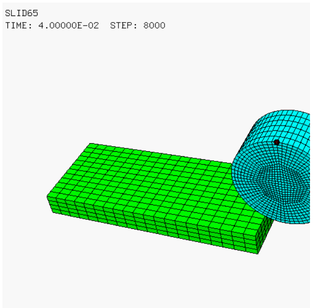
(b) $t = 10$ ms



(c) $t = 20$ ms

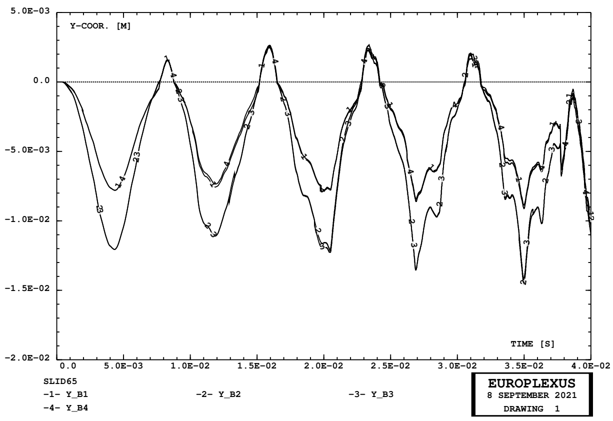


(d) $t = 30$ ms

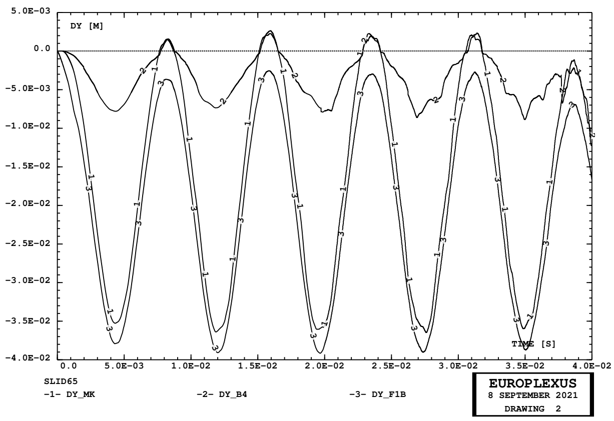


(e) $t = 40$ ms

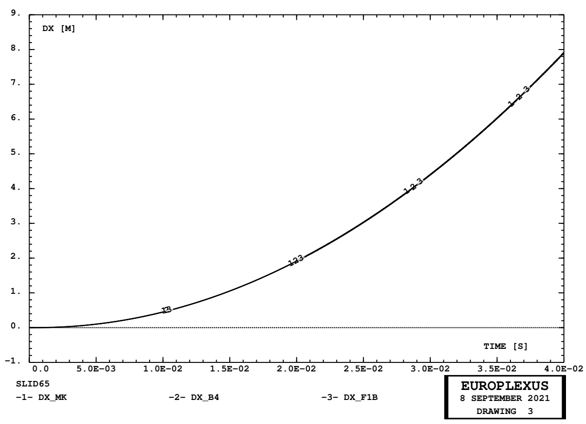
Figure 136: Result of test SLID65



(a) Vertical coordinate

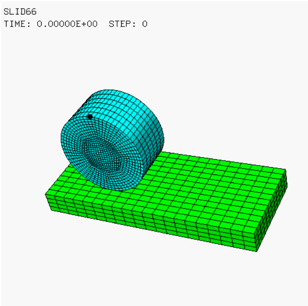


(b) Vertical displacements

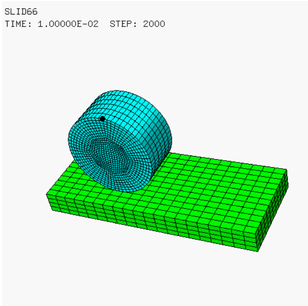


(c) Horizontal displacements

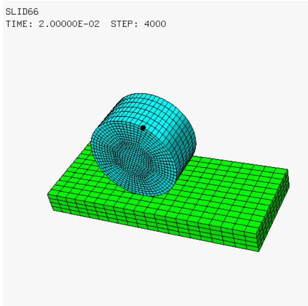
Figure 137: Further results of case SLID65



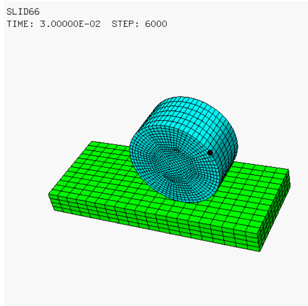
(a) $t = 0$



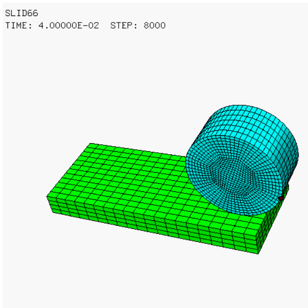
(b) $t = 10$ ms



(c) $t = 20$ ms

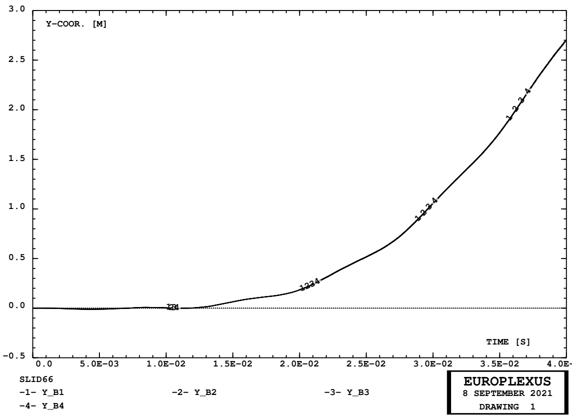


(d) $t = 30$ ms

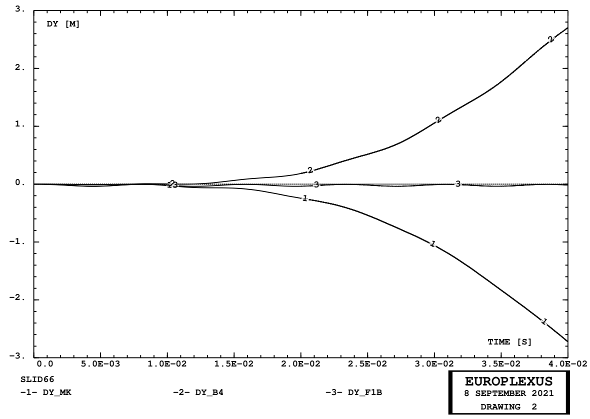


(e) $t = 40$ ms

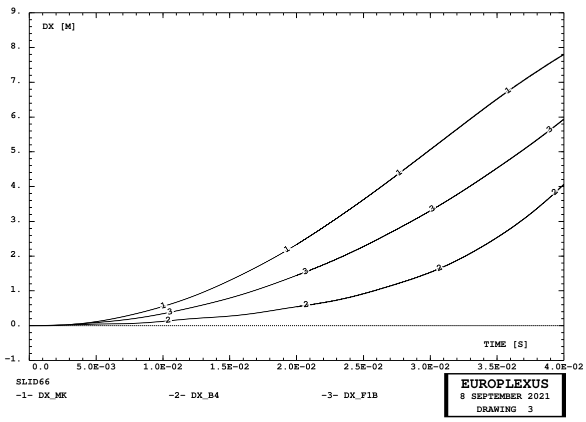
Figure 138: Result of test SLID66



(a) Vertical coordinate



(b) Vertical displacements



(c) Horizontal displacements

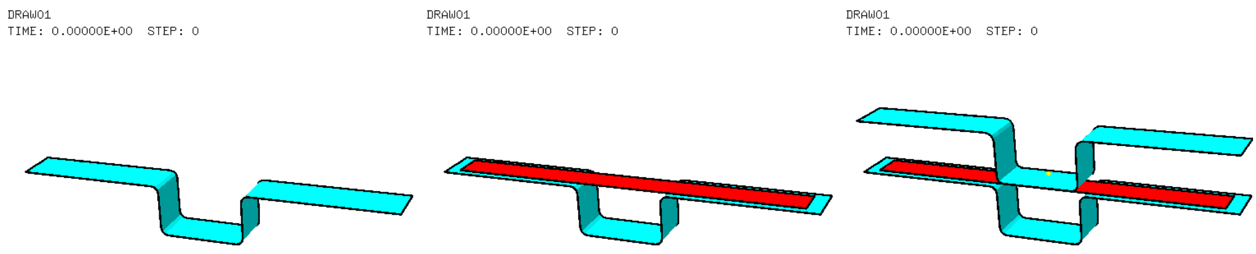
Figure 139: Further results of case SLID66

5 Application — Metal forming tests

We now apply the contact algorithm to some simplified fast dynamic metal forming problems. The examples are taken from very old EPX examples that had been solved with the `GLIS` contact model, used here as a reference.

5.1 Metal strip punching

A straight elongated metallic strip is dynamically formed into a "U" shape by using a punch and a die. The initial geometry is shown in Figure 140 with the piece shown in red, the die and the punch in cyan. The piece has initial dimensions of $0.250 \times 0.020 \times 0.005$ m and is made of aluminum-like material (elastoplastic von Mises law). It is meshed by Q4GS quadrilateral shells. The die and punch are also meshed by shells, have a thickness of 0.001 m and use a linear elastic material. The depth of the "U" in the die is 0.035 m.



(a) Die (b) Die and piece (c) Die, piece and punch

Figure 140: Initial geometry of the strip punching problem

All degrees of freedom (dofs), i.e. both translations and rotations, are completely blocked for the die. For the punch all dofs are also blocked except vertical translation, which is imposed to occur at a constant speed of 8.08383 m/s towards the piece. *No friction* is assumed between the various components.

The numerical solutions obtained for this problem are summarized in Table 11.

Case	Mesh	Description	Final time [ms]	Steps	CPU [s]
DRAW01	3904 Q4GS 2 PMAT	`LIAI GLIS`	4.5	15 700	156.8
DRAWL1	3904 Q4GS 2 PMAT	`LINK COUP SPLT NONE GLIS`	4.5	15 700	4 365.1
DRAWL2	3904 Q4GS 2 PMAT	`LINK COUP GLIS`	4.5	15 700	564.9
DRAWL3	3904 Q4GS 2 PMAT	`LINK COUP SPLT NONE SOLV PARD GLIS`	4.5	15 700	403.4
DRAWL4	3904 Q4GS 2 PMAT	`LINK COUP SPLT NONE SOLV SPLI GLIS`	4.5	15 700	370.1
DRAWL5	3904 Q4GS 2 PMAT	`LINK COUP SOLV PARD GLIS`	4.5	15 700	663.4
DRAWL6	3904 Q4GS 2 PMAT	`LINK COUP SOLV SPLI GLIS`	4.5	15 700	640.3
DRAWS1	3904 Q4GS 2 PMAT	`LINK COUP SPLT NONE SLID`	4.5	15 700	3 733.5
DRAWS2	3904 Q4GS 2 PMAT	`LINK COUP SLID`	4.5	15 700	729.7

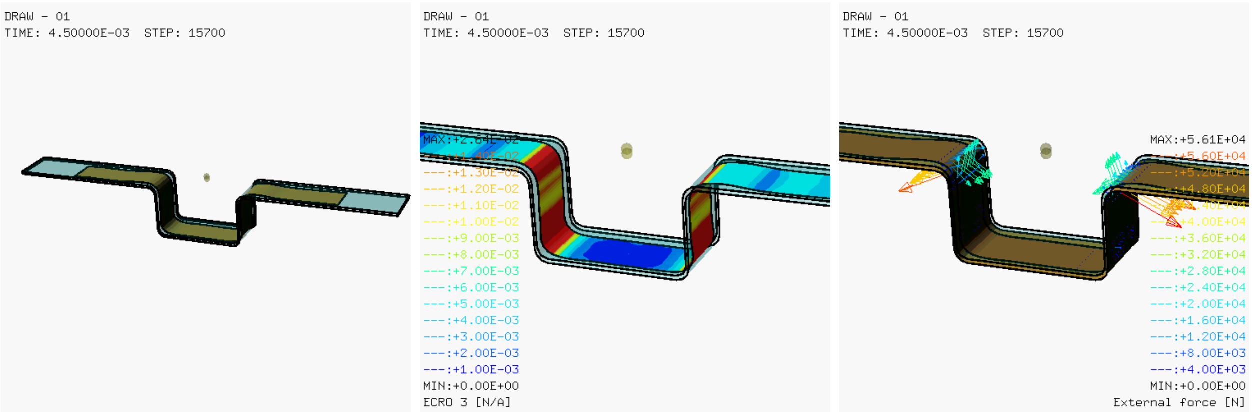
Table 11: Calculations for the metal strip punching problem.

5.1.1 Case DRAW01

The input file for this test is taken from the old EPX examples. The mesh geometry is hard-coded in the input file, which is quite lengthy. For this reason, this file and the following ones for this example are not included in the Appendix at the end of the present report. However, they are available in a folder `Inputs_Extra` associated with the report's distribution. To impose the boundary conditions use is made of the old (now obsolescent) `LIAI` directive.

```
*-------------------------------------------------------------Couplings
LIAIS
 BLOQ 123456 LECT die   TERM
       12456 LECT punch TERM
         246 LECT piece TERM
 DEPL 3 0.1E+01 FONC 1 LECT punch TERM
 GLIS 2
   CMAI LECT cmait TERM EXTE LECT n_ext1 TERM
   CESC LECT cesc1 TERM
   CMAI LECT cmait TERM EXTE LECT n_ext2 TERM
   CESC LECT cesc2 TERM
 FONC 1 TABL 2
        0.0E+00    0.0E+00
        0.501E-02 -0.405E-01
*----------------------------------------------------Initial conditions
INIT VITE 3 -8.08383 LECT punch TERM
```

The computed final configuration, plastic strain and contact forces are shown in Figure 141.



(a) Configuration (b) Plastic strain (c) Contact forces

Figure 141: Final results of test DRAW01.

5.1.2 Case DRAWL1

This is a repetition of case DRAW01 by using the `LINK COUP` instead of `LIAI` for the boundary conditions. The `SPLT NONE` option is activated since it usually speeds up the solution.

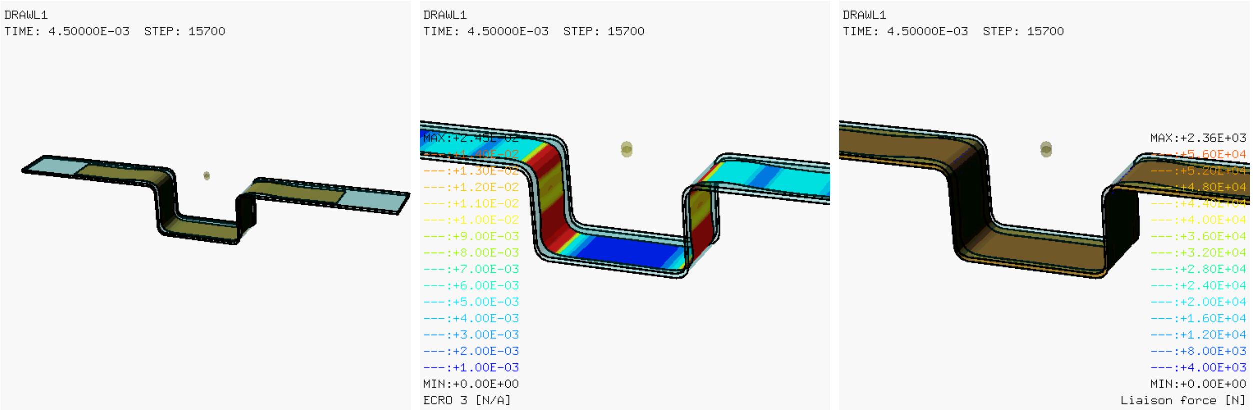
Unfortunately, the solution was almost 28 times slower than the reference, which is very upsetting. This problem is dominated by the boundary conditions, which act on all nodes of the mesh. The choice of blocking all dofs of the die and of prescribing all dofs of the punch in order to simulate these parts as rigid is very penalizing since it produces a huge links matrix. However, it is not clear why the solution with `LINK` is so much slower than with `LIAI`, which uses the same solver (Choleski) by default.

From the listing, we see that 97% of the CPU time of this solution is spent in treating the links. It is true that the manipulation of links is much more complicated (and more general) in the `LINK` model than in the old `LIAI`, but the overhead in this case is enormous.

The computed final configuration, plastic strain and contact forces are shown in Figure 142. The solution (in particular the plastic strain distribution) looks similar to the previous one obtained with `GLIS` except for the final contact forces, which are an order of magnitude smaller and are not visible in the last picture, which uses the same scale as the reference solution.

5.1.3 Case DRAWL2

This is a repetition of case DRAWL1 by removing the `SPLT NONE` option. The links set is therefore split into a number of mutually independent (smaller) sets before solving each set individually.

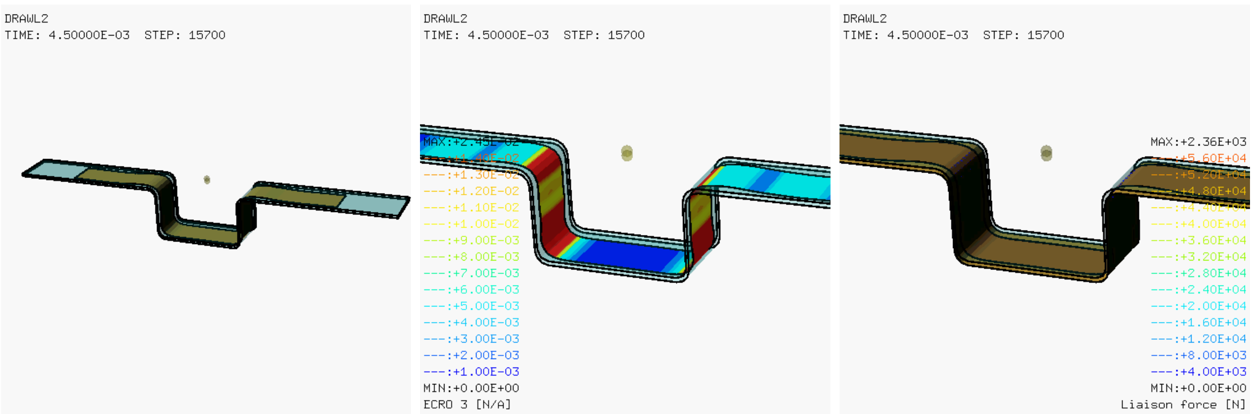


(a) Configuration (b) Plastic strain (c) Contact forces

Figure 142: Final results of test DRAWL1.

The solution is 3.6 times slower than the reference that used `LIAI`, and 7.7 times faster than the previous one. It seems therefore that in this particular case (which has very many links) splitting up the system is very convenient, and the extra CPU needed for the splitting pays off in terms of total CPU.

The computed final configuration, plastic strain and contact forces are shown in Figure 143. The solution is similar to the previous one including the contact forces (much smaller than in the reference).



(a) Configuration (b) Plastic strain (c) Contact forces

Figure 143: Final results of test DRAWL2.

5.1.4 Cases DRAWL3, DRAWL4, DRAWL5 and DRAWL6

Tests DRAWL3 and DRAWL4 are repetitions of DRAWL1 (with `SPLT NONE`) by using two alternative solvers available for the `LINK` model, respectively the Pardiso (`PARD`) and the SPLIB (`SPLI`) solver. The results are very similar, if not identical, to the solution DRAWL1 with the standard solver (Choleski) and the CPU times are much smaller, only slightly larger than those obtained by removing the `SPLT NONE` option in case DRAWL2.

This seems to indicate that an important portion of the CPU time in the slowest case DRAWL1 is spent in the solution of the linear system, which in that case uses a single large matrix (no splitting).

The tests DRAWL5 and DRAWL6 are repetitions of DRAWL2 (without `SPLT NONE`) by using the Pardiso (`PARD`) and the SPLIB (`SPLI`) solver, respectively. The results are very similar, if not identical, to the solution DRAWL2 with the standard solver (Choleski). A bit surprisingly, the CPU times are a bit larger than in case DRAWL2 and some of the benefits of using a faster solver seem to be lost.

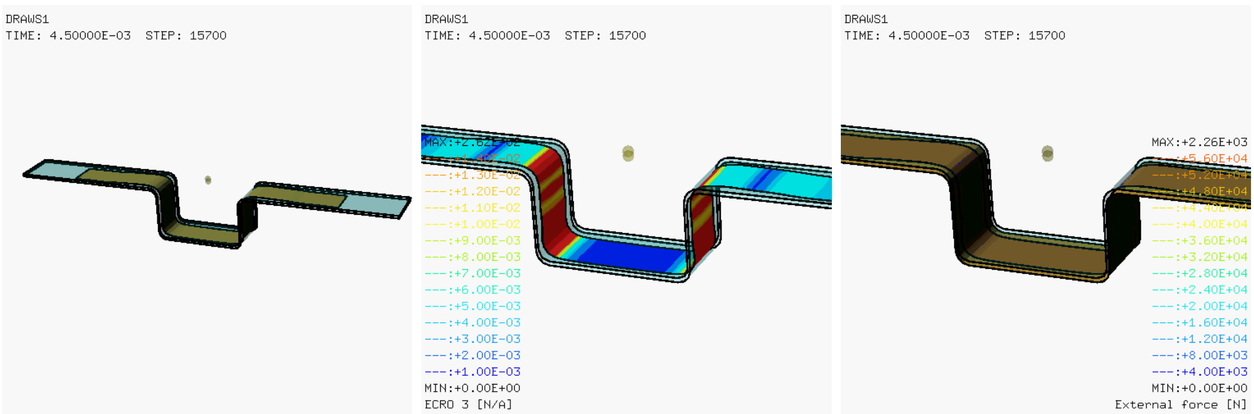
The best combination (slower CPU) using the LINK model in this case seems to be the SPLIB solver without splitting of the links system, case DRAWL4, which is “only” 2.4 times slower than LIAI (DRAW01). However, the question of how the solution with LIAI can be so fast remains open, since it uses the default Choleski solver (and no splitting).

5.1.5 Case DRAWS1

This test is identical to DRAWL1 but uses the SLID contact model instead of GLIS.

```
*----------------------------------------------------------------Couplings
LINK COUP SPLT NONE
 BLOQ 123456 LECT die   TERM
       12456 LECT punch TERM
         246 LECT piece TERM
 DEPL 3 0.1E+01 FONC 1 LECT punch TERM
 SLID 2
      SURF EMAS LECT piece TERM
           NMAS LECT piece TERM
           NSLA LECT punch TERM
      SURF EMAS LECT piece TERM
           NMAS LECT piece TERM
           NSLA LECT die TERM
 FONC 1 TABL 2
        0.0E+00     0.0E+00
        0.501E-02 -0.405E-01
*-------------------------------------------------------Initial conditions
INIT VITE 3 -8.08383 LECT punch TERM
```

The simulation was about 14% faster than the equivalent one with GLIS (case DRAWL1). The computed final configuration, plastic strain and contact forces are shown in Figure 144. The results are similar to those obtained with GLIS, the high plastic strain zone being only slightly larger than with the other contact algorithm.



(a) Configuration (b) Plastic strain (c) Contact forces

Figure 144: Final results of test DRAWS1.

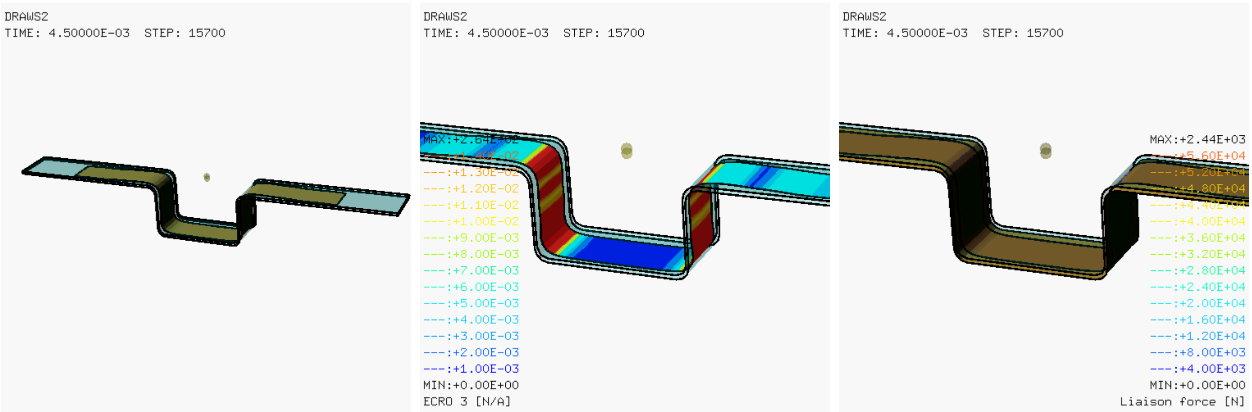
5.1.6 Case DRAWS2

This test is identical to DRAWS1 but we remove the SPLT NONE option. The CPU time drops considerably with respect to the previous solution and is about 30% higher than with GLIS. This may perhaps be due to the fact that GLIS uses a more efficient fast search algorithm than the one currently implemented in SLID (which only checks the bbox).

The results are very similar if not identical to those of case DRAWS1.

5.2 Metal box punching

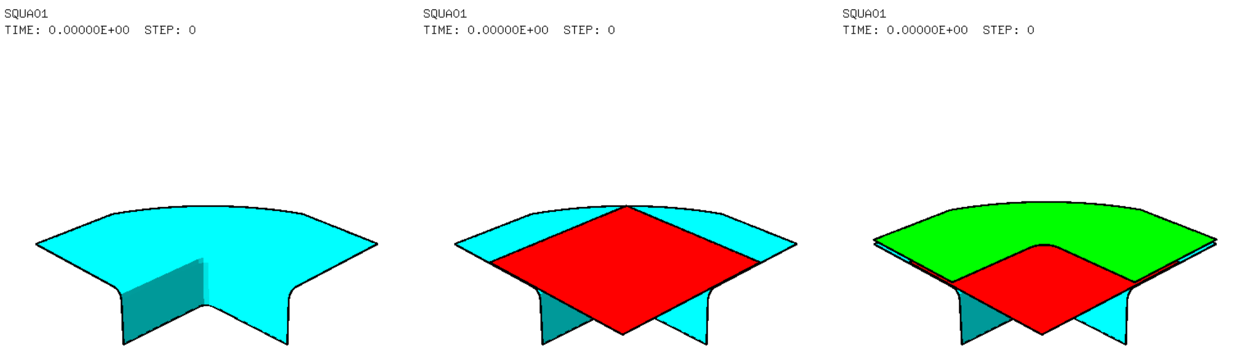
A plane square thin metallic plate is dynamically formed into a box by using a punch, a die and a holder. The initial geometry is shown in Figure 146 with the piece shown in red, the die in cyan, the



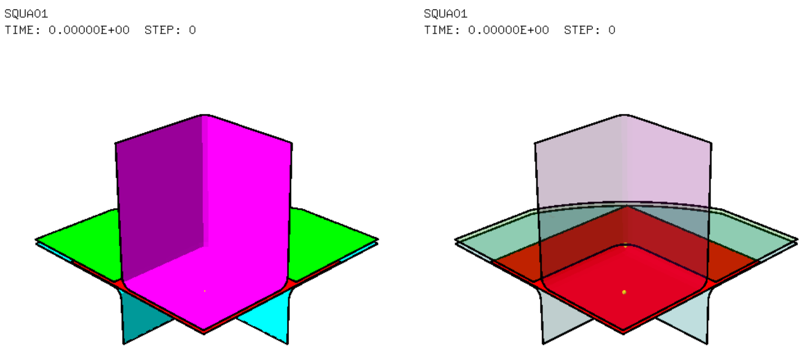
(a) Configuration (b) Plastic strain (c) Contact forces

Figure 145: Final results of test DRAWS2.

holder in green and the punch in magenta. The last picture highlights the position of the piece with respect to the other components of the assembly.



(a) Die (b) Die and piece (c) Die, piece and holder



(d) Complete assembly (e) Transparent view

Figure 146: Initial geometry of the metal box punching problem

By exploiting the two symmetries of the problem, only 1/4 of the assembly is meshed. All components are meshed by mostly Q4GS quadrilateral and a few DST3 triangular shell elements. Friction is assumed between the various components.

This problem is much more severe than the strip punching problem considered in the previous Section. The metal undergoes much more complex deformations due to the complicated geometrical shape especially near the rounded corners. The presence of symmetry and friction also poses a challenge from the computational viewpoint.

In the 1/4 model the piece is a square of 0.19×0.19 m with a thickness of 0.0008 m. The box-like cavity in the die measures 0.1125×0.1125 m with a depth of 0.06 m (with an open bottom). The holder is a square of 0.25×0.25 m with one rounded corner. The punch measures 0.11×0.11 m and has a depth of 0.145 m. The piece has an aluminum-like elastoplastic material while the die, holder and punch use a linear steel-like material. A thickness of 0.001 m is assigned to the die, holder and punch which, however, are treated as rigid bodies by suitable blockages.

The die is completely blocked, both in translation and in rotation. The holder and the punch are completely blocked except in the vertical translation. A vertical force is applied to a node of the holder while a constant vertical velocity of 4.9505 m/s is imposed to the punch. The symmetry conditions are imposed by blocking the relevant displacements.

The numerical solutions obtained for this problem are summarized in Table 12.

Case	Mesh	Description	Final time [ms]	Steps	CPU [s]
SQUA01	6977 Q4GS 33 DST3 3 PMAT	`LIAI GLIS`	10	34 720	669.7
SQUAL1	6977 Q4GS 33 DST3 3 PMAT	`LINK COUP SPLT NONE GLIS`	[0.78]	[2 730]	[500.3]
SQUAL2	6977 Q4GS 33 DST3 3 PMAT	Idem L1 but add `CONT SPLA` and `SYME`	10	157 623	101 158.0
SQUAL3	6977 Q4GS 33 DST3 3 PMAT	Idem L2 but remove `SPLT NONE`	[8.54]	[100 963]	[36 866.9]
SQUAL4	6977 Q4GS 33 DST3 3 PMAT	Idem L2 but add `SOLV PARD`	[9.66]	[145 940]	[6 930.2]
SQUAL5	6977 Q4GS 33 DST3 3 PMAT	Idem L2 but add `SOLV SPLI`	[9.51]	[145 387]	[5 878.4]
SQUAL6	6977 Q4GS 33 DST3 3 PMAT	Idem L3 but add `SOLV PARD`	[8.79]	[125 126]	[49 154.8]
SQUAL7	6977 Q4GS 33 DST3 3 PMAT	Idem L3 but add `SOLV SPLI`	10	106 736	39 452.9
SQUAL8	6977 Q4GS 33 DST3 3 PMAT	Idem L7 but swap master and slave	[8.88]	[38 525]	[14 024.0]
SQUAS5	6977 Q4GS 33 DST3 3 PMAT	Idem L5 but `LINK COUP SLID`	10	165 790	11 019.1
SQUAS9	7392 Q4GS 136 DST3	Idem S5 but Cast3m mesh	[4.12]	[63 957]	[4 265.0]

Table 12: Calculations for the metal box punching problem.

5.2.1 Case SQUA01

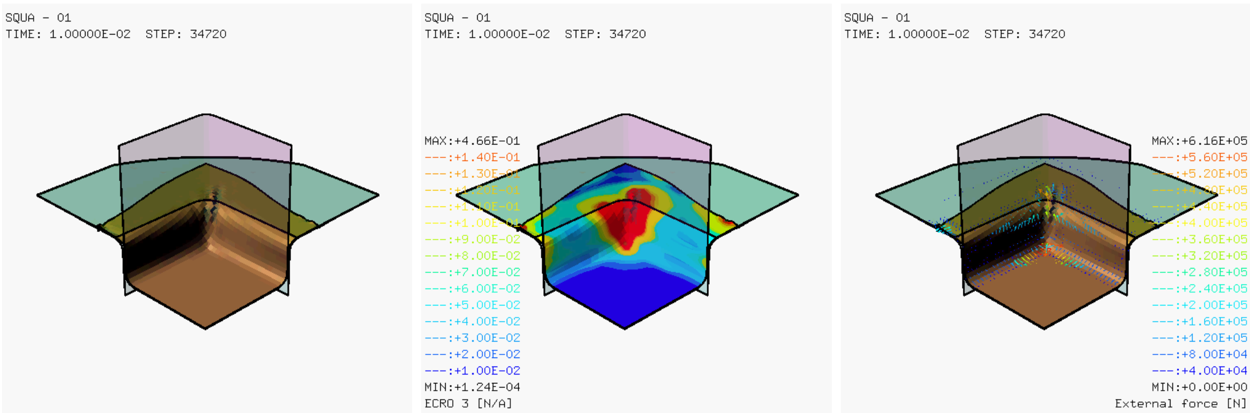
The input file for this test is taken from the old EPX examples. The mesh geometry is hard-coded in the input file, which is quite lengthy. For this reason, this file and the following ones for this example are not included in the Appendix at the end of the present report. However, they are available in a folder `Inputs_Extra` associated with the report's distribution. To impose the boundary conditions use is made of the old (now obsolescent) `LIAI` directive.

```
 FROT 1 MU0 0.25  MU1 0.25  GAMMA 1
 FROT 2 MU0 0.125 MU1 0.125 GAMMA 1
*--------------------------------------------------------------Materials
MATE
 VMIS ISOT RO 2.767E+03 YOUN 7.0E+10 NU 3.E-01 ELAS 2.93E+08
      TRAC  12  2.93000E+08               4.18571E-03
                3.09400E+08               6.10600E-03
                3.16350E+08               7.12129E-03
                3.24380E+08               8.46700E-03
                3.33800E+08               1.03196E-02
                3.45120E+08               1.29853E-02
                3.59060E+08               1.70604E-02
                3.76870E+08               2.38049E-02
                4.00710E+08               3.62904E-02
                4.34740E+08               6.35266E-02
                4.87940E+08               1.40321E-01
                1.09500E+09               1.01564E+00
       LECT piece TERM
 LINE RO 7.8E+03 YOUN  2.E+11 NU 3.E-01
       LECT die punch holder TERM
 MASS 0.1E-02
       LECT masses TERM
*--------------------------------------------------------------Couplings
LIAI
 BLOQ 123456 LECT die                     TERM
         156 LECT n_bl156                 TERM
```

```
       12456 LECT n_pibloq n_punch n_holder TERM
         246 LECT n_bl246                   TERM
 DEPL 3 0.1E+01 FONC 1 LECT punch TERM
 GLIS 3
   CMAI LECT piece  TERM EXTE LECT n_ext1 TERM
   CESC LECT punch  TERM
   CMAI LECT piece  TERM EXTE LECT n_ext2 TERM
   CESC LECT die    TERM
   CMAI LECT piece  TERM EXTE LECT n_ext3 TERM
   CESC LECT holder TERM
 FONC 1 TABL 2
        0.000E+00  0.000E+00
        0.101E-01 -0.500E-01
*-------------------------------------------------------Factorized loads
CHAR 1 FACT 2
 FORC 3 0.1E+01 LECT n_forcz TERM
        TABL 3
        0.000E+00  0.000E+00
        0.100E-02 -0.200E+05
        0.100E-00 -0.200E+05
*-----------------------------------------------------Initial conditions
INIT VITE 3 -4.95050 LECT punch TERM
```

Three GLIS sliding surfaces are specified, in all of which the piece acts as shell master, while the shell slave is represented by the punch, the die and the holder, respectively.

The computed final configuration, plastic strain and contact forces are shown in Figure 147.



(a) Configuration (b) Plastic strain (c) Contact forces

Figure 147: Final results of test SQUA01.

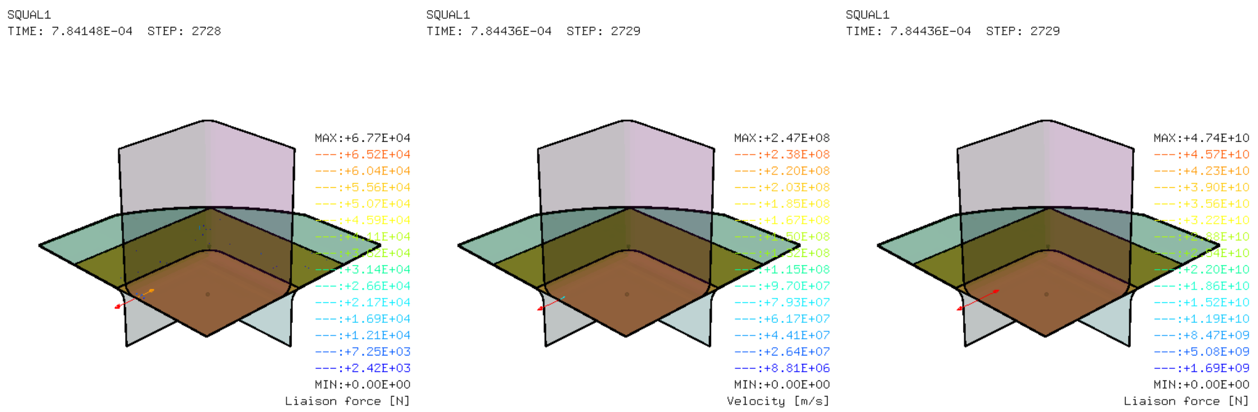
5.2.2 Case SQUAL1

This is a repetition of case SQUA01 by using the LINK COUP instead of LIAI for the boundary conditions. The SPLT NONE option is activated since it usually speeds up the solution.

```
*---------------------------------------------------------------Couplings
LINK COUP SPLT NONE
 BLOQ 123456 LECT die                       TERM
         156 LECT n_bl156                   TERM
       12456 LECT n_pibloq n_punch n_holder TERM
         246 LECT n_bl246                   TERM
 DEPL 3 0.1E+01 FONC 1 LECT punch TERM
 GLIS 3
   FROT MUST 0.25 MUDY 0.25 GAMM 1
   CMAI LECT piece  TERM EXTE LECT n_ext1 TERM
   CESC LECT punch  TERM
   FROT MUST 0.125 MUDY 0.125 GAMM 1
   CMAI LECT piece  TERM EXTE LECT n_ext2 TERM
   CESC LECT die    TERM
   CMAI LECT piece  TERM EXTE LECT n_ext3 TERM
   CESC LECT holder TERM
 FONC 1 TABL 2
```

```
        0.000E+00  0.000E+00
        0.101E-01 -0.500E-01
*-------------------------------------------------------Factorized loads
CHAR 1 FACT 2
 FORC 3 0.1E+01 LECT n_forcz TERM
        TABL 3
        0.000E+00  0.000E+00
        0.100E-02 -0.200E+05
        0.100E-00 -0.200E+05
*-----------------------------------------------------Initial conditions
INIT VITE 3 -4.95050 LECT punch TERM
```

Unfortunately, this simulation crashed at step 2730, $t = 0.784$ ms, with huge velocities and a bad energy check, indicating a probable numerical instability. Drawing the result at step 2729 (last drawable step, after which the geometry becomes weird) revealed huge contact forces (horizontal components) and huge velocities on some nodes of the edges subjected to symmetries, see Figure 148.



(a) Force @ step 2728 (b) Force @ step 2729 (c) Velocity @ step 2729

Figure 148: Results of test SQUAL1 just before crash.

5.2.3 Case SQUAL2

The difficulties observed in the previous solution are believed to stem from the incompatibility of the GLIS contact model with symmetry conditions, especially in the presence of friction like in this case.

It is therefore attempted to add the option OPTI GLIS SYME which has been recently developed in order to eliminate such incompatibility. A first attempt at running the code with this option gave results identical to SQUAL1. After some inspection it was found that, in order for the SYME option to work, it is necessary that the symmetries be imposed by the CONT SPLA directive, and not by simply blocking some global dofs as it is done in the previous solutions.

By replacing the symmetry-related blockages with the CONT SPLA directive, a solution was obtained until the final time, albeit at a very high cost in terms of CPU.

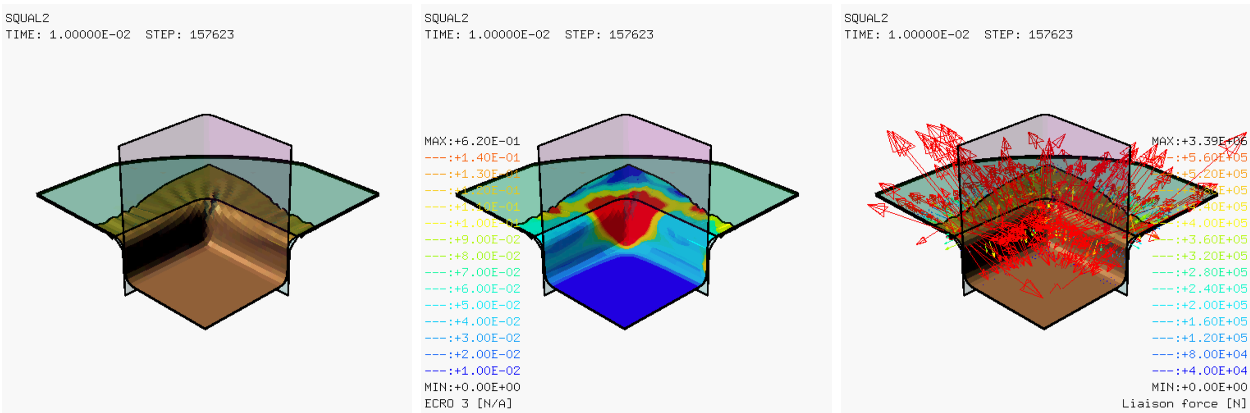
```
LINK COUP SPLT NONE
 BLOQ 123456 LECT die DIFF symx symy TERM
       12456 LECT n_punch n_holder DIFF symx symy TERM
 CONT SPLA NX 1 NY 0 NZ 0 LECT symx TERM
      SPLA NX 0 NY 1 NZ 0 LECT symy TERM
 DEPL 3 0.1E+01 FONC 1 LECT punch TERM
 GLIS 3
   FROT MUST 0.25 MUDY 0.25 GAMM 1
   CMAI LECT piece  TERM EXTE LECT n_ext1 TERM
   CESC LECT punch  TERM
   FROT MUST 0.125 MUDY 0.125 GAMM 1
   CMAI LECT piece  TERM EXTE LECT n_ext2 TERM
   CESC LECT die    TERM
   CMAI LECT piece  TERM EXTE LECT n_ext3 TERM
   CESC LECT holder TERM
 FONC 1 TABL 2
        0.000E+00  0.000E+00
```

```
        0.101E-01 -0.500E-01
*-------------------------------------------------------Factorized loads
CHAR 1 FACT 2
 FORC 3 0.1E+01 LECT n_forcz TERM
        TABL 3
        0.000E+00  0.000E+00
        0.100E-02 -0.200E+05
        0.100E-00 -0.200E+05
*-----------------------------------------------------Initial conditions
INIT VITE 3 -4.95050 LECT punch TERM
*----------------------------------------------------------------Storage
ECRI
  DEPL VITE TFRE 1.0E-3 POIN LECT n_alit TERM
  FICH ALIC      TFRE 1.0E-04
  FICH ALIC TEMP TFRE 1.0E-05
                 POIN LECT n_alit TERM
                 ELEM LECT e_alit TERM
*----------------------------------------------------------------Options
OPTI LOG 1
     step io
     GLIS SYME
```

The CPU cost of this simulation was 151 *times* the solution SQUA01 with the `LIAI` model, and the observations in that respect that were done in case DRAWL1 vs. DRAW01 in the previous Section are even more appropriate here.

The computed final configuration, plastic strain and contact forces are shown in Figure 149. By comparing against the results of case SQUA01, one observes larger wrinkles being formed in the part of the piece that remains clamped between the die and the holder. Furthermore, the final contact forces are much larger.

It is believed that the `LIAI`-based version of the `GLIS` contact model used in solution SQUA01 was less (if at all) sensitive to the presence of symmetries when friction was activated in the model.



(a) Configuration (b) Plastic strain (c) Contact forces

Figure 149: Final results of test SQUAL2.

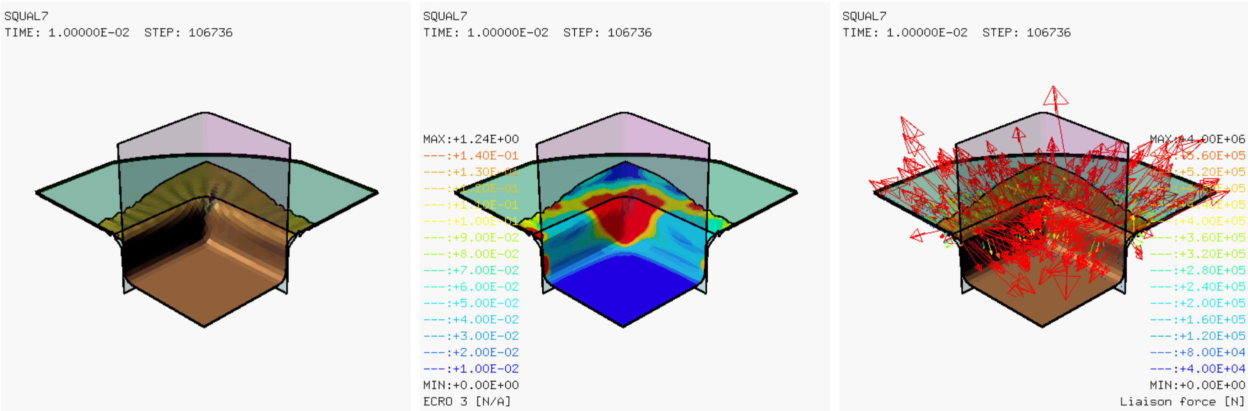
5.2.4 Cases SQUAL3, SQUAL4, SQUAL5, SQUAL6 and SQUAL7

The next five simulations are repetitions of case SQUAL2 in an attempt to reduce the CPU time by removing the `SPLT NONE` option (like in the strip punching problem) and/or selecting a different (supposedly faster) solver for the links linear problem.

Unfortunately, all these simulations except the last one (SQUAL7) crashed prematurely, between 8.5 and 9.6 ms of physical time, due to numerical instability. Results for these faulty simulations are not presented for brevity.

The only simulation that reached the final time was SQUAL7, which used the SPLIB solver (`SOLV SPLI`) and the default splitting of the linear problem into a set of independent problems (no `SPLT NONE`). The CPU time was about 2.5 times less than in solution SQUAL2 but still 59 *times* the value required by the solution with the old `LIAI` model (case SQUA01). Furthermore, at the final time some spurious penetrations of the piece into the die and the holder were observed, especially near the symmetry planes.

The computed final configuration, plastic strain and contact forces are shown in Figure 150. The solution appears very similar to that of case SQUAL2.



(a) Configuration (b) Plastic strain (c) Contact forces

Figure 150: Final results of test SQUAL7.

5.2.5 Case SQUAL8

This test is a repetition of case SQUAL7 by inverting the roles of master and slave in the `GLIS` sliding surfaces, in an attempt to avoid the spurious penetrations observed in the previous solution.

```
*--------------------------------------------Additional geometrical data
COMP
 GROU 6 'masses' LECT    1 PAS 1    3 TERM
        'piece'  LECT   37 PAS 1 1480 TERM
        'die'    LECT   23 PAS 1   36 4769 PAS 1 7013 TERM
        'punch'  LECT   22 3082 PAS 1 4768 TERM
        'holder' LECT    4 PAS 1   21 1481 PAS 1 3081 TERM
        'e_alit' LECT    1              TERM
 COUL jaun LECT masses TERM
      roug LECT piece  TERM
      turq LECT die    TERM
      rose LECT punch  TERM
      vert LECT holder TERM
 NGRO 17 'n_masses' LECT masses TERM
         'n_piece'  LECT piece  TERM
         'n_die'    LECT die    TERM
         'n_punch'  LECT punch  TERM
         'n_holder' LECT holder TERM
         'n_ext1'   LECT 7342   TERM
         'n_ext2'   LECT 7343   TERM
         'n_ext3'   LECT 7344   TERM
         'n_pibloq' LECT 39     TERM
         'n_bl156'  LECT 1 PAS 1 38 TERM
         'n_bl246'  LECT 78 116 PAS 1 152 TERM
         'n_forcz'  LECT 2673 TERM
         'n_ali1'   LECT 1522 TERM
         'n_ali2'   LECT 3439 TERM
         'n_alit'   LECT n_ali1 n_ali2 TERM
         'symx'     LECT piece die punch holder TERM COND X LT 0.001
         'symy'     LECT piece die punch holder TERM COND Y LT 0.001
 EPAI 0.8E-03 LECT piece TERM
 EPAI 1.0E-03 LECT die punch holder TERM
 EPAI 1.0E-03 LECT masses TERM
!FROT 1 MU0 0.25  MU1 0.25  GAMMA 1
!FROT 2 MU0 0.125 MU1 0.125 GAMMA 1
*------------------------------------------------------------Materials
MATE
 VMIS ISOT RO 2.767E+03 YOUN 7.0E+10 NU 3.E-01 ELAS 2.93E+08
      TRAC   12  2.93000E+08                4.18571E-03
                 3.09400E+08                6.10600E-03
```

```
                3.16350E+08                 7.12129E-03
                3.24380E+08                 8.46700E-03
                3.33800E+08                 1.03196E-02
                3.45120E+08                 1.29853E-02
                3.59060E+08                 1.70604E-02
                3.76870E+08                 2.38049E-02
                4.00710E+08                 3.62904E-02
                4.34740E+08                 6.35266E-02
                4.87940E+08                 1.40321E-01
                1.09500E+09                 1.01564E+00
       LECT piece TERM
 LINE RO 7.8E+03 YOUN  2.E+11 NU 3.E-01
       LECT die punch holder TERM
 MASS 0.1E-02
       LECT masses TERM
*--------------------------------------------------------------Couplings
LINK COUP ! SPLT NONE
            SOLV SPLI
 BLOQ 123456 LECT die DIFF symx symy TERM
       12456 LECT n_punch n_holder DIFF symx symy TERM
 CONT SPLA NX 1 NY 0 NZ 0 LECT symx TERM
      SPLA NX 0 NY 1 NZ 0 LECT symy TERM
 DEPL 3 0.1E+01 FONC 1 LECT punch TERM
 GLIS 3
   FROT MUST 0.25 MUDY 0.25 GAMM 1
   CMAI LECT punch  TERM INTE POIN 0 0 0.15
   CESC LECT piece  TERM
   FROT MUST 0.125 MUDY 0.125 GAMM 1
   CMAI LECT die    TERM EXTE POIN 0 0 0.15
   CESC LECT piece  TERM
   CMAI LECT holder TERM EXTE POIN 0 0 -0.15
   CESC LECT piece  TERM
 FONC 1 TABL 2
        0.000E+00  0.000E+00
        0.101E-01 -0.500E-01
*-------------------------------------------------------Factorized loads
CHAR 1 FACT 2
 FORC 3 0.1E+01 LECT n_forcz TERM
        TABL 3
        0.000E+00  0.000E+00
        0.100E-02 -0.200E+05
        0.100E-00 -0.200E+05
*-----------------------------------------------------Initial conditions
INIT VITE 3 -4.95050 LECT punch TERM
```

Unfortunately, the simulation crashed before the final time, at about 8.9 ms, showing some signs of numerical instability (large velocities). The results obtained until then are not shown for brevity.

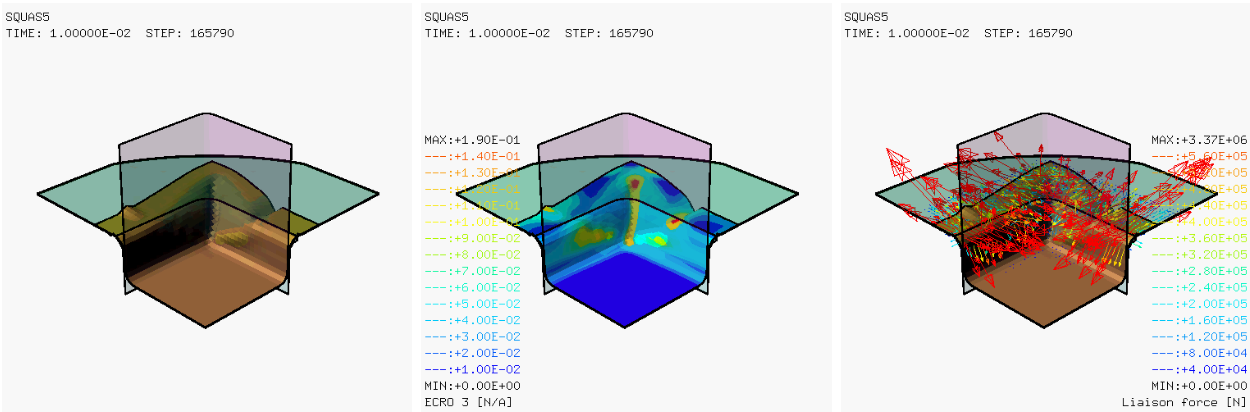
5.2.6 Case SQUAS5

This test is equivalent to SQUAL5 but it uses the `SLID` contact model instead of `GLIS`.

```
*--------------------------------------------------------------Couplings
LINK COUP SPLT NONE SOLV SPLI
 BLOQ 123456 LECT die DIFF symx symy TERM
       12456 LECT n_punch n_holder DIFF symx symy TERM
 CONT SPLA NX 1 NY 0 NZ 0 LECT symx TERM
      SPLA NX 0 NY 1 NZ 0 LECT symy TERM
 DEPL 3 0.1E+01 FONC 1 LECT punch TERM
!GLIS 3
!  FROT MUST 0.25 MUDY 0.25 GAMM 1
!  CMAI LECT piece  TERM EXTE LECT n_ext1 TERM
!  CESC LECT punch  TERM
!  FROT MUST 0.125 MUDY 0.125 GAMM 1
!  CMAI LECT piece  TERM EXTE LECT n_ext2 TERM
!  CESC LECT die    TERM
!  CMAI LECT piece  TERM EXTE LECT n_ext3 TERM
!  CESC LECT holder TERM
 SLID 3
   SURF FROT MUST 0.25 MUDY 0.25 GAMM 1
        EMAS LECT piece  TERM
        NMAS LECT piece  TERM
        NSLA LECT punch  TERM
   SURF FROT MUST 0.125 MUDY 0.125 GAMM 1
```

```
        EMAS LECT piece  TERM
        NMAS LECT piece  TERM
        NSLA LECT die    TERM
   SURF EMAS LECT piece  TERM
        NMAS LECT piece  TERM
        NSLA LECT holder TERM
 FONC 1 TABL 2
        0.000E+00  0.000E+00
        0.101E-01 -0.500E-01
```

The computed final configuration, plastic strain and contact forces are shown in Figure 151. The solution presents relatively heavy penetrations of the piece into the die and, towards the end of the solution, also into the holder, and therefore it does not look acceptable.



(a) Configuration (b) Plastic strain (c) Contact forces

Figure 151: Final results of test SQUAS5.

5.2.7 Case SQUAS9

A completely new mesh produced by Cast3m is used for this test, in an attempt to obtain a more regular grid on the rounded corners and especially in the toroidal parts of the corner in the punch and the die. The mesh generation file reads:

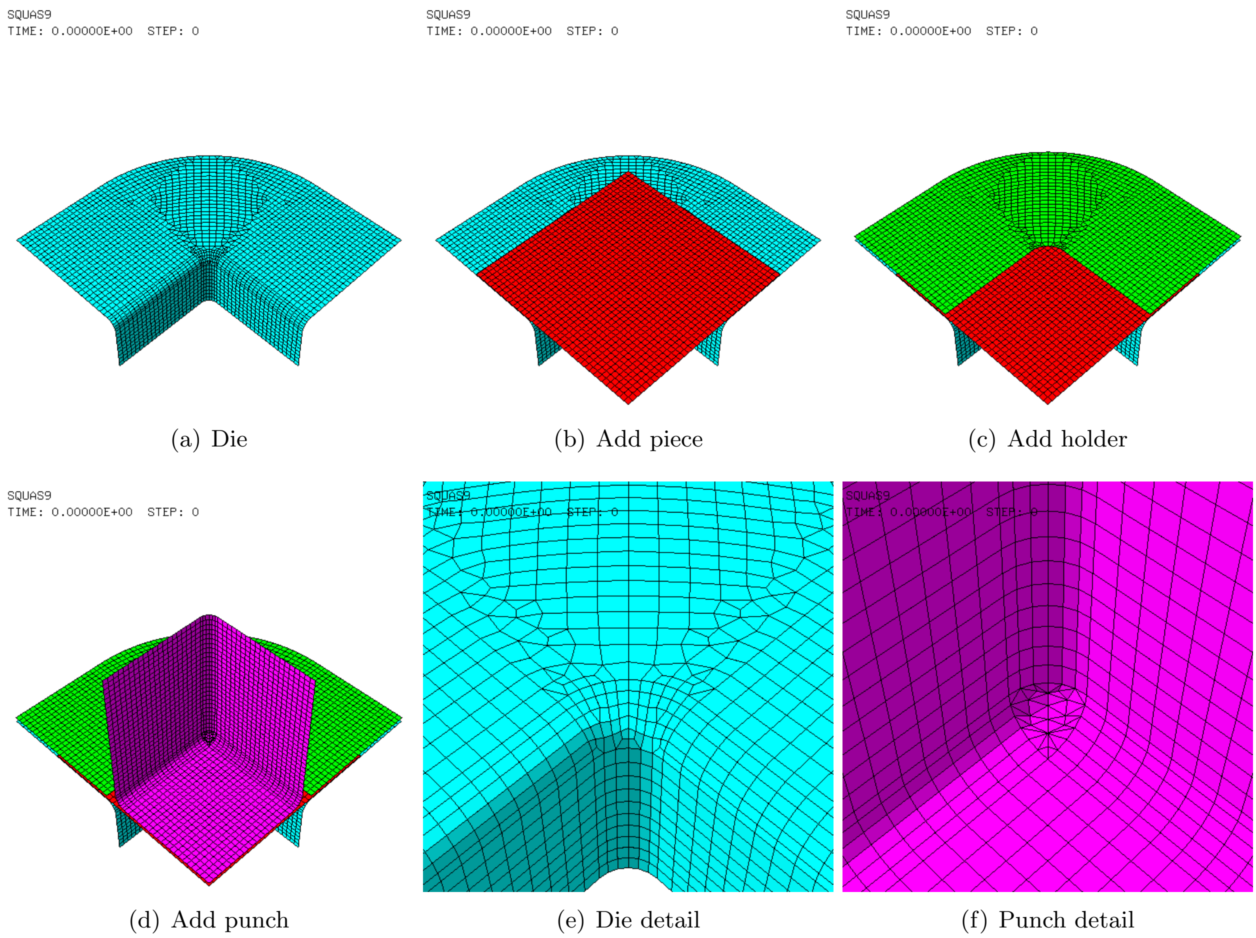
```
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'squas9_mesh.ps';
opti sauv form 'squas9.msh';
*
ncham = 6;
nchamz = 6;
nchamz2 = nchamz / 2;
*
n = 38;
ppi1 = 0 0 0.001;
ppi2 = 0.19 0 0.001;
ppi3 = 0.19 0.19 0.001;
ppi4 = 0 0.19 0.001;
cpi1 = ppi1 d n ppi2;
cpi2 = ppi2 d n ppi3;
cpi3 = ppi3 d n ppi4;
cpi4 = ppi4 d n ppi1;
piece = inve (dall cpi1 cpi2 cpi3 cpi4 plan);
*trac cach qual piece;
*
nx = 26;
ny = 20;
pho1 = 0.1225 0 0.005;
pho2 = 0.25 0 0.005;
pho3 = 0.25 0.1025 0.005;
pho4 = 0.1225 0.1025 0.005;
cho1 = pho1 d nx pho2;
cho2 = pho2 d ny pho3;
cho3 = pho3 d nx pho4;
cho4 = pho4 d ny pho1;
hold1 = dall cho1 cho2 cho3 cho4 plan;
*trac cach qual hold1;
*trac cach qual (piece et hold1);
p0 = 0 0 0;
pc = 0.1025 0.1025 0;
pch = pc plus (0 0 0.005);
p45 = 1 1 0;
pz = 0 0 1;
tol = 0.0001;
*hold2 = cho3 rota ncham 45 pc (pc plus pz);
pho5 = pho3 tour 45 pc (pc plus pz);
pho6 = pho4 tour 45 pc (pc plus pz);
cho5 = pho4 d nx pho3;
cho6 = c 21 pho3 pch pho5;
cho7 = pho5 d nx pho6;
cho8 = c ncham pho6 pch pho4;
hold2 = surf (cho5 et cho6 et cho7 et cho8) plan;
*
hold12 = hold1 et hold2;
hold34 = hold12 syme plan p0 p45 pz;
holder = orie (hold12 et hold34) poin (0 0 1000);
elim tol holder;
*trac cach (piece et holder);
oeil = 0 0 100000;
*trac cach oeil (piece et holder);
*
np = 20;
ppu1 = 0 0 0.005;
ppu2 = 0.10 0 0.005;
ppu3 = 0.10 0.10 0.005;
ppu4 = 0 0.10 0.005;
cpu1 = ppu1 d np ppu2;
cpu2 = ppu2 d np ppu3;
cpu3 = ppu3 d np ppu4;
cpu4 = ppu4 d np ppu1;
punc1 = dall cpu1 cpu2 cpu3 cpu4 plan;
*
npz = 27;
ppu5 = 0.11 0 0.015;
ppu6 = 0.11 0 0.15;
ppu7 = 0.11 0.10 0.15;
ppu8 = 0.11 0.10 0.015;
cpu5 = ppu5 d npz ppu6;
cpu6 = ppu6 d np ppu7;
cpu7 = ppu7 d npz ppu8;
```

```
cpu8 = ppu8 d np ppu5;
punc2 = dall cpu5 cpu6 cpu7 cpu8 plan;
*
punc3 = punc2 syme plan p0 p45 pz;
*
pcp1 = 0.10 0 0.015;
cpu9 = c ncham ppu2 pcp1 ppu5;
vy = 0 0.10 0;
punc4 = cpu9 tran np vy;
*
punc5 = punc4 syme plan p0 p45 pz;
*
pcp2 = 0.10 0.10 0.15;
ppu9 = 0.10 0.11 0.15;
cpu9 = c nchamz ppu7 pcp2 ppu9;
vz = 0 0 -0.135;
punc6 = cpu9 tran npz vz;
*
pcp3 = 0.1 0.1 0.015;
ppu10 = ppu8 tour 45 ppu3 (ppu3 plus pz);
cpu10 = c ncham ppu3 pcp3 ppu8;
cpu11 = c nchamz2 ppu8 pcp3 ppu10;
cpu12 = c ncham ppu10 pcp3 ppu3;
cpu101112 = cpu10 et cpu11 et cpu12;
punc7 = chan tri3 (surf cpu101112 sphe pcp3);
punc8 = punc7 syme plan p0 p45 pz;
trac cach (punc7 et punc8);
*
punch = inve (orie
             (punc1 et punc2 et punc3 et punc4 et punc5 et punc6
              et punc7 et punc8) poin (0 0 0.075));
elim tol punch;
*trac cach punch;
*trac cach (punc4 et punc5 et punc6);
*
nd1 = 10;
nd2 = 21;
pdi1 = 0.1125 0 -0.06;
pdi2 = 0.1125 0 -0.01;
pdi3 = 0.1125 0.1025 -0.01;
pdi4 = 0.1125 0.1025 -0.06;
cdi1 = pdi1 d nd1 pdi2;
cdi2 = pdi2 d nd2 pdi3;
cdi3 = pdi3 d nd1 pdi4;
cdi4 = pdi4 d nd2 pdi1;
die1 = dall cdi1 cdi2 cdi3 cdi4 plan;
*
nd3 = 26;
pdi5 = 0.1225 0 0;
pdi6 = 0.25 0 0;
pdi7 = 0.25 0.1025 0;
pdi8 = 0.1225 0.1025 0;
cdi5 = pdi5 d nd3 pdi6;
cdi6 = pdi6 d nd2 pdi7;
cdi7 = pdi7 d nd3 pdi8;
cdi8 = pdi8 d nd2 pdi5;
die2 = dall cdi5 cdi6 cdi7 cdi8 plan;
*
die3 = die1 syme plan p0 p45 pz;
die4 = die2 syme plan p0 p45 pz;
*
pcdi1 = 0.1025 0.1025 0;
pdi9 = pdi7 tour 45 pcdi1 (pcdi1 plus pz);
pdi10 = pdi8 tour 45 pcdi1 (pcdi1 plus pz);
cdi9 = pdi8 d nd3 pdi7;
cdi10 = c 21 pdi7 pcdi1 pdi9;
cdi11 = pdi9 d nd3 pdi10;
cdi12 = c ncham pdi10 pcdi1 pdi8;
die5 = surf (cdi9 et cdi10 et cdi11 et cdi12) plan;
*
die6 = die5 syme plan p0 p45 pz;
*
pcdi2 = 0.1225 0 -0.01;
cdi13 = c ncham pdi2 pcdi2 pdi5;
vyd = 0 0.1025 0;
die7 = cdi13 tran nd2 vyd;
*
die8 = die7 syme plan p0 p45 pz;
*
pcdi3 = 0.1025 0.1025 -0.06;
pdi11 = 0.1125 0.1025 -0.06;
pdi12 = pdi11 tour 90 pcdi3 (pcdi3 plus pz);
cdi13 = c ncham pdi11 pcdi3 pdi12;
vzd = 0 0 0.05;
die9 = cdi13 tran nd1 vzd;
*trac cach (die7 et die8 et die9);
*
pcdi4 = 0.1025 0.1025 -0.01;
pcdi5 = 0.1025 0.1025 0;
pdi13 = pdi3 tour 45 pcdi4 (pcdi4 plus pz);
cdi14 = 0.1225 0.1025 -0.01;
cdi15 = cdi14 tour 45 pcdi4 (pcdi4 plus pz);
con1 = c ncham pdi3 cdi14 pdi8;
con2 = c nchamz pdi8 pcdi5 pdi10;
con3 = c ncham pdi10 cdi15 pdi13;
con4 = c nchamz2 pdi13 pcdi4 pdi3;
*con4 = c nchamz pdi13 pcdi4 pdi3;
coco = con1 et con2 et con3 et con4;
trac qual (coco et pcdi4 et cdi14 et cdi15);
trac noeu (coco et pcdi4 et cdi14 et cdi15);
oe = 0 0 100000;
trac oe qual (coco et pcdi4 et cdi14 et cdi15);
oe = 0 -100000 0;
trac oe qual (coco et pcdi4 et cdi14 et cdi15);
die10 = surf coco tori pcdi4 (pcdi4 plus pz) cdi14;
die11 = die10 syme plan p0 p45 pz;
trac cach (die10 et die11);
*
die = orie (die1 et die2 et die3 et die4 et die5 et die6 et die7
          et die8 et die9 et die10 et die11) poin (0 0 0.075);
elim tol die;
*trac cach die;
*
mesh = piece et holder et punch et die;
sh3 = mesh elem tri3;
sh4 = mesh elem qua4;
tass mesh noop;
sauv form mesh;
trac cach mesh;
*
fin;
```

Details of the Cast3m mesh are presented in Figure 152.

The EPX input file is listed below, and it uses the SLID contact model like the previous example. The material points are no longer meshed since they were necessary only for the GLIS model.

```
SQUAS9
*
 ECHO
!CONV WIN
*--------------------------------------------------------Type of problem
CAST mesh
 TRID
 AMOR
*--------------------------------------------------------Geometry (Mesh)
GEOM
 DST3 sh3
 Q4GS sh4
TERM
*--------------------------------------------Additional geometrical data
COMP
 GROU 1 'e_alit' LECT 1 TERM
 COUL roug LECT piece  TERM
      turq LECT die    TERM
      rose LECT punch  TERM
      vert LECT holder TERM
NGRO 6 ! 17
       'n_forcz'  LECT holder TERM COND NEAR POIN 0.15 0.15 0.005
       'n_ali1'   LECT holder TERM COND NEAR POIN 0.1225 0.1025 0.005
       'n_ali2'   LECT punch  TERM COND NEAR POIN 0 0 0.005
       'n_alit'   LECT n_ali1 n_ali2 TERM
       'symx'     LECT piece die punch holder TERM COND X LT 0.001
       'symy'     LECT piece die punch holder TERM COND Y LT 0.001
 EPAI 0.8E-03 LECT piece TERM
 EPAI 1.0E-03 LECT die punch holder TERM
*--------------------------------------------------------------Materials
MATE
 VMIS ISOT RO 2.767E+03 YOUN 7.0E+10 NU 3.E-01 ELAS 2.93E+08
      TRAC  12  2.93000E+08              4.18571E-03
                3.09400E+08              6.10600E-03
                3.16350E+08              7.12129E-03
                3.24380E+08              8.46700E-03
                3.33800E+08              1.03196E-02
                3.45120E+08              1.29853E-02
                3.59060E+08              1.70604E-02
                3.76870E+08              2.38049E-02
                4.00710E+08              3.62904E-02
                4.34740E+08              6.35266E-02
                4.87940E+08              1.40321E-01
                1.09500E+09              1.01564E+00
       LECT piece TERM
 LINE RO 7.8E+03 YOUN  2.E+11 NU 3.E-01
       LECT die punch holder TERM
*--------------------------------------------------------------Couplings
LINK COUP SPLT NONE SOLV SPLI
 BLOQ 123456 LECT die DIFF symx symy TERM
       12456 LECT punch holder DIFF symx symy TERM
 CONT SPLA NX 1 NY 0 NZ 0 LECT symx TERM
      SPLA NX 0 NY 1 NZ 0 LECT symy TERM
 DEPL 3 0.1E+01 FONC 1 LECT punch TERM
!!GLIS 3
!!  FROT MUST 0.25 MUDY 0.25 GAMM 1
!!  CMAI LECT piece  TERM EXTE LECT n_ext1 TERM
!!  CESC LECT punch  TERM
!!  FROT MUST 0.125 MUDY 0.125 GAMM 1
!!  CMAI LECT piece  TERM EXTE LECT n_ext2 TERM
!!  CESC LECT die    TERM
!!  CMAI LECT piece  TERM EXTE LECT n_ext3 TERM
!!  CESC LECT holder TERM
 SLID 3
```



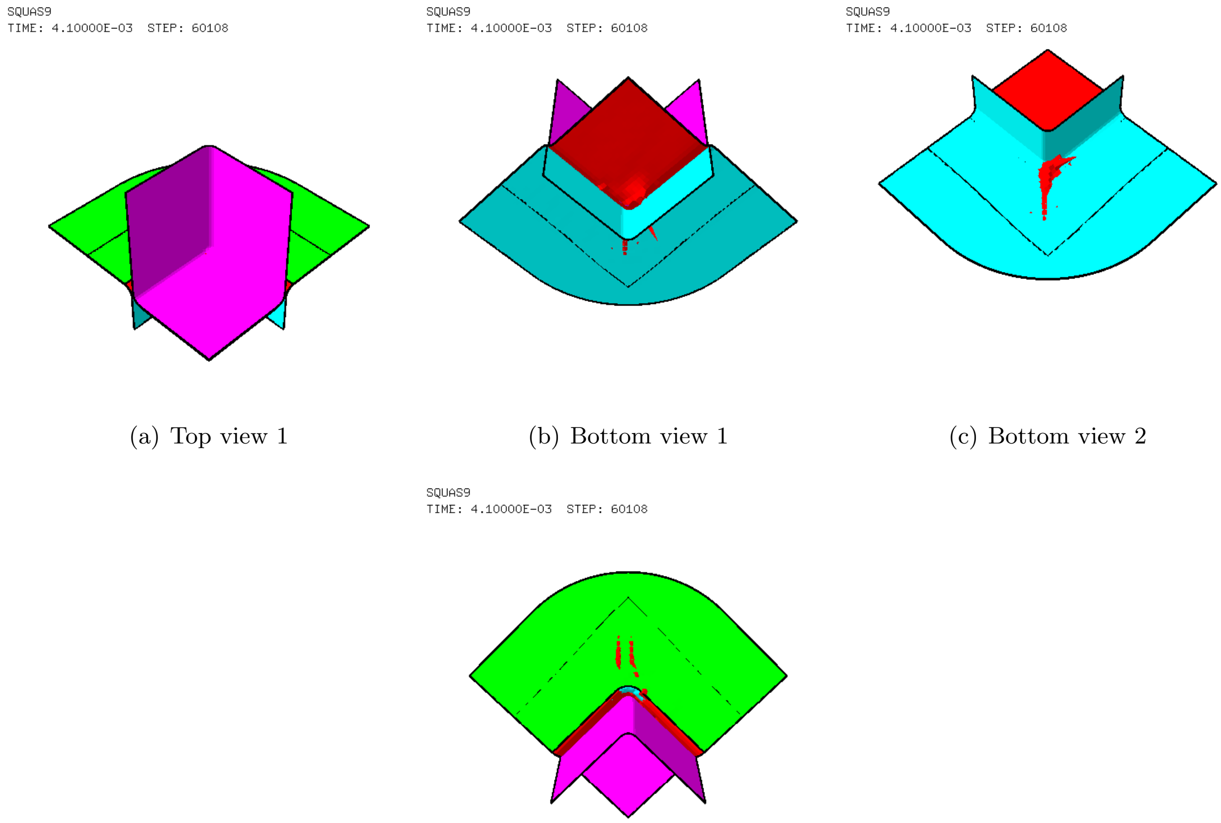
(a) Die (b) Add piece (c) Add holder

(d) Add punch (e) Die detail (f) Punch detail

Figure 152: Initial Cast3m mesh for test SQUAS9.

```
   SURF FROT MUST 0.25 MUDY 0.25 GAMM 1
        EMAS LECT piece  TERM
        NMAS LECT piece  TERM
        NSLA LECT punch  TERM
   SURF FROT MUST 0.125 MUDY 0.125 GAMM 1
        EMAS LECT piece  TERM
        NMAS LECT piece  TERM
        NSLA LECT die    TERM
   SURF EMAS LECT piece  TERM
        NMAS LECT piece  TERM
        NSLA LECT holder TERM
 FONC 1 TABL 2
        0.000E+00  0.000E+00
        0.101E-01 -0.500E-01
*-------------------------------------------------------Factorized loads
CHAR 1 FACT 2
 FORC 3 0.1E+01 LECT n_forcz TERM
        TABL 3
        0.000E+00  0.000E+00
        0.100E-02 -0.200E+05
        0.100E-00 -0.200E+05
*-----------------------------------------------------Initial conditions
INIT VITE 3 -4.95050 LECT punch TERM
*----------------------------------------------------------------Storage
ECRI
  DEPL VITE TFRE 1.0E-3 ! POIN LECT n_alit TERM
  FICH ALIC      TFRE 1.0E-04
  FICH ALIC TEMP TFRE 1.0E-05
                 POIN LECT n_alit TERM
                 ELEM LECT e_alit TERM
*-----------------------------------------------------------------Options
OPTI LOG 1
     step io
     GLIS SYME
*--------------------------------------------------------------Time Steps
CALC TINI 0.E+00 TFIN 10.E-03
*=======================================================================
SUIT
Post-treatment (time curves from alice temps file)
ECHO
*
RESU ALIC TEMP GARD PSCR
*
SORT GRAP
*
AXTE 1000.0 'Time [ms]'
*
COUR  1 'dz_1' DEPL COMP 3 NOEU LECT n_ali1 TERM
COUR  2 'dz_2' DEPL COMP 3 NOEU LECT n_ali2 TERM
COUR  3 'vz_1' VITE COMP 3 NOEU LECT n_ali1 TERM
COUR  4 'vz_2' VITE COMP 3 NOEU LECT n_ali2 TERM
*
trac 1 2 axes 1.0 'DISPL. [M]'
trac 3 4 axes 1.0 'VELOC. [M/S]'
*
QUAL DEPL COMP 3 LECT n_ali2 TERM REFE -4.95050E-2 TOLE 5.E-3
*=======================================================================
FIN
```

Unfortunately, the simulation crashed at 4.124 ms of physical time. Some results at the last stored time station (4.1 ms) are presented in Figure 153, where one can observe spurious penetrations of the piece into the die, the holder and the punch.



(a) Top view 1 (b) Bottom view 1 (c) Bottom view 2

(d) Top view 2

Figure 153: Results of test SQUAS9 at $t = 4.1$ ms.

6 Preliminary conclusions

The report has detailed a first formulation and implementation of the novel SLID contact model in EPX. Some of the model features are still experimental. As mentioned in the Introduction, further work will be required to make the model as general and as robust as possible.

Although several numerical examples, some of which also relatively realistic and with promising results, have been presented in the previous Sections, many additional tests will be required to complete the verification process and to finalize the formulation and implementation of the model.

For these reasons, drawing any conclusions on the relative performance of SLID compared with other similar models, most notably GLIS, appears as premature in this early phase of the development.

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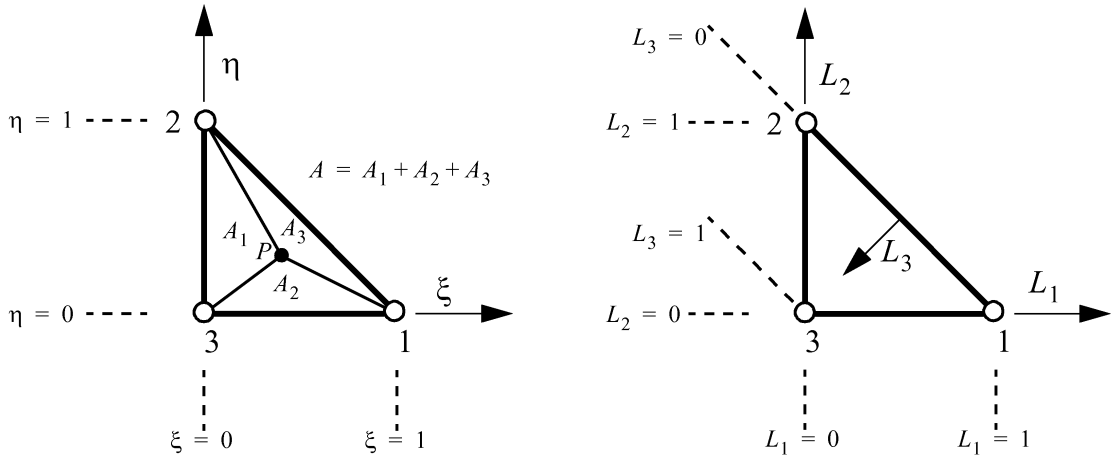
Appendix A — Area coordinates

The triangle

The area coordinates for the triangle are defined in Figure 154.



(a) Parent triangle (b) Area coordinates

Figure 154: Area coordinates for the triangle.

Let A denote the area of the triangle. Then, for each point P in the plane of the triangle one may define three areas A_1, A_2, A_3 as shown in Figure 154(a), such that:

$$A = A_1 + A_2 + A_3 \tag{1}$$

where ξ, η are the normalized coordinates, ranging from 0 to 1 over the triangle and such that, for a point within the triangle or on its perimeter it is:

$$0 \le \xi + \eta \le 1 \tag{2}$$

If P is internal to the triangle, then all three areas are positive ($A_I > 0$). If P is on the perimeter of the triangle, then one of the areas is zero (two are zero for a point coinciding with a node) and the rest are greater than zero. Finally, if P is outside the triangle, then one or two of the areas are less than zero.

The *area coordinates* L_I are shown in Figure 154(b) and are defined as:

$$\begin{aligned} L_1 &= A_1/A \\ L_2 &= A_2/A \\ L_3 &= A_3/A \end{aligned} \tag{3}$$

so that:

$$L_1 + L_2 + L_3 = 1 \tag{4}$$

The element's *shape functions* are simply:

$$\begin{aligned} N_1 &= L_1 = \xi \\ N_2 &= L_2 = \eta \\ N_3 &= L_3 = 1 - \xi - \eta \end{aligned} \tag{5}$$

They can be used to interpolate a quantity q on the element at a generic point P from the nodal values q_I of the quantity:

$$q_P = N_1(P) q_1 + N_2(P) q_2 + N_3(P) q_3 \tag{6}$$

The quadrangle

Native area coordinates

The area coordinates for the quadrangle are rarely used in the literature. There exist several definitions. The definition tested in the present work, taken from [25], is shown in Figure 155 illustrating the parent quadrangle.

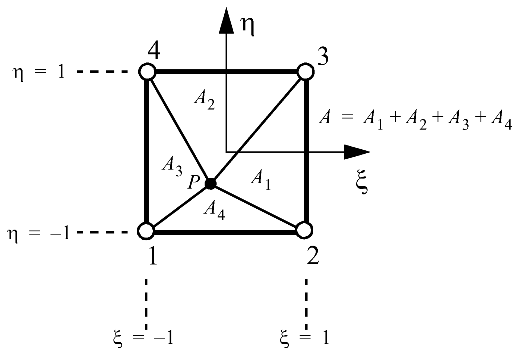


Figure 155: Area coordinates for the quadrangle.

Let A denote the area of the quadrangle. Then, for each point P in the plane of the quadrangle (assumed here to be flat, i.e. not warped) one may define four areas A_1, A_2, A_3, A_4 as shown in the Figure, such that:

$$A = A_1 + A_2 + A_3 + A_4 \tag{7}$$

where ξ, η are the normalized coordinates, ranging from -1 to 1 over the quadrangle.

If P is internal to the quadrangle, then all four areas are positive ($A_I > 0$). If P is on the perimeter of the quadrangle, then one of the areas is zero (two are zero for a point coinciding with a node) and the rest are greater than zero. Finally, if P is outside the quadrangle, then at least one of the areas is less than zero.

The *area coordinates* ϕ_I are defined as:

$$\begin{aligned} \phi_1 &= A_1 A_2/\alpha \\ \phi_2 &= A_2 A_3/\alpha \\ \phi_3 &= A_3 A_4/\alpha \\ \phi_4 &= A_4 A_1/\alpha \end{aligned} \tag{8}$$

where:

$$\alpha = (A_1 + A_3)(A_2 + A_4) \tag{9}$$

Note that α is *not* the total area of the quadrangle, which is denoted A. From (8) and (9) it follows that:

$$\phi_1 + \phi_2 + \phi_3 + \phi_4 = 1 \tag{10}$$

The element's *shape functions* (in terms of normalized coordinates ξ and η) are:

$$\begin{aligned} N_1 &= \frac{1}{4}(1-\xi)(1-\eta) \\ N_2 &= \frac{1}{4}(1+\xi)(1-\eta) \\ N_3 &= \frac{1}{4}(1+\xi)(1+\eta) \\ N_4 &= \frac{1}{4}(1-\xi)(1+\eta) \end{aligned} \tag{11}$$

They can be used to interpolate a quantity q on the element at a generic point P from the nodal values q_I of the quantity:

$$q_P = N_1(P)q_1 + N_2(P)q_2 + N_3(P)q_3 + N_4(P)q_4 \tag{12}$$

In order to pass from the area coordinates ϕ_I to the normalized coordinates ξ, η of a generic point P of the quadrangle, reference [25] proposes the following *linear approximations*:

$$\xi_P = \sum_{I=1}^{4} \phi_I(P)\xi_I \qquad \eta_P = \sum_{I=1}^{4} \phi_I(P)\eta_I \tag{13}$$

where ξ_I, η_I are the normalized coordinates of the quadrangle's vertices, so that one obtains:

$$\begin{aligned} \xi &= -\phi_1 + \phi_2 + \phi_3 - \phi_4 \\ \eta &= -\phi_1 - \phi_2 + \phi_3 + \phi_4 \end{aligned} \tag{14}$$

The origin and justification for the above expressions is a bit obscure. Therefore, they are tested numerically in some simple examples. If a regular quadrangle (a square) is used, then the expressions are exact for points P both inside and (reasonably) outside the quadrangle (in the quadrangle's plane). However, when the quadrangle is even moderately distorted, the expressions are only approximate and the error seems to be rather large (of the order of 20% or more).

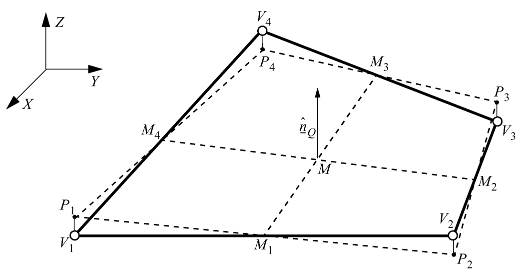
Alternative procedure based on triangles

An alternative procedure based on the decomposition of the quadrangle (assumed here to be planar, i.e. not warped) into triangles is now presented, consisting of the following steps:

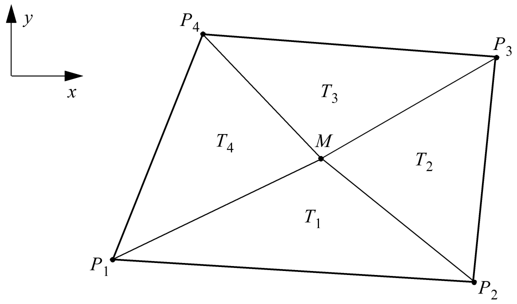
- Compute the quadrangle's *centroid* as the intersection of the two medians and the quadrangle's *normal* as the vector product of the medians.
- Build the quadrangle's *mid-plane* as the plane through the centroid perpendicular to the normal and project the four vertices onto the plane in order to ensure that the projected quadrangle is not warped.
- Split the projected quadrangle into four triangles by using the quadrangle's centroid.
- Determine the position of the generic point P (assumed to be in the quadrangle's mid plane) with respect to the triangles.
- Reconstruct the position of P with respect to the (projected) quadrangle.

With reference to Figure 156(a), let $\boldsymbol{V}_1$, $\boldsymbol{V}_2$, $\boldsymbol{V}_3$, $\boldsymbol{V}_3$ be the (position vectors of the) vertices of the quadrangle (not necessarily co-planar). First we build up the mid-side points:

$$\begin{aligned} \boldsymbol{M}_1 &= (\boldsymbol{V}_1 + \boldsymbol{V}_2)/2 \\ \boldsymbol{M}_2 &= (\boldsymbol{V}_2 + \boldsymbol{V}_3)/2 \\ \boldsymbol{M}_3 &= (\boldsymbol{V}_3 + \boldsymbol{V}_4)/2 \\ \boldsymbol{M}_4 &= (\boldsymbol{V}_4 + \boldsymbol{V}_1)/2 \end{aligned} \tag{15}$$



(a) Project on mid-plane



(b) Split into triangles

Figure 156: Quadrangle projection and splitting

The position of the centroid $\boldsymbol{M}$ of the (projected) quadrangle is:

$$\boldsymbol{M} = \frac{1}{2}(\boldsymbol{M}_1 + \boldsymbol{M}_3) = \frac{1}{2}(\boldsymbol{M}_2 + \boldsymbol{M}_4) = \frac{1}{4}(\boldsymbol{V}_1 + \boldsymbol{V}_2 + \boldsymbol{V}_3 + \boldsymbol{V}_4) \tag{16}$$

The unit normal $\hat{\boldsymbol{n}}_Q$ to the quadrangle (i.e. the unit normal to the projection plane) is given by the vector product:

$$\hat{\boldsymbol{n}}_Q = \frac{(\boldsymbol{M}_3 - \boldsymbol{M}_1) \times (\boldsymbol{M}_4 - \boldsymbol{M}_2)}{||\,(\boldsymbol{M}_3 - \boldsymbol{M}_1) \times (\boldsymbol{M}_4 - \boldsymbol{M}_2)\,||} \tag{17}$$

The position of the projection $\boldsymbol{P}_I$ on the plane of the generic vertex $\boldsymbol{V}_I$, $I = 1, \cdots, 4$ is:

$$\boldsymbol{P}_I = \boldsymbol{V}_I - [(\boldsymbol{V}_I - \boldsymbol{M}) \cdot \hat{\boldsymbol{n}}_Q]\, \hat{\boldsymbol{n}}_Q \tag{18}$$

All subsequent calculations are done by using the projected vertices $\boldsymbol{P}_I$ instead of the original vertices (nodes) $\boldsymbol{V}_I$.

As shown in Figure 156(b), the quadrangle is split into four triangles: $T_1 = P_1P_2M$, $T_2 = P_2P_3M$, $T_3 = P_3P_4M$ and $T_4 = P_4P_1M$, each using one side of the quadrangle plus the centroid M. The triangles are guaranteed to be co-planar since they are derived from the projected quadrangle.

Next, consider a generic point P in the quadrangle's mid-plane (if it is outside the plane, we first project it onto the plane by using Eq. 18). We evaluate the position of P with respect to each triangle T_i, $i = 1, \cdots, 4$, i.e. the area coordinates L_{Ii}, with the procedure described in the previous sub-section for the triangle (see Eqs. 3).

Finally, we want to compute the normalized coordinates ξ, η of P with respect to the (projected) quadrangle. With reference to Figure 157 showing the parent quadrangle and the four parent triangles, we first determine in which of the four quadrants Q_I of the plane lies the point P. Each quadrant has its vertex in M and sides along the diagonals of the quadrangle. We see that:

- If $L_{11} \geq 0$ and $L_{21} \geq 0$, then P lies in Q_1.
- Else if $L_{12} \geq 0$ and $L_{22} \geq 0$, then P lies in Q_2.
- Else if $L_{13} \geq 0$ and $L_{23} \geq 0$, then P lies in Q_3.
- Else it must be $L_{14} \geq 0$ and $L_{24} \geq 0$. Then P lies in Q_4.

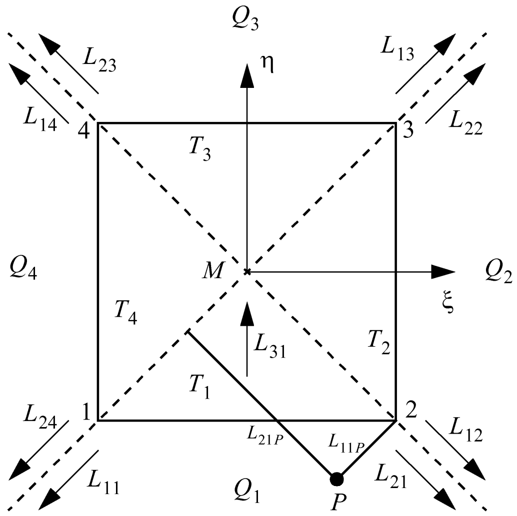


Figure 157: Calculation of the normalized coordinates.

Next, if for example P lies in Q_1 as in Figure 157, then one has:

$$\begin{aligned} \xi_P &= -L_{11P} + L_{21P} \\ \eta_P &= +L_{11P} + L_{21P} \end{aligned} \tag{19}$$

Similar expressions are obtained when P lies in one of the other three quadrants. Summarizing, we have:

$$\begin{array}{lll} P \text{ in } Q_1: & \xi_P = -L_{11P} + L_{21P} & \eta_P = -L_{11P} - L_{21P} \\ P \text{ in } Q_2: & \xi_P = +L_{12P} + L_{22P} & \eta_P = -L_{12P} + L_{22P} \\ P \text{ in } Q_3: & \xi_P = +L_{13P} - L_{23P} & \eta_P = +L_{13P} + L_{23P} \\ P \text{ in } Q_4: & \xi_P = -L_{14P} - L_{24P} & \eta_P = +L_{14P} - L_{24P} \end{array} \tag{20}$$

The procedure is tested numerically in the same simple examples as the previous one. If a regular quadrangle (a square) is used, then the expressions are exact for points P both inside and (reasonably) outside the quadrangle (in the quadrangle's plane). When the quadrangle is even moderately distorted, the expressions are only approximate. The error seems to be smaller than with the previous procedure (reaching a few percent), but it is not completely negligible.

Nearly exact procedure

A nearly exact procedure is based on inverse iso-parametric mapping [22, 23]. This procedure is much more CPU intensive than the previous ones since it requires iterations, but when tested on the same simple examples as the previous ones it gives results within machine precision both for the regular and for the distorted quadrangle.

Appendix I — Input files

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

frot23.dgibi

```
opti echo 0;
opti donn 'px4cir2d.proc';
opti donn 'pxordpoi.proc';
opti echo 1;
opti dime 2 elem qua4;
opti trac psc ftra 'frot23_mesh.ps';
opti sauv form 'frot23.msh';
r = 2.0;
x0 = 3.0;
pc = x0 r;
n = 8;
tol = 0.001;
c1 ier = px4cir2d (x0 0) ((x0+r) r) pc n tol;
c2 = c1 tour 90 pc;
c3 = c2 tour 90 pc;
c4 = c3 tour 90 pc;
circ = c1 et c2 et c3 et c4;
elim tol circ;
p1 = x0 0;
p2 = (x0+r) r;
p3 = x0 (r+r);
p4 = (x0-r) r;
elim tol (circ et p1 et p2 et p3 et p4);
cc1 = cerc n p1 pc p2;
cc2 = cc1 tour 90 pc;
cc3 = cc2 tour 90 pc;
cc4 = cc3 tour 90 pc;
elim tol (circ et cc1 et cc2 et cc3 et cc4);
pc1 = pxordpoi (chan POI1 cc1) p1;
pc2 = pxordpoi (chan POI1 cc2) p2;
pc3 = pxordpoi (chan POI1 cc3) p3;
pc4 = pxordpoi (chan POI1 cc4) p4;
pm = pc plus (0 r);
elim tol (pm et circ);
mark = manu poi1 pm;
h = 3.0;
len = 10.0;
nh = enti (h / 1.0);
nb = enti (len / 1.0);
bas = (0 (0-h)) d nb (len (0-h));
base = bas tran nh (0 h);
bas2 = (len 0) d nb (0 0);
*list (nbno bas2);
elim tol (bas2 et base);
p5 = len 0;
elim tol (p5 et bas2);
pbas2 = chan POI1 bas2;
*list (nbno pbas2);
pb2 = pxordpoi pbas2 p5;
list (nbno pb2);
mesh = circ et base et pb2 et pc1 et pc2 et pc3 et pc4 et mark;
tass mesh noop;
sauv form mesh;
trac qual mesh;
fin;
```

frot23.epx

```
FROT23
ECHO
!CONV WIN
CAST mesh
LAGR DPLA
DIME GLIS 1 200 TERM
GEOM CAR4 circ base PMAT mark TERM
COMP EPAI 0.2 LECT mark TERM ! Only for visualization
     NGRO 1 'b1' LECT circ TERM COND NEAR POIN 3 0
     COUL TURQ LECT circ TERM
          VERT LECT base TERM
          ROUG LECT mark TERM
MATE LINE RO 7800. YOUN 2.E11 NU 0.
          LECT circ base TERM
     MASS 0.0 LECT mark TERM
!LINK COUP
LIAI
     BLOQ 12 LECT bas TERM
     GLIS 1
          MAIT LECT pb2 TERM
          ESCL LECT pc1 pc2 pc3 pc4 TERM
CHAR 1 FACT 2
     FORC 1  6.E8 LECT pc TERM
     FORC 2 -6.E8 LECT pc TERM
     TABL 3 0. 0.  6.E-4 1.  6. 1.
ECRI DEPL VITE COOR FINT FEXT FLIA FREQ 10000
     FICH ALIC FREQ 5000
     FICH ALIC TEMP FREQ 1
          POIN LECT b1 pc mark TERM
OPTI PAS UTIL
     LOG 1
     LNKS STAT
CALC TINI 0 TFIN 60.E-3 PASF 2.E-6 NMAX 30000
PLAY
CAME   1 EYE   5.00000E+00  5.50000E-01  3.06645E+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 :  5.00000E+00  5.50000E-01  0.00000E+00
!RSPHERE:  6.13290E+00
!RADIUS :  3.06645E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.39183E+01
!FAR    :  4.29303E+01
SCEN GEOM NAVI FREE
          POIN SPHP
     VECT SCCO FIEL VITE SCAL USER PROG 100.0 PAS 100.0 1400.0 TERM
SLER CAM1 1 NFRA 1
FREQ 5000
TRAC OFFS FICH AVI NOCL NFTO 7 FPS 5 KFRE 5 COMP -1 REND
GOTR LOOP 5 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1. 'Time [s]'
COUR  1 'y_b1'   COOR COMP 2 NOEU LECT b1 TERM
COUR  5 'dy_mk'  DEPL COMP 2 NOEU LECT mark TERM
COUR  6 'dy_b1'  DEPL COMP 2 NOEU LECT b1 TERM
COUR  7 'dy_pc'  DEPL COMP 2 NOEU LECT pc TERM
COUR  8 'dx_mk'  DEPL COMP 1 NOEU LECT mark TERM
COUR  9 'dx_b1'  DEPL COMP 1 NOEU LECT b1 TERM
COUR 10 'dx_pc'  DEPL COMP 1 NOEU LECT pc TERM
COUR 11 'vy_b1'  VITE COMP 2 NOEU LECT b1 TERM
COUR 15 'vy_pc'  VITE COMP 2 NOEU LECT pc TERM
COUR 17 'vx_pc'  VITE COMP 1 NOEU LECT pc TERM
TRAC 1 AXES 1.0 'Y-COOR. [M]' YZER
TRAC 5 6 7 AXES 1.0 'DY [M]' YZER
TRAC 8 9 10 AXES 1.0 'DX [M]' YZER
TRAC 11 15 AXES 1.0 'VY [M/S]' YZER
TRAC 15 AXES 1.0 'VY [M/S]' YZER
TRAC 15 17 AXES 1.0 'V [M/S]' YZER
FIN
```

frot24.dgibi

```
opti echo 0;
opti donn 'px4cir2d.proc';
opti donn 'pxordpoi.proc';
opti echo 1;
opti dime 2 elem qua4;
opti trac psc ftra 'frot24_mesh.ps';
opti sauv form 'frot24.msh';
r = 2.0;
x0 = 3.0;
pc = x0 r;
n = 8;
tol = 0.001;
c1 ier = px4cir2d (x0 0) ((x0+r) r) pc n tol;
c2 = c1 tour 90 pc;
c3 = c2 tour 90 pc;
c4 = c3 tour 90 pc;
circ = c1 et c2 et c3 et c4;
elim tol circ;
p1 = x0 0;
p2 = (x0+r) r;
p3 = x0 (r+r);
p4 = (x0-r) r;
elim tol (circ et p1 et p2 et p3 et p4);
cc1 = cerc n p1 pc p2;
cc2 = cc1 tour 90 pc;
cc3 = cc2 tour 90 pc;
cc4 = cc3 tour 90 pc;
elim tol (circ et cc1 et cc2 et cc3 et cc4);
pc1 = pxordpoi (chan POI1 cc1) p1;
pc2 = pxordpoi (chan POI1 cc2) p2;
pc3 = pxordpoi (chan POI1 cc3) p3;
pc4 = pxordpoi (chan POI1 cc4) p4;
pm = pc plus (0 r);
elim tol (pm et circ);
mark = manu poi1 pm;
h = 3.0;
len = 10.0;
nh = enti (h / 1.0);
nb = enti (len / 1.0);
bas = (0 (0-h)) d nb (len (0-h));
base = bas tran nh (0 h);
bas2 = (len 0) d nb (0 0);
*list (nbno bas2);
elim tol (bas2 et base);
p5 = len 0;
elim tol (p5 et bas2);
```

```
pbas2 = chan POI1 bas2;
*list (nbno pbas2);
pb2 = pxordpoi pbas2 p5;
list (nbno pb2);
mesh = circ et base et pb2 et pc1 et pc2 et pc3 et pc4 et mark;
tass mesh noop;
sauv form mesh;
trac qual mesh;
fin;
```

frot24.epx

```
FROT24
ECHO
!CONV WIN
CAST mesh
LAGR DPLA
DIME GLIS 1 200 TERM
GEOM CAR4 circ base PMAT mark TERM
COMP EPAI 0.2 LECT mark TERM ! Only for visualization
     NGRO 1 'b1' LECT circ TERM COND NEAR POIN 3 0
     COUL TURQ LECT circ TERM
          VERT LECT base TERM
          ROUG LECT mark TERM
     FROT 1 MU0 0.25 MU1 0.25 GAMM 0.1
MATE LINE RO 7800. YOUN 2.E11 NU 0.
          LECT circ base TERM
     MASS 0.0 LECT mark TERM
!LINK COUP
LIAI
     BLOQ 12 LECT bas TERM
     GLIS 1
          MAIT LECT pb2 TERM
          ESCL LECT pc1 pc2 pc3 pc4 TERM
CHAR 1 FACT 2
     FORC 1  6.E8 LECT pc TERM
     FORC 2 -6.E8 LECT pc TERM
     TABL 3 0. 0.  6.E-4 1.  6. 1.
ECRI DEPL VITE COOR FINT FEXT FLIA FREQ 10000
     FICH ALIC FREQ 5000
     FICH ALIC TEMP FREQ 1
          POIN LECT b1 pc mark TERM
OPTI PAS UTIL
     LOG 1
     LNKS STAT
CALC TINI 0 TFIN 60.E-3 PASF 2.E-6 NMAX 30000
PLAY
CAME   1 EYE   5.00000E+00  5.50000E-01  3.06645E+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 :  5.00000E+00  5.50000E-01  0.00000E+00
!RSPHERE:  6.13290E+00
!RADIUS :  3.06645E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.39183E+01
!FAR    :  4.29303E+01
SCEN GEOM NAVI FREE
          POIN SPHP
     VECT SCCO FIEL VITE SCAL USER PROG 100.0 PAS 100.0 1400.0 TERM
SLER CAM1 1 NFRA 1
FREQ 5000
TRAC OFFS FICH AVI NOCL NFTO 7 FPS 5 KFRE 5 COMP -1 REND
GOTR LOOP 5 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1. 'Time [s]'
COUR  1 'y_b1'   COOR COMP 2 NOEU LECT b1 TERM
COUR  5 'dy_mk'  DEPL COMP 2 NOEU LECT mark TERM
COUR  6 'dy_b1'  DEPL COMP 2 NOEU LECT b1 TERM
COUR  7 'dy_pc'  DEPL COMP 2 NOEU LECT pc TERM
COUR  8 'dx_mk'  DEPL COMP 1 NOEU LECT mark TERM
COUR  9 'dx_b1'  DEPL COMP 1 NOEU LECT b1 TERM
COUR 10 'dx_pc'  DEPL COMP 1 NOEU LECT pc TERM
COUR 11 'vy_b1'  VITE COMP 2 NOEU LECT b1 TERM
COUR 15 'vy_pc'  VITE COMP 2 NOEU LECT pc TERM
COUR 17 'vx_pc'  VITE COMP 1 NOEU LECT pc TERM
TRAC 1 AXES 1.0 'Y-COOR. [M]' YZER
TRAC 5 6 7 AXES 1.0 'DY [M]' YZER
TRAC 8 9 10 AXES 1.0 'DX [M]' YZER
TRAC 11 15 AXES 1.0 'VY [M/S]' YZER
TRAC 15 AXES 1.0 'VY [M/S]' YZER
TRAC 15 17 AXES 1.0 'V [M/S]' YZER
FIN
```

frot66.dgibi

```
opti echo 0;
opti donn 'px4cir3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'frot66_mesh.ps';
opti sauv form 'frot66.msh';
r = 2.0;
x0 = 3.0;
pc = x0 r 0;
pz = 0 0 1;
n = 8;
tol = 0.001;
ci1 ier = px4cir3d (x0 0 0) ((x0+r) r 0) pc (pc plus pz) n tol;
w = 2.0;
vzcir = 0 0 w;
nzc = 3;
c1 = ci1 volu tran nzc vzcir;
c2 = c1 tour 90 pc (pc plus pz);
c3 = c2 tour 90 pc (pc plus pz);
c4 = c3 tour 90 pc (pc plus pz);
circ = c1 et c2 et c3 et c4;
elim tol circ;
axe = pc d nzc (pc plus vzcir);
elim tol (circ et axe);
*trac cach qual circ;
*p1 = x0 0;
*p2 = (x0+r) r;
*p3 = x0 (r+r);
*p4 = (x0-r) r;
*elim tol (circ et p1 et p2 et p3 et p4);
*cc1 = cerc n p1 pc p2;
*cc2 = cc1 tour 90 pc;
*cc3 = cc2 tour 90 pc;
*cc4 = cc3 tour 90 pc;
*elim tol (circ et cc1 et cc2 et cc3 et cc4);
*pc1 = pxordpoi (chan POI1 cc1) p1;
*pc2 = pxordpoi (chan POI1 cc2) p2;
*pc3 = pxordpoi (chan POI1 cc3) p3;
*pc4 = pxordpoi (chan POI1 cc4) p4;
pm = pc plus (0 r w);
elim tol (pm et circ);
mark = manu poi1 pm;
trac cach qual (circ et mark);
*
h = 1.0;
len = 10.0;
a = 4.0;
nh = 2;
nb = enti (len / 1.0);
na = 6;
bas2d = (0 (0-h) -1.0) d nb (len (0-h) -1.0);
base2d = bas2d tran nh (0 h 0);
base = base2d volu tran na (0 0 a);
trac cach qual base;
trac cach qual (base et circ et mark);
*
*bas2 = (len 0) d nb (0 0);
*elim tol (bas2 et base);
*p5 = len 0;
*elim tol (p5 et bas2);
*pbas2 = chan POI1 bas2;
*pb2 = pxordpoi pbas2 p5;
mesh = circ et base et mark;
tass mesh noop;
sauv form mesh;
trac cach qual mesh;
fin;
```

frot66.epx

```
FROT66
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM CUB8 circ base PMAT mark TERM
COMP NGRO 9 'bloc' LECT base TERM COND Y LT -0.99
            'f1a'  LECT axe TERM COND NEAR POIN 3 2 0
            'f1b'  LECT axe TERM COND NEAR POIN 3 2 2
            'f1'   LECT f1a f1b TERM
            'f2'   LECT axe DIFF f1 TERM
            'b1'   LECT circ TERM COND NEAR POIN 3 0 0
            'b2'   LECT circ TERM COND NEAR POIN 3 0 0.667
            'b3'   LECT circ TERM COND NEAR POIN 3 0 1.333
            'b4'   LECT circ TERM COND NEAR POIN 3 0 2
     EPAI 0.2 LECT mark TERM ! Only for visualization
     COUL TURQ LECT circ TERM
          VERT LECT base TERM
          ROUG LECT mark TERM
MATE LINE RO 7800. YOUN 2.E11 NU 0.
          LECT circ base TERM
     MASS 0.0 LECT mark TERM
LINK COUP
     BLOQ 123 LECT bloc TERM
     GLIS 1 ELIM
          MAIT LECT circ TERM
          ESCL LECT base TERM
CHAR 1 FACT 2
     FORC 1  3.33333E8 LECT f1 TERM
     FORC 1  6.66667E8 LECT f2 TERM
     FORC 2 -3.33333E8 LECT f1 TERM
     FORC 2 -6.66667E8 LECT f2 TERM
     TABL 3 0. 0.  12.E-4 1.  6. 1.
ECRI DEPL VITE COOR FINT FEXT FLIA FREQ 600
     FICH ALIC FREQ 100
     FICH ALIC TEMP FREQ 1
```

```
          POIN LECT b1 b2 b3 b4 f1 f2 mark TERM
OPTI PAS UTIL
     LOG 1
     GLIS NORM ELEM
     LNKS STAT VISU
CALC TINI 0 TFIN 40.E-3 PASF 2.E-5 NMAX 2000
PLAY
CAME   1 EYE   1.84447E+01  1.93365E+01  2.07597E+01
!        Q     9.11780E-01 -3.31861E-01  2.41333E-01 -1.68756E-02
         VIEW -4.51285E-01 -5.97022E-01 -6.63254E-01
         RIGH  8.82948E-01 -1.90951E-01 -4.28884E-01
         UP   -1.29404E-01  7.79167E-01 -6.13313E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E+00  1.55000E+00  1.00000E+00
!RSPHERE:  5.95840E+00
!RADIUS :  2.97920E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.32377E+01
!FAR    :  4.17088E+01
SCEN GEOM NAVI FREE
          POIN SPHP
          FACE HFRO
        ! LINE HEOU SSHA
        ! LNKS SHOW GLIS JOIN
     VECT SCCO FIEL FLIA SCAL USER PROG 0.25E8 PAS 0.25E8 3.5E8 TERM
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 2001 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 1999 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR  1 'y_b1'   COOR COMP 2 NOEU LECT b1 TERM
COUR  2 'y_b2'   COOR COMP 2 NOEU LECT b2 TERM
COUR  3 'y_b3'   COOR COMP 2 NOEU LECT b3 TERM
COUR  4 'y_b4'   COOR COMP 2 NOEU LECT b4 TERM
COUR  5 'dy_mk'  DEPL COMP 2 NOEU LECT mark TERM
COUR  6 'dy_b4'  DEPL COMP 2 NOEU LECT b4 TERM
COUR  7 'dy_f1b' DEPL COMP 2 NOEU LECT f1b TERM
COUR  8 'dx_mk'  DEPL COMP 1 NOEU LECT mark TERM
COUR  9 'dx_b4'  DEPL COMP 1 NOEU LECT b4 TERM
COUR 10 'dx_f1b' DEPL COMP 1 NOEU LECT f1b TERM
TRAC 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
TRAC 5 6 7 AXES 1.0 'DY [M]' YZER
TRAC 8 9 10 AXES 1.0 'DX [M]' YZER
LIST 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
LIST 5 6 7 AXES 1.0 'DY [M]' YZER
LIST 8 9 10 AXES 1.0 'DX [M]' YZER
QUAL COUR  8 REFE  7.08659E+00 TOLE 1.E-2
     COUR  9 REFE  7.52663E+00 TOLE 1.E-2
     COUR 10 REFE  7.31216E+00 TOLE 1.E-2
FIN
```

frot67.dgibi

```
opti echo 0;
opti donn 'px4cir3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'frot67_mesh.ps';
opti sauv form 'frot67.msh';
r = 2.0;
x0 = 3.0;
pc = x0 r 0;
pz = 0 0 1;
n = 8;
tol = 0.001;
ci1 ier = px4cir3d (x0 0 0) ((x0+r) r 0) pc (pc plus pz) n tol;
w = 2.0;
vzcir = 0 0 w;
nzc = 3;
c1 = ci1 volu tran nzc vzcir;
c2 = c1 tour 90 pc (pc plus pz);
c3 = c2 tour 90 pc (pc plus pz);
c4 = c3 tour 90 pc (pc plus pz);
circ = c1 et c2 et c3 et c4;
elim tol circ;
axe = pc d nzc (pc plus vzcir);
elim tol (circ et axe);
*trac cach qual circ;
*p1 = x0 0;
*p2 = (x0+r) r;
*p3 = x0 (r+r);
*p4 = (x0-r) r;
*elim tol (circ et p1 et p2 et p3 et p4);
*cc1 = cerc n p1 pc p2;
*cc2 = cc1 tour 90 pc;
*cc3 = cc2 tour 90 pc;
*cc4 = cc3 tour 90 pc;
*elim tol (circ et cc1 et cc2 et cc3 et cc4);
*pc1 = pxordpoi (chan POI1 cc1) p1;
*pc2 = pxordpoi (chan POI1 cc2) p2;
*pc3 = pxordpoi (chan POI1 cc3) p3;
*pc4 = pxordpoi (chan POI1 cc4) p4;
pm = pc plus (0 r w);
elim tol (pm et circ);
mark = manu poi1 pm;
trac cach qual (circ et mark);
*
h = 1.0;
len = 10.0;
a = 4.0;
nh = 2;
nb = enti (len / 1.0);
na = 6;
bas2d = (0 (0-h) -1.0) d nb (len (0-h) -1.0);
base2d = bas2d tran nh (0 h 0);
base = base2d volu tran na (0 0 a);
trac cach qual base;
trac cach qual (base et circ et mark);
*
*bas2 = (len 0) d nb (0 0);
*elim tol (bas2 et base);
*p5 = len 0;
*elim tol (p5 et bas2);
*pbas2 = chan POI1 bas2;
*pb2 = pxordpoi pbas2 p5;
mesh = circ et base et mark;
tass mesh noop;
sauv form mesh;
trac cach qual mesh;
fin;
```

frot67.epx

```
FROT67
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM CUB8 circ base PMAT mark TERM
COMP NGRO 9 'bloc' LECT base TERM COND Y LT -0.99
            'f1a'  LECT axe TERM COND NEAR POIN 3 2 0
            'f1b'  LECT axe TERM COND NEAR POIN 3 2 2
            'f1'   LECT f1a f1b TERM
            'f2'   LECT axe DIFF f1 TERM
            'b1'   LECT circ TERM COND NEAR POIN 3 0 0
            'b2'   LECT circ TERM COND NEAR POIN 3 0 0.667
            'b3'   LECT circ TERM COND NEAR POIN 3 0 1.333
            'b4'   LECT circ TERM COND NEAR POIN 3 0 2
     EPAI 0.2 LECT mark TERM ! Only for visualization
     COUL TURQ LECT circ TERM
          VERT LECT base TERM
          ROUG LECT mark TERM
MATE LINE RO 7800. YOUN 2.E11 NU 0.
          LECT circ base TERM
     MASS 0.0 LECT mark TERM
LINK COUP
     BLOQ 123 LECT bloc TERM
     GLIS 1 ELIM
          FROT MUST 0.25 MUDY 0.25 GAMM 0.1
          MAIT LECT circ TERM
          ESCL LECT base TERM
CHAR 1 FACT 2
     FORC 1  3.33333E8 LECT f1 TERM
     FORC 1  6.66667E8 LECT f2 TERM
     FORC 2 -3.33333E8 LECT f1 TERM
     FORC 2 -6.66667E8 LECT f2 TERM
     TABL 3 0. 0.  12.E-4 1.  6. 1.
ECRI DEPL VITE COOR FINT FEXT FLIA FREQ 600
     FICH ALIC FREQ 100
     FICH ALIC TEMP FREQ 1
          POIN LECT b1 b2 b3 b4 f1 f2 mark TERM
OPTI PAS UTIL
     LOG 1
     GLIS NORM ELEM
     LNKS STAT VISU
CALC TINI 0 TFIN 40.E-3 PASF 2.E-5 NMAX 2000
PLAY
CAME   1 EYE   1.84447E+01  1.93365E+01  2.07597E+01
!        Q     9.11780E-01 -3.31861E-01  2.41333E-01 -1.68756E-02
         VIEW -4.51285E-01 -5.97022E-01 -6.63254E-01
         RIGH  8.82948E-01 -1.90951E-01 -4.28884E-01
         UP   -1.29404E-01  7.79167E-01 -6.13313E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E+00  1.55000E+00  1.00000E+00
!RSPHERE:  5.95840E+00
!RADIUS :  2.97920E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.32377E+01
!FAR    :  4.17088E+01
SCEN GEOM NAVI FREE
          POIN SPHP
          FACE HFRO
        ! LINE HEOU SSHA
        ! LNKS SHOW GLIS JOIN
     VECT SCCO FIEL FLIA SCAL USER PROG 0.25E8 PAS 0.25E8 3.5E8 TERM
SLER CAM1 1 NFRA 1
FREQ 1
TRAC OFFS FICH AVI NOCL NFTO 2001 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 1999 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment (time curves from alice temp file)
```

```
ECHO
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR  1 'y_b1'   COOR COMP 2 NOEU LECT b1 TERM
COUR  2 'y_b2'   COOR COMP 2 NOEU LECT b2 TERM
COUR  3 'y_b3'   COOR COMP 2 NOEU LECT b3 TERM
COUR  4 'y_b4'   COOR COMP 2 NOEU LECT b4 TERM
COUR  5 'dy_mk'  DEPL COMP 2 NOEU LECT mark TERM
COUR  6 'dy_b4'  DEPL COMP 2 NOEU LECT b4 TERM
COUR  7 'dy_f1b' DEPL COMP 2 NOEU LECT f1b TERM
COUR  8 'dx_mk'  DEPL COMP 1 NOEU LECT mark TERM
COUR  9 'dx_b4'  DEPL COMP 1 NOEU LECT b4 TERM
COUR 10 'dx_f1b' DEPL COMP 1 NOEU LECT f1b TERM
TRAC 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
TRAC 5 6 7 AXES 1.0 'DY [M]' YZER
TRAC 8 9 10 AXES 1.0 'DX [M]' YZER
LIST 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
LIST 5 6 7 AXES 1.0 'DY [M]' YZER
LIST 8 9 10 AXES 1.0 'DX [M]' YZER
QUAL COUR  8 REFE  7.62251E+00 TOLE 1.E-2
     COUR  9 REFE  3.78616E+00 TOLE 1.E-2
     COUR 10 REFE  5.70888E+00 TOLE 1.E-2
FIN
```

frotn3.dgibi

```
opti echo 0;
opti donn 'px4cir2d.proc';
opti donn 'pxordpoi.proc';
opti echo 1;
opti dime 2 elem qua4;
opti trac psc ftra 'frotn3_mesh.ps';
opti sauv form 'frotn3.msh';
r = 2.0;
x0 = 3.0;
pc = x0 r;
n = 8;
tol = 0.001;
c1 ier = px4cir2d (x0 0) ((x0+r) r) pc n tol;
c2 = c1 tour 90 pc;
c3 = c2 tour 90 pc;
c4 = c3 tour 90 pc;
circ = c1 et c2 et c3 et c4;
elim tol circ;
p1 = x0 0;
p2 = (x0+r) r;
p3 = x0 (r+r);
p4 = (x0-r) r;
elim tol (circ et p1 et p2 et p3 et p4);
cc1 = cerc n p1 pc p2;
cc2 = cc1 tour 90 pc;
cc3 = cc2 tour 90 pc;
cc4 = cc3 tour 90 pc;
elim tol (circ et cc1 et cc2 et cc3 et cc4);
pc1 = pxordpoi (chan POI1 cc1) p1;
pc2 = pxordpoi (chan POI1 cc2) p2;
pc3 = pxordpoi (chan POI1 cc3) p3;
pc4 = pxordpoi (chan POI1 cc4) p4;
pm = pc plus (0 r);
elim tol (pm et circ);
mark = manu poi1 pm;
h = 3.0;
len = 10.0;
nh = enti (h / 1.0);
nb = enti (len / 1.0);
bas = (0 (0-h)) d nb (len (0-h));
base = bas tran nh (0 h);
bas2 = (len 0) d nb (0 0);
*list (nbno bas2);
elim tol (bas2 et base);
p5 = len 0;
elim tol (p5 et bas2);
pbas2 = chan POI1 bas2;
*list (nbno pbas2);
pb2 = pxordpoi pbas2 p5;
list (nbno pb2);
mesh = circ et base et pb2 et pc1 et pc2 et pc3 et pc4 et mark;
tass mesh noop;
sauv form mesh;
trac qual mesh;
fin;
```

frotn3.epx

```
FROTN3
ECHO
!CONV WIN
CAST mesh
LAGR DPLA
DIME GLIS 1 200 TERM
GEOM CAR4 circ base PMAT mark TERM
COMP EPAI 0.2 LECT mark TERM ! Only for visualization
     NGRO 1 'b1' LECT circ TERM COND NEAR POIN 3 0
     COUL TURQ LECT circ TERM
          VERT LECT base TERM
          ROUG LECT mark TERM
MATE LINE RO 7800. YOUN 2.E11 NU 0.
          LECT circ base TERM
     MASS 0.0 LECT mark TERM
!LINK COUP
LIAI
     BLOQ 12 LECT bas TERM
     GLIS 1
          MAIT LECT pb2 TERM
          ESCL LECT pc1 pc2 pc3 pc4 TERM
CHAR 1 FACT 2
     FORC 1  6.E8 LECT pc TERM
     FORC 2 -6.E8 LECT pc TERM
     TABL 3 0. 0.  6.E-4 1.  6. 1.
ECRI DEPL VITE COOR FINT FEXT FLIA FREQ 10000
     FICH ALIC FREQ 5000
     FICH ALIC TEMP FREQ 1
          POIN LECT b1 pc mark TERM
OPTI PAS UTIL
     LOG 1
     GLIS NORM ELEM
     LNKS STAT
CALC TINI 0 TFIN 60.E-3 PASF 2.E-6 NMAX 30000
PLAY
CAME   1 EYE   5.00000E+00  5.50000E-01  3.06645E+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 :  5.00000E+00  5.50000E-01  0.00000E+00
!RSPHERE:  6.13290E+00
!RADIUS :  3.06645E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.39183E+01
!FAR    :  4.29303E+01
SCEN GEOM NAVI FREE
          POIN SPHP
     VECT SCCO FIEL VITE SCAL USER PROG 100.0 PAS 100.0 1400.0 TERM
SLER CAM1 1 NFRA 1
FREQ 5000
TRAC OFFS FICH AVI NOCL NFTO 7 FPS 5 KFRE 5 COMP -1 REND
GOTR LOOP 5 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1. 'Time [s]'
COUR  1 'y_b1'   COOR COMP 2 NOEU LECT b1 TERM
COUR  5 'dy_mk'  DEPL COMP 2 NOEU LECT mark TERM
COUR  6 'dy_b1'  DEPL COMP 2 NOEU LECT b1 TERM
COUR  7 'dy_pc'  DEPL COMP 2 NOEU LECT pc TERM
COUR  8 'dx_mk'  DEPL COMP 1 NOEU LECT mark TERM
COUR  9 'dx_b1'  DEPL COMP 1 NOEU LECT b1 TERM
COUR 10 'dx_pc'  DEPL COMP 1 NOEU LECT pc TERM
COUR 11 'vy_b1'  VITE COMP 2 NOEU LECT b1 TERM
COUR 15 'vy_pc'  VITE COMP 2 NOEU LECT pc TERM
COUR 17 'vx_pc'  VITE COMP 1 NOEU LECT pc TERM
TRAC 1 AXES 1.0 'Y-COOR. [M]' YZER
TRAC 5 6 7 AXES 1.0 'DY [M]' YZER
TRAC 8 9 10 AXES 1.0 'DX [M]' YZER
TRAC 11 15 AXES 1.0 'VY [M/S]' YZER
TRAC 15 AXES 1.0 'VY [M/S]' YZER
TRAC 15 17 AXES 1.0 'V [M/S]' YZER
FIN
```

px4cir2d.proc

```
*$$$$ PX4CIR2D
*
* Pour generer le maillage 2D 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) et par le centre du cercle.
*
* Input:
* =====
* P1 = premiere extremite de l'arc
* P2 = deuxieme extremite de l'arc
* PC = centre de l'arc
* 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' PX4CIR2D P1*'POINT' P2*'POINT' PC*'POINT'
                   N*'ENTIER' TOL*'FLOTTANT';
*------------------------------------------------------------------
*
ier=0;
n2 = n / 2;
p0 = 0 0;
pm1 = p1 plus p0;
depl pm1 tour 45 pc;
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;
```

px4cir3d.proc

```
*$$$$ 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;
```

pxhex2pr.proc

```
'DEBPROC' pxhex2pr hexa*'MAILLAGE';
*
*-------------------------------------------------
* Splits a hexahedron into 2 prisms.
*
* Input :
* -----
*     hexa : a mesh containing just one hexahedron
* Output :
* ------
*     pris : mesh containing 2 prisms
*-------------------------------------------------
*
hh = chan poi1 hexa;
*h = hh elem 1;
*
p1 = hh poin 1;
p2 = hh poin 2;
p3 = hh poin 3;
p4 = hh poin 4;
p5 = hh poin 5;
p6 = hh poin 6;
p7 = hh poin 7;
p8 = hh poin 8;
*
* Prisms # 1 to 2
*
pr1 = manu pri6 p1 p2 p3 p5 p6 p7;
pr2 = manu pri6 p3 p4 p1 p7 p8 p5;
*
pris = pr1 et pr2;
*
finproc pris;
```

pxhex2t2.proc

```
'DEBPROC' pxhex2t2 hexa*'MAILLAGE';
*
*-------------------------------------------------
* Splits a hexahedron into 24 tetrahedra.
* First, the hexahedron is split into 6 pyramids,
* one for each face, by introducing an extra node
* at the centre of the hexahedron.
* Then, each pyramid is split into 4 tetrahedra,
* by adding an extra node at the centre of the
* corresponding face of the hexahedron.
* This produces twice as much tetrahedra as
* the procedure pxhex2te, and they are worse
* shaped (thinner), but the advantage
* is that the resulting mesh is symmetric.
*
* Input :
* -----
*     hexa : a mesh containing just one hexahedron
* Output :
* ------
*     tetr : mesh containing 24 tetrahedra
*-------------------------------------------------
*
hh = chan poi1 hexa;
*h = hh elem 1;
*
p1 = hh poin 1;
p2 = hh poin 2;
p3 = hh poin 3;
p4 = hh poin 4;
p5 = hh poin 5;
p6 = hh poin 6;
p7 = hh poin 7;
p8 = hh poin 8;
*
n1 = noeu p1;
n2 = noeu p2;
n3 = noeu p3;
n4 = noeu p4;
n5 = noeu p5;
n6 = noeu p6;
n7 = noeu p7;
n8 = noeu p8;
*
x1 y1 z1 = coor p1;
x2 y2 z2 = coor p2;
x3 y3 z3 = coor p3;
x4 y4 z4 = coor p4;
x5 y5 z5 = coor p5;
x6 y6 z6 = coor p6;
x7 y7 z7 = coor p7;
x8 y8 z8 = coor p8;
*
x9 = (x1 + x2 + x3 + x4 + x5 + x6 + x7 + x8) / 8.0;
y9 = (y1 + y2 + y3 + y4 + y5 + y6 + y7 + y8) / 8.0;
z9 = (z1 + z2 + z3 + z4 + z5 + z6 + z7 + z8) / 8.0;
*
p9 = x9 y9 z9;
*
* Pyramid # 1
*
x10 = (x1 + x2 + x3 + x4) / 4.0;
y10 = (y1 + y2 + y3 + y4) / 4.0;
z10 = (z1 + z2 + z3 + z4) / 4.0;
*
p10 = x10 y10 z10;
t1 = manu tet4 p1 p2 p10 p9;
t2 = manu tet4 p2 p3 p10 p9;
t3 = manu tet4 p3 p4 p10 p9;
t4 = manu tet4 p4 p1 p10 p9;
*
* Pyramid # 2
*
x11 = (x1 + x2 + x5 + x6) / 4.0;
y11 = (y1 + y2 + y5 + y6) / 4.0;
z11 = (z1 + z2 + z5 + z6) / 4.0;
*
p11 = x11 y11 z11;
t5 = manu tet4 p2 p1 p11 p9;
t6 = manu tet4 p6 p2 p11 p9;
t7 = manu tet4 p5 p6 p11 p9;
t8 = manu tet4 p1 p5 p11 p9;
*
* Pyramid # 3
*
x12 = (x2 + x3 + x6 + x7) / 4.0;
y12 = (y2 + y3 + y6 + y7) / 4.0;
z12 = (z2 + z3 + z6 + z7) / 4.0;
*
```

```
p12 = x12 y12 z12;
t9  = manu tet4 p3 p2 p12 p9;
t10 = manu tet4 p7 p3 p12 p9;
t11 = manu tet4 p6 p7 p12 p9;
t12 = manu tet4 p2 p6 p12 p9;
*
* Pyramid # 4
*
x13 = (x3 + x4 + x7 + x8) / 4.0;
y13 = (y3 + y4 + y7 + y8) / 4.0;
z13 = (z3 + z4 + z7 + z8) / 4.0;
*
p13 = x13 y13 z13;
t13 = manu tet4 p4 p3 p13 p9;
t14 = manu tet4 p3 p7 p13 p9;
t15 = manu tet4 p7 p8 p13 p9;
t16 = manu tet4 p8 p4 p13 p9;
*
* Pyramid # 5
*
x14 = (x1 + x4 + x5 + x8) / 4.0;
y14 = (y1 + y4 + y5 + y8) / 4.0;
z14 = (z1 + z4 + z5 + z8) / 4.0;
*
p14 = x14 y14 z14;
t17 = manu tet4 p1 p4 p14 p9;
t18 = manu tet4 p4 p8 p14 p9;
t19 = manu tet4 p8 p5 p14 p9;
t20 = manu tet4 p5 p1 p14 p9;
*
* Pyramid # 6
*
x15 = (x5 + x6 + x7 + x8) / 4.0;
y15 = (y5 + y6 + y7 + y8) / 4.0;
z15 = (z5 + z6 + z7 + z8) / 4.0;
*
p15 = x15 y15 z15;
t21 = manu tet4 p6 p5 p15 p9;
t22 = manu tet4 p7 p6 p15 p9;
t23 = manu tet4 p8 p7 p15 p9;
t24 = manu tet4 p5 p8 p15 p9;
*
tetr = t1 et t2 et t3 et t4 et t5 et t6
       et t7 et t8 et t9 et t10 et t11 et t12
       et t13 et t14 et t15 et t16 et t17 et t18
       et t19 et t20 et t21 et t22 et t23 et t24;
*
finproc tetr;
```

pxhex2te.proc

```
'DEBPROC' pxhex2te hexa*'MAILLAGE';
*
*--------------------------------------------------
* Splits a hexahedron into 12 tetrahedra.
* First, the hexahedron is split into 6 pyramids,
* one for each face, by introducing an extra node
* at the centre of the hexahedron.
* Then, each pyramid is split into 2 tetrahedra.
* This is done along the plane that passes
* across the node (on the 4-node face of the pyramid)
* with the LOWEST global index, thus possible
* neighbours on the other side of the face will
* be split consistently.
* The advantage of this algorithm is that it is
* independent from the neighbours and yields
* consistent tetrahedra (faces are coincident).
*
* Input :
* -----
*     hexa : a mesh containing just one hexahedron
* Output :
* ------
*     tetr : mesh containing 12 tetrahedra
*--------------------------------------------------
*
hh = chan poi1 hexa;
*h = hh elem 1;
*
p1 = hh poin 1;
p2 = hh poin 2;
p3 = hh poin 3;
p4 = hh poin 4;
p5 = hh poin 5;
p6 = hh poin 6;
p7 = hh poin 7;
p8 = hh poin 8;
*
n1 = noeu p1;
n2 = noeu p2;
n3 = noeu p3;
n4 = noeu p4;
n5 = noeu p5;
n6 = noeu p6;
n7 = noeu p7;
n8 = noeu p8;
*
x1 y1 z1 = coor p1;
x2 y2 z2 = coor p2;
x3 y3 z3 = coor p3;
x4 y4 z4 = coor p4;
x5 y5 z5 = coor p5;
x6 y6 z6 = coor p6;
x7 y7 z7 = coor p7;
x8 y8 z8 = coor p8;
*
x9 = (x1 + x2 + x3 + x4 + x5 + x6 + x7 + x8) / 8.0;
y9 = (y1 + y2 + y3 + y4 + y5 + y6 + y7 + y8) / 8.0;
z9 = (z1 + z2 + z3 + z4 + z5 + z6 + z7 + z8) / 8.0;
*
p9 = x9 y9 z9;
n9 = noeu p9;
*
* Pyramid # 1
*
nlow = n1; ilow = 1;
si ( n2 < nlow ) ; nlow = n2; ilow = 2; finsi;
si ( n6 < nlow ) ; nlow = n6; ilow = 1; finsi;
si ( n5 < nlow ) ; nlow = n5; ilow = 2; finsi;
si (ilow ega 1);
  t1 = manu tet4 p1 p5 p6 p9;
  t2 = manu tet4 p6 p2 p1 p9;
sinon;
  t1 = manu tet4 p2 p1 p5 p9;
  t2 = manu tet4 p5 p6 p2 p9;
finsi;
*
* Pyramid # 2
*
nlow = n2; ilow = 1;
si ( n3 < nlow ) ; nlow = n3; ilow = 2; finsi;
si ( n7 < nlow ) ; nlow = n7; ilow = 1; finsi;
si ( n6 < nlow ) ; nlow = n6; ilow = 2; finsi;
si (ilow ega 1);
  t3 = manu tet4 p2 p6 p7 p9;
  t4 = manu tet4 p7 p3 p2 p9;
sinon;
  t3 = manu tet4 p3 p2 p6 p9;
  t4 = manu tet4 p6 p7 p3 p9;
finsi;
*
* Pyramid # 3
*
nlow = n5; ilow = 1;
si ( n6 < nlow ) ; nlow = n6; ilow = 2; finsi;
si ( n7 < nlow ) ; nlow = n7; ilow = 1; finsi;
si ( n8 < nlow ) ; nlow = n8; ilow = 2; finsi;
si (ilow ega 1);
  t5 = manu tet4 p5 p8 p7 p9;
  t6 = manu tet4 p7 p6 p5 p9;
sinon;
  t5 = manu tet4 p6 p5 p8 p9;
  t6 = manu tet4 p8 p7 p6 p9;
finsi;
*
* Pyramid # 4
*
nlow = n4; ilow = 1;
si ( n1 < nlow ) ; nlow = n1; ilow = 2; finsi;
si ( n5 < nlow ) ; nlow = n5; ilow = 1; finsi;
si ( n8 < nlow ) ; nlow = n8; ilow = 2; finsi;
si (ilow ega 1);
  t7 = manu tet4 p4 p8 p5 p9;
  t8 = manu tet4 p5 p1 p4 p9;
sinon;
  t7 = manu tet4 p1 p4 p8 p9;
  t8 = manu tet4 p8 p5 p1 p9;
finsi;
*
* Pyramid # 5
*
nlow = n1; ilow = 1;
si ( n2 < nlow ) ; nlow = n2; ilow = 2; finsi;
si ( n3 < nlow ) ; nlow = n3; ilow = 1; finsi;
si ( n4 < nlow ) ; nlow = n4; ilow = 2; finsi;
si (ilow ega 1);
  t9  = manu tet4 p1 p2 p3 p9;
  t10 = manu tet4 p3 p4 p1 p9;
sinon;
  t9  = manu tet4 p4 p1 p2 p9;
  t10 = manu tet4 p2 p3 p4 p9;
finsi;
*
* Pyramid # 6
*
nlow = n3; ilow = 1;
si ( n4 < nlow ) ; nlow = n4; ilow = 2; finsi;
si ( n8 < nlow ) ; nlow = n8; ilow = 1; finsi;
si ( n7 < nlow ) ; nlow = n7; ilow = 2; finsi;
si (ilow ega 1);
  t11 = manu tet4 p3 p7 p8 p9;
  t12 = manu tet4 p8 p4 p3 p9;
sinon;
  t11 = manu tet4 p4 p3 p7 p9;
  t12 = manu tet4 p7 p8 p4 p9;
finsi;
*
tetr = t1 et t2 et t3 et t4 et t5 et t6
       et t7 et t8 et t9 et t10 et t11 et t12;
*
finproc tetr;
```

pxordpoi.proc

```
*$$$$ PXORDPOI
*
* pour ordonner une serie de points PLIN en partant de P1
*
* Input:
* =====
* PLIN = objet MAILLAGE de type POI1 (ligne de points)
* P1   = premier point de la ligne (typ POINT)
*
* Output:
* ======
* PORDO = objet MAILLAGE de type POI1 (ligne de points) contenant
*         les points ordonnes a partir de P1
*
'DEBPROC' PXORDPOI PLIN*'MAILLAGE' P1*'POINT' ;
*----------------------------------------------------------------
*
PORDO=P1;
PPA=P1;
NE='NBEL' PLIN;
*
I=0;
'REPETER' LAB1 (NE-1);
  I=I + 1;
* mess I;
  PLIN= 'DIFF' ((PPA 'ET' PPA) 'ELEM' 1) PLIN;
  PPA=PLIN 'POIN' 'PROC' PPA;
  PORDO=PORDO 'ET' PPA;
'FIN' LAB1;
*
'FINPROC' PORDO;
```

slid01.epx

```
SLID01
ECHO
 CONV win
DPLA LAGR
GEOM LIBR POIN 14 Q42L 5 TERM
 0 0  1 0  2 0  3 0
 0 1  1 1  2 1  3 1
 0.5 1  1.5 1 2.5 1
 0.5 2  1.5 2 2.5 2
 1 2 6 5
 2 3 7 6
 3 4 8 7
 9 10 13 12
 10 11 14 13
COMP EPAI 1.0 LECT tous TERM
     GROU 2 'targ' LECT 1 2 3 TERM
            'proj' LECT 4 5 TERM
     NGRO 1 'bloc' LECT 1 2 3 4 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.257E8 MXIT 500
          QR1 2.348E8 CR1 56.2 QR2 4.457E8 CR2 4.7
          PDOT 5.E-4 C 1.E-2 TQ 0.9 CP 452.0
          TM 1800.0 M 1.0 DC 1.0 WC 555.0E6
          resi 1
          LECT targ proj TERM
LINK COUP SPLT NONE
     BLOQ 12 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 5 6 7 8 TERM
                 NSLA LECT 9 10 11 TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3 nmax 0
fin

PLAY
CAME   1 EYE   7.66358E-01 -8.91360E-01  8.25636E-01
!        Q     8.53854E-01  4.18258E-01  1.94114E-01  2.41481E-01
         VIEW -5.33494E-01  6.20513E-01 -5.74760E-01
         RIGH  8.08013E-01  5.74760E-01 -1.29487E-01
         UP   -2.50000E-01  5.33494E-01  8.08013E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  0.00000E+00
!RSPHERE:  2.87298E-01
!RADIUS :  1.43649E+00
!ASPECT :  1.00000E+00
!NEAR   :  1.12046E+00
!FAR    :  2.01109E+00
CAME   2 EYE   5.99574E-01 -1.02500E+00 -8.08319E-01
!        Q     4.59533E-01  8.32368E-01  2.97517E-01  8.64705E-02
         VIEW -4.17388E-01  7.13548E-01  5.62704E-01
         RIGH  8.08013E-01  5.74759E-01 -1.29487E-01
         UP    4.15815E-01 -4.00626E-01  8.16454E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  0.00000E+00
!RSPHERE:  2.87298E-01
!RADIUS :  1.43649E+00
!ASPECT :  1.00000E+00
!NEAR   :  1.14920E+00
!FAR    :  1.72379E+00
SCEN OBJE USLM LECT tous TERM
     GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
          GLIS SURF LECT 1 TERM MFAC SNOD
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH BMP
          REND
SCEN OBJE USLM LECT tous TERM
     GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
          GLIS SURF LECT 2 TERM MFAC SNOD
     LIMA ON
SLER CAM1 2 NFRA 1
TRAC OFFS FICH BMP
          REND
!trac rend
*
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 31 FPS 15 KFRE 10 COMP -1
          OBJE LECT lframe uframe TERM REND
FREQ 0 TFRE 0.1E-3
GOTR LOOP 29 OFFS FICH AVI CONT NOCL
          OBJE LECT lframe uframe TERM REND
GO
TRAC OFFS FICH AVI CONT
          OBJE LECT lframe uframe TERM REND
FREQ 0
GO
ENDPLAY
FIN
```

slid02.epx

```
SLID02
ECHO
 CONV win
TRID LAGR
GEOM LIBR POIN 28 CUB8 5 TERM
 0 0 0  1 0 0  2 0 0  3 0 0
 0 1 0  1 1 0  2 1 0  3 1 0
 0.5 1 0  1.5 1 0  2.5 1 0
 0.5 2 0  1.5 2 0  2.5 2 0
 0 0 1  1 0 1  2 0 1  3 0 1
 0 1 1  1 1 1  2 1 1  3 1 1
 0.5 1 1  1.5 1 1  2.5 1 1
 0.5 2 1  1.5 2 1  2.5 2 1
 1 2 6 5 15 16 20 19
 2 3 7 6 16 17 21 20
 3 4 8 7 17 18 22 21
 9 10 13 12 23 24 27 26
 10 11 14 13 24 25 28 27
COMP GROU 2 'targ' LECT 1 2 3 TERM
            'proj' LECT 4 5 TERM
     NGRO 1 'bloc' LECT 1 2 3 4 15 16 17 18 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.257E8 MXIT 500
          QR1 2.348E8 CR1 56.2 QR2 4.457E8 CR2 4.7
          PDOT 5.E-4 C 1.E-2 TQ 0.9 CP 452.0
          TM 1800.0 M 1.0 DC 1.0 WC 555.0E6
          resi 1
          LECT targ proj TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 5 6 7 8 19 20 21 22 TERM
                 NSLA LECT 9 10 11 23 24 25 TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
fin

PLAY
CAME   1 EYE   7.66358E-01 -8.91360E-01  8.25636E-01
!        Q     8.53854E-01  4.18258E-01  1.94114E-01  2.41481E-01
         VIEW -5.33494E-01  6.20513E-01 -5.74760E-01
         RIGH  8.08013E-01  5.74760E-01 -1.29487E-01
         UP   -2.50000E-01  5.33494E-01  8.08013E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  0.00000E+00
!RSPHERE:  2.87298E-01
!RADIUS :  1.43649E+00
!ASPECT :  1.00000E+00
```

```
!NEAR   :  1.12046E+00
!FAR    :  2.01109E+00
CAME   2 EYE   5.99574E-01 -1.02500E+00 -8.08319E-01
!         Q     4.59533E-01  8.32368E-01  2.97517E-01  8.64705E-02
         VIEW -4.17388E-01  7.13548E-01  5.62704E-01
         RIGH  8.08013E-01  5.74759E-01 -1.29487E-01
         UP    4.15815E-01 -4.00626E-01  8.16454E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  0.00000E+00
!RSPHERE:  2.87298E-01
!RADIUS :  1.43649E+00
!ASPECT :  1.00000E+00
!NEAR   :  1.14920E+00
!FAR    :  1.72379E+00
SCEN OBJE USLM LECT tous TERM
     GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
          GLIS SURF LECT 1 TERM MFAC SNOD
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH BMP
          REND
SCEN OBJE USLM LECT tous TERM
     GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
          GLIS SURF LECT 2 TERM MFAC SNOD
     LIMA ON
SLER CAM1 2 NFRA 1
TRAC OFFS FICH BMP
          REND
!trac rend
*
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 31 FPS 15 KFRE 10 COMP -1
          OBJE LECT lframe uframe TERM REND
FREQ 0 TFRE 0.1E-3
GOTR LOOP 29 OFFS FICH AVI CONT NOCL
          OBJE LECT lframe uframe TERM REND
GO
TRAC OFFS FICH AVI CONT
          OBJE LECT lframe uframe TERM REND
FREQ 0
GO
ENDPLAY
FIN
```

slid03.epx

```
SLID03
ECHO
!CONV win
DPLA LAGR
GEOM LIBR POIN 5 Q42L 1 PMAT 1 TERM
 0 0  1 0
 0 1  1 1
 0.5 1.1
 1 2 4 3
 5
COMP EPAI 1.0 LECT tous TERM
     GROU 2 'targ' LECT 1 TERM
            'proj' LECT 2 TERM
     EPAI 1.0 LECT targ TERM
          0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 12 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 3 4 TERM
                 NSLA LECT 5 TERM
INIT VITE 2 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   5.00000E-01  5.50000E-01  3.75000E+00
!         Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.50000E-01  0.00000E+00
!RSPHERE:  7.50000E-01
!RADIUS :  3.75000E+00
!ASPECT :  1.00000E+00
!NEAR   :  2.92500E+00
!FAR    :  5.25000E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 29 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 27 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR  2 'dy_5' DEPL COMP 2 NOEU LECT 5 TERM
COUR 11 'vy_3' VITE COMP 2 NOEU LECT 3 TERM
COUR 12 'vy_5' VITE COMP 2 NOEU LECT 5 TERM
COUR 21 'y_3'  COOR COMP 2 NOEU LECT 3 TERM
COUR 22 'y_5'  COOR COMP 2 NOEU LECT 5 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -7.51287E-02 TOLE 1.E-2
     COUR 12 REFE  1.48998E+01 TOLE 1.E-2
     COUR 22 REFE  1.02487E+00 TOLE 1.E-2
FIN
```

slid04.epx

```
SLID04
ECHO
!CONV win
DPLA LAGR
GEOM LIBR POIN 5 Q42L 1 PMAT 1 TERM
 0 0  1 0
 0 1  1 1
 0.5 1.2
 1 2 4 3
 5
COMP EPAI 1.0 LECT tous TERM
     GROU 2 'targ' LECT 1 TERM
            'proj' LECT 2 TERM
     EPAI 1.0 LECT targ TERM
          0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 12 LECT bloc TERM
     PINB BODY MLEV 5 LECT targ TERM
          BODY DIAM 0.2 LECT proj TERM
INIT VITE 2 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   5.00000E-01  5.50000E-01  3.75000E+00
!         Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.50000E-01  0.00000E+00
!RSPHERE:  7.50000E-01
!RADIUS :  3.75000E+00
!ASPECT :  1.00000E+00
!NEAR   :  2.92500E+00
!FAR    :  5.25000E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 29 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 27 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
```

```
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR  2 'dy_5' DEPL COMP 2 NOEU LECT 5 TERM
COUR 11 'vy_3' VITE COMP 2 NOEU LECT 3 TERM
COUR 12 'vy_5' VITE COMP 2 NOEU LECT 5 TERM
COUR 21 'y_3'  COOR COMP 2 NOEU LECT 3 TERM
COUR 22 'y_5'  COOR COMP 2 NOEU LECT 5 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
RCOU 101 'dy_3' FICH 'slid03.pun' RENA 'dy_3_03'
RCOU 102 'dy_5' FICH 'slid03.pun' RENA 'dy_5_03'
RCOU 111 'vy_3' FICH 'slid03.pun' RENA 'vy_3_03'
RCOU 112 'vy_5' FICH 'slid03.pun' RENA 'vy_5_03'
RCOU 121 'y_3'  FICH 'slid03.pun' RENA 'y_3_03'
RCOU 122 'y_5'  FICH 'slid03.pun' RENA 'y_5_03'
TRAC  1  2 101 102 AXES 1.0 'DEPL. [M]' YZER
COLO NOIR NOIR ROUG ROUG
TRAC 11 12 111 112 AXES 1.0 'VITE. [M/S]' YZER
COLO NOIR NOIR ROUG ROUG
TRAC 21 22 121 122 AXES 1.0 'COOR. [M]' YZER
COLO NOIR NOIR ROUG ROUG
QUAL COUR  2 REFE -7.56787E-02 TOLE 1.E-2
     COUR 12 REFE  1.45632E+01 TOLE 1.E-2
     COUR 22 REFE  1.12432E+00 TOLE 1.E-2
FIN
```

slid05.epx

```
SLID05
ECHO
 CONV win
DPLA LAGR
GEOM LIBR POIN 5 Q42L 1 PMAT 1 TERM
 0 0  1 0
 0 1  1 1
 0.5 1.1
 1 2 4 3
 5
COMP EPAI 1.0 LECT tous TERM
     GROU 2 'targ' LECT 1 TERM
            'proj' LECT 2 TERM
     EPAI 1.0 LECT targ TERM
          0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
!MATE VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.257E8 MXIT 500
!          QR1 2.348E8 CR1 56.2 QR2 4.457E8 CR2 4.7
!          PDOT 5.E-4 C 1.E-2 TQ 0.9 CP 452.0
!          TM 1800.0 M 1.0 DC 1.0 WC 555.0E6
!          resi 1
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 12 LECT bloc TERM
     GLIS 1 MAIT NOEU LECT 3 4 TERM
            PESC LECT 5 TERM
INIT VITE 2 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
fin
PLAY
CAME   1 EYE   5.00000E-01  5.50000E-01  3.75000E+00
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.50000E-01  0.00000E+00
!RSPHERE:  7.50000E-01
!RADIUS :  3.75000E+00
!ASPECT :  1.00000E+00
!NEAR   :  2.92500E+00
!FAR    :  5.25000E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 29 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 27 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR  2 'dy_5' DEPL COMP 2 NOEU LECT 5 TERM
COUR 11 'vy_3' VITE COMP 2 NOEU LECT 3 TERM
COUR 12 'vy_5' VITE COMP 2 NOEU LECT 5 TERM
COUR 21 'y_3'  COOR COMP 2 NOEU LECT 3 TERM
COUR 22 'y_5'  COOR COMP 2 NOEU LECT 5 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
FIN
```

slid06.epx

```
SLID06
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 7 PR6 1 PMAT 1 TERM
 0 0 0  1 0 0  0 1 0
 0 0 1  1 0 1  0 1 1
 0.33333 0.33333 1.1
 1 2 3 4 5 6
 7
COMP GROU 2 'targ' LECT 1 TERM
            'proj' LECT 2 TERM
     EPAI 0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 3 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 4 5 6 TERM
                 NSLA LECT 7 TERM
INIT VITE 3 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE  -2.66700E+00 -2.66700E+00  1.80009E+00
!        Q     7.32963E-01  5.62422E-01 -2.32963E-01 -3.03603E-01
         VIEW  6.83013E-01  6.83013E-01 -2.58819E-01
         RIGH  7.07107E-01 -7.07107E-01 -5.55112E-17
         UP    1.83013E-01  1.83013E-01  9.65926E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 35 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 33 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_4' DEPL COMP 3 NOEU LECT 4 TERM
COUR  2 'dz_7' DEPL COMP 3 NOEU LECT 7 TERM
COUR 11 'vz_4' VITE COMP 3 NOEU LECT 4 TERM
COUR 12 'vz_7' VITE COMP 3 NOEU LECT 7 TERM
COUR 21 'z_4'  COOR COMP 3 NOEU LECT 4 TERM
COUR 22 'z_7'  COOR COMP 3 NOEU LECT 7 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -5.70652E-02 TOLE 1.E-2
     COUR 12 REFE  3.41691E+01 TOLE 1.E-2
     COUR 22 REFE  1.04293E+00 TOLE 1.E-2
FIN
```

slid07.epx

```
SLID07
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 7 PR6 1 PMAT 1 TERM
 0 0 0  1 0 0  0 1 0
 0 0 1  1 0 1  0 1 1
 0.33333 0.33333 1.2
 1 2 3 4 5 6
 7
COMP GROU 2 'targ' LECT 1 TERM
            'proj' LECT 2 TERM
     EPAI 0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 3 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     PINB BODY MLEV 5 LECT targ TERM
          BODY DIAM 0.2 LECT proj TERM
INIT VITE 3 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE  -2.66700E+00 -2.66700E+00  1.80009E+00
!        Q     7.32963E-01  5.62422E-01 -2.32963E-01 -3.03603E-01
         VIEW  6.83013E-01  6.83013E-01 -2.58819E-01
         RIGH  7.07107E-01 -7.07107E-01 -5.55112E-17
         UP    1.83013E-01  1.83013E-01  9.65926E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 35 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 33 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_4' DEPL COMP 3 NOEU LECT 4 TERM
COUR  2 'dz_7' DEPL COMP 3 NOEU LECT 7 TERM
COUR 11 'vz_4' VITE COMP 3 NOEU LECT 4 TERM
COUR 12 'vz_7' VITE COMP 3 NOEU LECT 7 TERM
COUR 21 'z_4'  COOR COMP 3 NOEU LECT 4 TERM
COUR 22 'z_7'  COOR COMP 3 NOEU LECT 7 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
RCOU 101 'dz_4' FICH 'slid06.pun' RENA 'dz_4_06'
RCOU 102 'dz_7' FICH 'slid06.pun' RENA 'dz_7_06'
RCOU 111 'vz_4' FICH 'slid06.pun' RENA 'vz_4_06'
RCOU 112 'vz_7' FICH 'slid06.pun' RENA 'vz_7_06'
RCOU 121 'z_4'  FICH 'slid06.pun' RENA 'z_4_06'
RCOU 122 'z_7'  FICH 'slid06.pun' RENA 'z_7_06'
TRAC  1  2 101 102 AXES 1.0 'DEPL. [M]' YZER
COLO NOIR NOIR ROUG ROUG
TRAC 11 12 111 112 AXES 1.0 'VITE. [M/S]' YZER
COLO NOIR NOIR ROUG ROUG
TRAC 21 22 121 122 AXES 1.0 'COOR. [M]' YZER
COLO NOIR NOIR ROUG ROUG
QUAL COUR  2 REFE -3.42214E-02 TOLE 1.E-2
     COUR 12 REFE  3.34961E+01 TOLE 1.E-2
     COUR 22 REFE  1.16578E+00 TOLE 1.E-2
FIN
```

slid08.epx

```
SLID08
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 7 PR6 1 PMAT 1 TERM
 0 0 0  1 0 0  0 1 0
 0 0 1  1 0 1  0 1 1
 0.33333 0.33333 1.1
 1 2 3 4 5 6
 7
COMP GROU 2 'targ' LECT 1 TERM
            'proj' LECT 2 TERM
     EPAI 0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 3 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     GLIS 1 MAIT NODE LECT 4 5 6 TERM
            PESC LECT 7 TERM
INIT VITE 3 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE  -2.66700E+00 -2.66700E+00  1.80009E+00
!        Q     7.32963E-01  5.62422E-01 -2.32963E-01 -3.03603E-01
         VIEW  6.83013E-01  6.83013E-01 -2.58819E-01
         RIGH  7.07107E-01 -7.07107E-01 -5.55112E-17
         UP    1.83013E-01  1.83013E-01  9.65926E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 35 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 33 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_4' DEPL COMP 3 NOEU LECT 4 TERM
COUR  2 'dz_7' DEPL COMP 3 NOEU LECT 7 TERM
COUR 11 'vz_4' VITE COMP 3 NOEU LECT 4 TERM
COUR 12 'vz_7' VITE COMP 3 NOEU LECT 7 TERM
COUR 21 'z_4'  COOR COMP 3 NOEU LECT 4 TERM
COUR 22 'z_7'  COOR COMP 3 NOEU LECT 7 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
RCOU 101 'dz_4' FICH 'slid06.pun' RENA 'dz_4_06'
RCOU 102 'dz_7' FICH 'slid06.pun' RENA 'dz_7_06'
RCOU 111 'vz_4' FICH 'slid06.pun' RENA 'vz_4_06'
RCOU 112 'vz_7' FICH 'slid06.pun' RENA 'vz_7_06'
RCOU 121 'z_4'  FICH 'slid06.pun' RENA 'z_4_06'
RCOU 122 'z_7'  FICH 'slid06.pun' RENA 'z_7_06'
TRAC  1  2 101 102 AXES 1.0 'DEPL. [M]' YZER
COLO NOIR NOIR ROUG ROUG
TRAC 11 12 111 112 AXES 1.0 'VITE. [M/S]' YZER
COLO NOIR NOIR ROUG ROUG
TRAC 21 22 121 122 AXES 1.0 'COOR. [M]' YZER
COLO NOIR NOIR ROUG ROUG
QUAL COUR  2 REFE -5.23767E-02 TOLE 1.E-2
     COUR 12 REFE  3.09344E+01 TOLE 1.E-2
     COUR 22 REFE  1.04762E+00 TOLE 1.E-2
FIN
```

slid09.epx

```
SLID09
ECHO
!CONV win
DPLA LAGR
GEOM LIBR POIN 14 Q42L 5 TERM
 0 0  1 0  2 0  3 0
 0 1  1 1  2 1  3 1
 0.5 1  1.5 1 2.5 1
 0.5 2  1.5 2 2.5 2
 1 2 6 5
```

```
 2 3 7 6
 3 4 8 7
 9 10 13 12
 10 11 14 13
COMP EPAI 1.0 LECT tous TERM
     GROU 2 'targ' LECT 1 2 3 TERM
            'proj' LECT 4 5 TERM
     NGRO 1 'bloc' LECT 1 2 3 4 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.257E8 MXIT 500
          QR1 2.348E8 CR1 56.2 QR2 4.457E8 CR2 4.7
          PDOT 5.E-4 C 1.E-2 TQ 0.9 CP 452.0
          TM 1800.0 M 1.0 DC 1.0 WC 555.0E6
          resi 1
          LECT targ proj TERM
LINK COUP ! SPLT NONE
     BLOQ 12 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 5 6 7 8 TERM
                 NSLA LECT 9 10 11 TERM
INIT VITE 2 -50 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   1.50000E+00  1.00000E+00  9.01388E+00
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  1.50000E+00  1.00000E+00  0.00000E+00
!RSPHERE:  1.80278E+00
!RADIUS :  9.01388E+00
!ASPECT :  1.00000E+00
!NEAR   :  7.03082E+00
!FAR    :  1.26194E+01
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 29 FPS 15 KFRE 10 COMP -1
          REND
FREQ 0 TFRE 0.1E-3
GOTR LOOP 27 OFFS FICH AVI CONT NOCL
          REND
GO
TRAC OFFS FICH AVI CONT
          REND
FREQ 0
GO
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dy_6' DEPL COMP 2 NOEU LECT 6 TERM
COUR  2 'dy_9' DEPL COMP 2 NOEU LECT 9 TERM
COUR 11 'vy_6' VITE COMP 2 NOEU LECT 6 TERM
COUR 12 'vy_9' VITE COMP 2 NOEU LECT 9 TERM
COUR 21 'y_6'  COOR COMP 2 NOEU LECT 6 TERM
COUR 22 'y_9'  COOR COMP 2 NOEU LECT 9 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
FIN
```

slid10.epx

```
SLID10
ECHO
!CONV win
DPLA LAGR
GEOM LIBR POIN 14 Q42L 5 PMAT 3 TERM
 0 0  1 0  2 0  3 0
 0 1  1 1  2 1  3 1
 0.5 1  1.5 1 2.5 1
 0.5 2  1.5 2 2.5 2
 1 2 6 5
 2 3 7 6
 3 4 8 7
 9 10 13 12
 10 11 14 13
 9
 10
 11
COMP GROU 3 'targ' LECT 1 2 3 TERM
            'proj' LECT 4 5 TERM
            'npin' LECT 6 7 8 TERM
     NGRO 1 'bloc' LECT 1 2 3 4 TERM
     EPAI 1.0 LECT targ proj TERM
          0.01 LECT npin TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
          GR50 LECT npin TERM
MATE VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.257E8 MXIT 500
          QR1 2.348E8 CR1 56.2 QR2 4.457E8 CR2 4.7
          PDOT 5.E-4 C 1.E-2 TQ 0.9 CP 452.0
          TM 1800.0 M 1.0 DC 1.0 WC 555.0E6
          resi 1
          LECT targ proj TERM
     MASS 0.0
          LECT npin TERM
OPTI PINS ASN
LINK COUP ! SPLT NONE
     BLOQ 12 LECT bloc TERM
     PINB BODY MLEV 5 LECT targ TERM
          BODY DIAM 0.01 LECT npin TERM
INIT VITE 2 -50 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   1.50000E+00  1.00000E+00  9.01388E+00
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  1.50000E+00  1.00000E+00  0.00000E+00
!RSPHERE:  1.80278E+00
!RADIUS :  9.01388E+00
!ASPECT :  1.00000E+00
!NEAR   :  7.03082E+00
!FAR    :  1.26194E+01
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 29 FPS 15 KFRE 10 COMP -1
          REND
FREQ 0 TFRE 0.1E-3
GOTR LOOP 27 OFFS FICH AVI CONT NOCL
          REND
GO
TRAC OFFS FICH AVI CONT
          REND
FREQ 0
GO
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dy_6' DEPL COMP 2 NOEU LECT 6 TERM
COUR  2 'dy_9' DEPL COMP 2 NOEU LECT 9 TERM
COUR 11 'vy_6' VITE COMP 2 NOEU LECT 6 TERM
COUR 12 'vy_9' VITE COMP 2 NOEU LECT 9 TERM
COUR 21 'y_6'  COOR COMP 2 NOEU LECT 6 TERM
COUR 22 'y_9'  COOR COMP 2 NOEU LECT 9 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
RCOU 101 'dy_6' FICH 'slid09.pun' RENA 'dy_6_09'
RCOU 102 'dy_9' FICH 'slid09.pun' RENA 'dy_9_09'
RCOU 111 'vy_6' FICH 'slid09.pun' RENA 'vy_6_09'
RCOU 112 'vy_9' FICH 'slid09.pun' RENA 'vy_9_09'
RCOU 121 'y_6'  FICH 'slid09.pun' RENA 'y_6_09'
RCOU 122 'y_9'  FICH 'slid09.pun' RENA 'y_9_09'
TRAC  1  2 101 102 AXES 1.0 'DEPL. [M]' YZER
COLO NOIR NOIR ROUG ROUG
TRAC 11 12 111 112 AXES 1.0 'VITE. [M/S]' YZER
COLO NOIR NOIR ROUG ROUG
TRAC 21 22 121 122 AXES 1.0 'COOR. [M]' YZER
COLO NOIR NOIR ROUG ROUG
FIN
```

slid11.epx

```
SLID11
ECHO
!CONV win
DPLA LAGR
GEOM LIBR POIN 7 Q42L 2 PMAT 1 TERM
 -1 0  0 0    1 0
 -1 1  0 1.1  1 1
 0 1.2
 1 2 5 4
 2 3 6 5
 7
```

```
COMP GROU 2 'targ' LECT 1 2 TERM
            'proj' LECT 3 TERM
     EPAI 1.0 LECT targ TERM
          0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 3 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 12 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 4 5 6 TERM
                 NSLA LECT 7 TERM
INIT VITE 2 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   0.00000E+00  6.50000E-01  5.98435E+00
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  6.50000E-01  0.00000E+00
!RSPHERE:  1.19687E+00
!RADIUS :  5.98435E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.66780E+00
!FAR    :  8.37810E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 28 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 26 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dy_5' DEPL COMP 2 NOEU LECT 5 TERM
COUR  2 'dy_7' DEPL COMP 2 NOEU LECT 7 TERM
COUR 11 'vy_5' VITE COMP 2 NOEU LECT 5 TERM
COUR 12 'vy_7' VITE COMP 2 NOEU LECT 7 TERM
COUR 21 'y_5'  COOR COMP 2 NOEU LECT 5 TERM
COUR 22 'y_7'  COOR COMP 2 NOEU LECT 7 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -7.19094E-02 TOLE 1.E-2
     COUR 12 REFE  1.82541E+01 TOLE 1.E-2
     COUR 22 REFE  1.12809E+00 TOLE 1.E-2
FIN
```

slid12.epx

```
SLID12
ECHO
!CONV win
DPLA LAGR
GEOM LIBR POIN 7 Q42L 2 PMAT 1 TERM
 -1 0  0 0    1 0
 -1 1.1  0 1  1 1.1
 0 1.1
 1 2 5 4
 2 3 6 5
 7
COMP GROU 2 'targ' LECT 1 2 TERM
            'proj' LECT 3 TERM
     EPAI 1.0 LECT targ TERM
          0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 3 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 12 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 4 5 6 TERM
                 NSLA LECT 7 TERM
INIT VITE 2 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   0.00000E+00  6.50000E-01  5.98435E+00
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  6.50000E-01  0.00000E+00
!RSPHERE:  1.19687E+00
!RADIUS :  5.98435E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.66780E+00
!FAR    :  8.37810E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 28 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 26 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dy_5' DEPL COMP 2 NOEU LECT 5 TERM
COUR  2 'dy_7' DEPL COMP 2 NOEU LECT 7 TERM
COUR 11 'vy_5' VITE COMP 2 NOEU LECT 5 TERM
COUR 12 'vy_7' VITE COMP 2 NOEU LECT 7 TERM
COUR 21 'y_5'  COOR COMP 2 NOEU LECT 5 TERM
COUR 22 'y_7'  COOR COMP 2 NOEU LECT 7 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -6.90854E-02 TOLE 1.E-2
     COUR 12 REFE  1.97314E+01 TOLE 1.E-2
     COUR 22 REFE  1.03091E+00 TOLE 1.E-2
FIN
```

slid13.epx

```
SLID13
ECHO
!CONV win
DPLA LAGR
GEOM LIBR POIN 16 Q42L 6 TERM
 0 0  1 0  2 0  3 0  4 0
 0 1  1 1  2 1  3 1  4 1
      1 1  2 1  3 1
      1 2  2 2  3 2
 1 2 7 6
 2 3 8 7
 3 4 9 8
 4 5 10 9
 11 12 15 14
 12 13 16 15
COMP EPAI 1.0 LECT tous TERM
     GROU 2 'targ' LECT 1 2 3 4 TERM
            'proj' LECT 5 6 TERM
     NGRO 1 'bloc' LECT 1 2 3 4 5 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.257E8 MXIT 500
          QR1 2.348E8 CR1 56.2 QR2 4.457E8 CR2 4.7
          PDOT 5.E-4 C 1.E-2 TQ 0.9 CP 452.0
          TM 1800.0 M 1.0 DC 1.0 WC 555.0E6
          resi 1
          LECT targ proj TERM
LINK COUP
     BLOQ 12 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 6 7 8 9 10 TERM
                 NSLA LECT 11 12 13 TERM
INIT VITE 2 -50 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
```

```
CAME   1 EYE   2.00000E+00  1.00000E+00  1.11803E+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 :  2.00000E+00  1.00000E+00  0.00000E+00
!RSPHERE:  2.23607E+00
!RADIUS :  1.11803E+01
!ASPECT :  1.00000E+00
!NEAR   :  8.72067E+00
!FAR    :  1.56525E+01
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 29 FPS 15 KFRE 10 COMP -1
         REND
FREQ 0 TFRE 0.1E-3
GOTR LOOP 27 OFFS FICH AVI CONT NOCL
         REND
GO
TRAC OFFS FICH AVI CONT
         REND
FREQ 0
GO
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dy_8' DEPL COMP 2 NOEU LECT 8 TERM
COUR  2 'dy_12' DEPL COMP 2 NOEU LECT 12 TERM
COUR 11 'vy_8' VITE COMP 2 NOEU LECT 8 TERM
COUR 12 'vy_12' VITE COMP 2 NOEU LECT 12 TERM
COUR 21 'y_8'  COOR COMP 2 NOEU LECT 8 TERM
COUR 22 'y_12'  COOR COMP 2 NOEU LECT 12 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE  2.85945E-02 TOLE 1.E-2
     COUR 12 REFE  1.35695E+01 TOLE 1.E-2
     COUR 22 REFE  1.02859E+00 TOLE 1.E-2
FIN
```

slid14.dgibi

```
opti echo 0;
opti donn 'px4cir2d.proc';
opti donn 'pxordpoi.proc';
opti echo 1;
opti dime 2 elem qua4;
opti trac psc ftra 'slid14_mesh.ps';
opti sauv form 'slid14.msh';
r = 2.0;
x0 = 3.0;
pc = x0 r;
n = 8;
tol = 0.001;
c1 ier = px4cir2d (x0 0) ((x0+r) r) pc n tol;
c2 = c1 tour 90 pc;
c3 = c2 tour 90 pc;
c4 = c3 tour 90 pc;
circ = c1 et c2 et c3 et c4;
elim tol circ;
p1 = x0 0;
p2 = (x0+r) r;
p3 = x0 (r+r);
p4 = (x0-r) r;
elim tol (circ et p1 et p2 et p3 et p4);
cc1 = cerc n p1 pc p2;
cc2 = cc1 tour 90 pc;
cc3 = cc2 tour 90 pc;
cc4 = cc3 tour 90 pc;
elim tol (circ et cc1 et cc2 et cc3 et cc4);
pc1 = pxordpoi (chan POI1 cc1) p1;
pc2 = pxordpoi (chan POI1 cc2) p2;
pc3 = pxordpoi (chan POI1 cc3) p3;
pc4 = pxordpoi (chan POI1 cc4) p4;
pm = pc plus (0 r);
elim tol (pm et circ);
mark = manu poi1 pm;
h = 3.0;
len = 10.0;
nh = enti (h / 1.0);
nb = enti (len / 1.0);
bas = (0 (0-h)) d nb (len (0-h));
base = bas tran nh (0 h);
bas2 = (len 0) d nb (0 0);
*list (nbno bas2);
elim tol (bas2 et base);
p5 = len 0;
elim tol (p5 et bas2);
pbas2 = chan POI1 bas2;
*list (nbno pbas2);
pb2 = pxordpoi pbas2 p5;
list (nbno pb2);
mesh = circ et base et pb2 et pc1 et pc2 et pc3 et pc4 et mark;
tass mesh noop;
sauv form mesh;
trac qual mesh;
fin;
```

slid14.epx

```
SLID14
ECHO
!CONV WIN
CAST mesh
LAGR DPLA
DIME GLIS 1 200 TERM
GEOM CAR4 circ base PMAT mark TERM
COMP EPAI 0.2 LECT mark TERM ! Only for visualization
     NGRO 1 'b1' LECT circ TERM COND NEAR POIN 3 0
     COUL TURQ LECT circ TERM
          VERT LECT base TERM
          ROUG LECT mark TERM
MATE LINE RO 7800. YOUN 2.E11 NU 0.
          LECT circ base TERM
     MASS 0.0 LECT mark TERM
!LINK COUP
LINK COUP
     BLOQ 12 LECT bas TERM
     SLID 1 SURF EMAS LECT base TERM
                 NMAS LECT pb2 TERM
                 NSLA LECT pc1 pc2 pc3 pc4 TERM
CHAR 1 FACT 2
     FORC 1  6.E8 LECT pc TERM
     FORC 2 -6.E8 LECT pc TERM
     TABL 3 0. 0.  6.E-4 1.  6. 1.
ECRI DEPL VITE COOR FINT FEXT FLIA FREQ 10000
     FICH ALIC FREQ 5000
     FICH ALIC TEMP FREQ 1
          POIN LECT b1 pc mark TERM
OPTI PAS UTIL
     LOG 1
     LNKS STAT
CALC TINI 0 TFIN 60.E-3 PASF 2.E-6 NMAX 30000
PLAY
CAME   1 EYE   5.00000E+00  5.50000E-01  3.06645E+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 :  5.00000E+00  5.50000E-01  0.00000E+00
!RSPHERE:  6.13290E+00
!RADIUS :  3.06645E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.39183E+01
!FAR    :  4.29303E+01
SCEN GEOM NAVI FREE
          POIN SPHP
     VECT SCCO FIEL VITE SCAL USER PROG 100.0 PAS 100.0 1400.0 TERM
SLER CAM1 1 NFRA 1
FREQ 5000
TRAC OFFS FICH AVI NOCL NFTO 7 FPS 5 KFRE 5 COMP -1 REND
GOTR LOOP 5 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1. 'Time [s]'
COUR  1 'y_b1'   COOR COMP 2 NOEU LECT b1 TERM
COUR  5 'dy_mk'  DEPL COMP 2 NOEU LECT mark TERM
COUR  6 'dy_b1'  DEPL COMP 2 NOEU LECT b1 TERM
COUR  7 'dy_pc'  DEPL COMP 2 NOEU LECT pc TERM
COUR  8 'dx_mk'  DEPL COMP 1 NOEU LECT mark TERM
COUR  9 'dx_b1'  DEPL COMP 1 NOEU LECT b1 TERM
COUR 10 'dx_pc'  DEPL COMP 1 NOEU LECT pc TERM
COUR 11 'vy_b1'  VITE COMP 2 NOEU LECT b1 TERM
COUR 15 'vy_pc'  VITE COMP 2 NOEU LECT pc TERM
COUR 17 'vx_pc'  VITE COMP 1 NOEU LECT pc TERM
TRAC 1 AXES 1.0 'Y-COOR. [M]' YZER
TRAC 5 6 7 AXES 1.0 'DY [M]' YZER
TRAC 8 9 10 AXES 1.0 'DX [M]' YZER
TRAC 11 15 AXES 1.0 'VY [M/S]' YZER
TRAC 15 AXES 1.0 'VY [M/S]' YZER
TRAC 15 17 AXES 1.0 'V [M/S]' YZER
FIN
```

slid15.dgibi

```
opti echo 0;
opti donn 'px4cir2d.proc';
opti donn 'pxordpoi.proc';
opti echo 1;
opti dime 2 elem qua4;
opti trac psc ftra 'slid15_mesh.ps';
opti sauv form 'slid15.msh';
r = 2.0;
```

```
x0 = 3.0;
pc = x0 r;
n = 8;
tol = 0.001;
c1 ier = px4cir2d (x0 0) ((x0+r) r) pc n tol;
c2 = c1 tour 90 pc;
c3 = c2 tour 90 pc;
c4 = c3 tour 90 pc;
circ = c1 et c2 et c3 et c4;
elim tol circ;
p1 = x0 0;
p2 = (x0+r) r;
p3 = x0 (r+r);
p4 = (x0-r) r;
elim tol (circ et p1 et p2 et p3 et p4);
cc1 = cerc n p1 pc p2;
cc2 = cc1 tour 90 pc;
cc3 = cc2 tour 90 pc;
cc4 = cc3 tour 90 pc;
elim tol (circ et cc1 et cc2 et cc3 et cc4);
pc1 = pxordpoi (chan POI1 cc1) p1;
pc2 = pxordpoi (chan POI1 cc2) p2;
pc3 = pxordpoi (chan POI1 cc3) p3;
pc4 = pxordpoi (chan POI1 cc4) p4;
pm = pc plus (0 r);
elim tol (pm et circ);
mark = manu poi1 pm;
h = 3.0;
len = 10.0;
nh = enti (h / 1.0);
nb = enti (len / 1.0);
bas = (0 (0-h)) d nb (len (0-h));
base = bas tran nh (0 h);
bas2 = (len 0) d nb (0 0);
*list (nbno bas2);
elim tol (bas2 et base);
p5 = len 0;
elim tol (p5 et bas2);
pbas2 = chan POI1 bas2;
*list (nbno pbas2);
pb2 = pxordpoi pbas2 p5;
list (nbno pb2);
mesh = circ et base et pb2 et pc1 et pc2 et pc3 et pc4 et mark;
tass mesh noop;
sauv form mesh;
trac qual mesh;
fin;
```

slid15.epx

```
SLID15
ECHO
!CONV WIN
CAST mesh
LAGR DPLA
DIME GLIS 1 200 TERM
GEOM CAR4 circ base PMAT mark TERM
COMP EPAI 0.2 LECT mark TERM ! Only for visualization
     NGRO 1 'b1' LECT circ TERM COND NEAR POIN 3 0
     COUL TURQ LECT circ TERM
          VERT LECT base TERM
          ROUG LECT mark TERM
MATE LINE RO 7800. YOUN 2.E11 NU 0.
          LECT circ base TERM
     MASS 0.0 LECT mark TERM
!LINK COUP
LINK COUP
     BLOQ 12 LECT bas TERM
     SLID 1 SURF FROT MUST 0.25 MUDY 0.25 GAMM 0.1
                 EMAS LECT base TERM
                 NMAS LECT pb2 TERM
                 NSLA LECT pc1 pc2 pc3 pc4 TERM
CHAR 1 FACT 2
     FORC 1  6.E8 LECT pc TERM
     FORC 2 -6.E8 LECT pc TERM
     TABL 3 0. 0.  6.E-4 1.  6. 1.
ECRI DEPL VITE COOR FINT FEXT FLIA FREQ 10000
     FICH ALIC FREQ 5000
     FICH ALIC TEMP FREQ 1
          POIN LECT b1 pc mark TERM
OPTI PAS UTIL
     LOG 1
     LNKS STAT
CALC TINI 0 TFIN 60.E-3 PASF 2.E-6 NMAX 30000
PLAY
CAME   1 EYE   5.00000E+00  5.50000E-01  3.06645E+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 :  5.00000E+00  5.50000E-01  0.00000E+00
!RSPHERE:  6.13290E+00
!RADIUS :  3.06645E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.39183E+01
!FAR    :  4.29303E+01
SCEN GEOM NAVI FREE
          POIN SPHP
     VECT SCCO FIEL VITE SCAL USER PROG 100.0 PAS 100.0 1400.0 TERM
SLER CAM1 1 NFRA 1
FREQ 5000
TRAC OFFS FICH AVI NOCL NFTO 7 FPS 5 KFRE 5 COMP -1 REND
GOTR LOOP 5 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1. 'Time [s]'
COUR  1 'y_b1'   COOR COMP 2 NOEU LECT b1 TERM
COUR  5 'dy_mk'  DEPL COMP 2 NOEU LECT mark TERM
COUR  6 'dy_b1'  DEPL COMP 2 NOEU LECT b1 TERM
COUR  7 'dy_pc'  DEPL COMP 2 NOEU LECT pc TERM
COUR  8 'dx_mk'  DEPL COMP 1 NOEU LECT mark TERM
COUR  9 'dx_b1'  DEPL COMP 1 NOEU LECT b1 TERM
COUR 10 'dx_pc'  DEPL COMP 1 NOEU LECT pc TERM
COUR 11 'vy_b1'  VITE COMP 2 NOEU LECT b1 TERM
COUR 15 'vy_pc'  VITE COMP 2 NOEU LECT pc TERM
COUR 17 'vx_pc'  VITE COMP 1 NOEU LECT pc TERM
TRAC 1 AXES 1.0 'Y-COOR. [M]' YZER
TRAC 5 6 7 AXES 1.0 'DY [M]' YZER
TRAC 8 9 10 AXES 1.0 'DX [M]' YZER
TRAC 11 15 AXES 1.0 'VY [M/S]' YZER
TRAC 15 AXES 1.0 'VY [M/S]' YZER
TRAC 15 17 AXES 1.0 'V [M/S]' YZER
FIN
```

slid16.epx

```
SLID16
ECHO
!CONV win
DPLA LAGR
GEOM LIBR POIN 5 Q42L 1 PMAT 1 TERM
 0 0  1 0
 0 1  1 1
 0.5 1.1
 1 2 4 3
 5
COMP EPAI 1.0 LECT tous TERM
     GROU 2 'targ' LECT 1 TERM
            'proj' LECT 2 TERM
     EPAI 1.0 LECT targ TERM
          0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 12 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 3 4 TERM
                 NSLA LECT 5 TERM
INIT VITE 2 -100 LECT proj TERM
          1  100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU dump
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   5.00000E-01  5.50000E-01  3.75000E+00
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.50000E-01  0.00000E+00
!RSPHERE:  7.50000E-01
!RADIUS :  3.75000E+00
!ASPECT :  1.00000E+00
!NEAR   :  2.92500E+00
!FAR    :  5.25000E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 29 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 27 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR  2 'dy_5' DEPL COMP 2 NOEU LECT 5 TERM
COUR  3 'dx_3' DEPL COMP 1 NOEU LECT 3 TERM
COUR  4 'dx_5' DEPL COMP 1 NOEU LECT 5 TERM
```

```
COUR 11 'vy_3' VITE COMP 2 NOEU LECT 3 TERM
COUR 12 'vy_5' VITE COMP 2 NOEU LECT 5 TERM
COUR 13 'vx_3' VITE COMP 1 NOEU LECT 3 TERM
COUR 14 'vx_5' VITE COMP 1 NOEU LECT 5 TERM
COUR 21 'y_3'  COOR COMP 2 NOEU LECT 3 TERM
COUR 22 'y_5'  COOR COMP 2 NOEU LECT 5 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC  3  4 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 13 14 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST  3  4 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 13 14 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -7.44682E-02 TOLE 1.E-2
     COUR  4 REFE  3.10968E-01 TOLE 1.E-2
     COUR 12 REFE  1.53657E+01 TOLE 1.E-2
     COUR 14 REFE  1.00042E+02 TOLE 1.E-2
     COUR 22 REFE  1.02553E+00 TOLE 1.E-2
FIN
```

slid17.epx

```
SLID17
ECHO
!CONV win
DPLA LAGR
GEOM LIBR POIN 5 Q42L 1 PMAT 1 TERM
 0 0  1 0
 0 1  1 1
 0.5 1.1
 1 2 4 3
 5
COMP EPAI 1.0 LECT tous TERM
     GROU 2 'targ' LECT 1 TERM
            'proj' LECT 2 TERM
     EPAI 1.0 LECT targ TERM
          0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 12 LECT bloc TERM
     SLID 1 SURF FROT MUST 0.25 MUDY 0.25 GAMM 0.1
                 EMAS LECT targ TERM
                 NMAS LECT 3 4 TERM
                 NSLA LECT 5 TERM
INIT VITE 2 -100 LECT proj TERM
          1  100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU dump
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   5.00000E-01  5.50000E-01  3.75000E+00
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.50000E-01  0.00000E+00
!RSPHERE:  7.50000E-01
!RADIUS :  3.75000E+00
!ASPECT :  1.00000E+00
!NEAR   :  2.92500E+00
!FAR    :  5.25000E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 29 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 27 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR  2 'dy_5' DEPL COMP 2 NOEU LECT 5 TERM
COUR  3 'dx_3' DEPL COMP 1 NOEU LECT 3 TERM
COUR  4 'dx_5' DEPL COMP 1 NOEU LECT 5 TERM
COUR 11 'vy_3' VITE COMP 2 NOEU LECT 3 TERM
COUR 12 'vy_5' VITE COMP 2 NOEU LECT 5 TERM
COUR 13 'vx_3' VITE COMP 1 NOEU LECT 3 TERM
COUR 14 'vx_5' VITE COMP 1 NOEU LECT 5 TERM
COUR 21 'y_3'  COOR COMP 2 NOEU LECT 3 TERM
COUR 22 'y_5'  COOR COMP 2 NOEU LECT 5 TERM
RCOU 103 'dx_3' FICH 'slid16.pun' RENA 'dx_3_16'
RCOU 104 'dx_5' FICH 'slid16.pun' RENA 'dx_5_16'
RCOU 113 'vx_3' FICH 'slid16.pun' RENA 'vx_3_16'
RCOU 114 'vx_5' FICH 'slid16.pun' RENA 'vx_5_16'
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC  3  4 AXES 1.0 'DEPL. [M]' YZER
TRAC  3  4 103 104 AXES 1.0 'DEPL. [M]' YZER
COLO NOIR NOIR ROUG ROUG
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 13 14 AXES 1.0 'VITE. [M/S]' YZER
TRAC 13 14 113 114 AXES 1.0 'VITE. [M/S]' YZER
COLO NOIR NOIR ROUG ROUG
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -7.57887E-02 TOLE 1.E-2
     COUR  4 REFE  2.52193E-01 TOLE 1.E-2
     COUR 12 REFE  1.47182E+01 TOLE 1.E-2
     COUR 14 REFE  7.13734E+01 TOLE 1.E-2
     COUR 22 REFE  1.02421E+00 TOLE 1.E-2
FIN
```

slid18.dgibi

```
opti echo 0;
opti donn 'px4cir2d.proc';
opti donn 'pxordpoi.proc';
opti echo 1;
opti dime 2 elem qua4;
opti trac psc ftra 'slid18_mesh.ps';
opti sauv form 'slid18.msh';
r = 2.0;
x0 = 3.0;
pc = x0 r;
n = 8;
tol = 0.001;
c1 ier = px4cir2d (x0 0) ((x0+r) r) pc n tol;
c2 = c1 tour 90 pc;
c3 = c2 tour 90 pc;
c4 = c3 tour 90 pc;
circ = c1 et c2 et c3 et c4;
elim tol circ;
p1 = x0 0;
p2 = (x0+r) r;
p3 = x0 (r+r);
p4 = (x0-r) r;
elim tol (circ et p1 et p2 et p3 et p4);
cc1 = cerc n p1 pc p2;
cc2 = cc1 tour 90 pc;
cc3 = cc2 tour 90 pc;
cc4 = cc3 tour 90 pc;
elim tol (circ et cc1 et cc2 et cc3 et cc4);
pc1 = pxordpoi (chan POI1 cc1) p1;
pc2 = pxordpoi (chan POI1 cc2) p2;
pc3 = pxordpoi (chan POI1 cc3) p3;
pc4 = pxordpoi (chan POI1 cc4) p4;
pm = pc plus (0 r);
elim tol (pm et circ);
mark = manu poi1 pm;
h = 3.0;
len = 10.0;
nh = enti (h / 1.0);
nb = enti (len / 1.0);
bas = (0 (0-h)) d nb (len (0-h));
base = bas tran nh (0 h);
bas2 = (len 0) d nb (0 0);
*list (nbno bas2);
elim tol (bas2 et base);
p5 = len 0;
elim tol (p5 et bas2);
pbas2 = chan POI1 bas2;
*list (nbno pbas2);
pb2 = pxordpoi pbas2 p5;
list (nbno pb2);
mesh = circ et base et pb2 et pc1 et pc2 et pc3 et pc4 et mark;
tass mesh noop;
sauv form mesh;
trac qual mesh;
fin;
```

slid18.epx

```
SLID18
ECHO
!CONV WIN
CAST mesh
LAGR DPLA
DIME GLIS 1 200 TERM
GEOM CAR4 circ base PMAT mark TERM
COMP EPAI 0.2 LECT mark TERM ! Only for visualization
     NGRO 3 'b1' LECT circ TERM COND NEAR POIN 3 0
            'm2' LECT circ TERM COND ENVE
            's2' LECT base TERM COND Y GT -0.1
     COUL TURQ LECT circ TERM
          VERT LECT base TERM
          ROUG LECT mark TERM
MATE LINE RO 7800. YOUN 2.E11 NU 0.
          LECT circ base TERM
```

```
     MASS 0.0 LECT mark TERM
!LINK COUP
LINK COUP
     BLOQ 12 LECT bas TERM
     SLID 2 SURF EMAS LECT base TERM
                 NMAS LECT pb2 TERM
                 NSLA LECT pc1 pc2 pc3 pc4 TERM
            SURF EMAS LECT circ TERM
                 NMAS LECT m2 TERM
                 NSLA LECT s2 TERM
CHAR 1 FACT 2
     FORC 1  6.E8 LECT pc TERM
     FORC 2 -6.E8 LECT pc TERM
     TABL 3 0. 0.  6.E-4 1.  6. 1.
ECRI DEPL VITE COOR FINT FEXT FLIA FREQ 10000
     FICH ALIC FREQ 5000
     FICH ALIC TEMP FREQ 1
          POIN LECT b1 pc mark TERM
OPTI PAS UTIL
     LOG 1
     LNKS STAT
CALC TINI 0 TFIN 60.E-3 PASF 2.E-6 NMAX 30000
PLAY
CAME   1 EYE   5.00000E+00  5.50000E-01  3.06645E+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 :  5.00000E+00  5.50000E-01  0.00000E+00
!RSPHERE:  6.13290E+00
!RADIUS :  3.06645E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.39183E+01
!FAR    :  4.29303E+01
SCEN GEOM NAVI FREE
          POIN SPHP
     VECT SCCO FIEL VITE SCAL USER PROG 100.0 PAS 100.0 1400.0 TERM
SLER CAM1 1 NFRA 1
FREQ 5000
TRAC OFFS FICH AVI NOCL NFTO 7 FPS 5 KFRE 5 COMP -1 REND
GOTR LOOP 5 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1. 'Time [s]'
COUR  1 'y_b1'   COOR COMP 2 NOEU LECT b1 TERM
COUR  5 'dy_mk'  DEPL COMP 2 NOEU LECT mark TERM
COUR  6 'dy_b1'  DEPL COMP 2 NOEU LECT b1 TERM
COUR  7 'dy_pc'  DEPL COMP 2 NOEU LECT pc TERM
COUR  8 'dx_mk'  DEPL COMP 1 NOEU LECT mark TERM
COUR  9 'dx_b1'  DEPL COMP 1 NOEU LECT b1 TERM
COUR 10 'dx_pc'  DEPL COMP 1 NOEU LECT pc TERM
COUR 11 'vy_b1'  VITE COMP 2 NOEU LECT b1 TERM
COUR 15 'vy_pc'  VITE COMP 2 NOEU LECT pc TERM
COUR 17 'vx_pc'  VITE COMP 1 NOEU LECT pc TERM
TRAC 1 AXES 1.0 'Y-COOR. [M]' YZER
TRAC 5 6 7 AXES 1.0 'DY [M]' YZER
TRAC 8 9 10 AXES 1.0 'DX [M]' YZER
TRAC 11 15 AXES 1.0 'VY [M/S]' YZER
TRAC 15 AXES 1.0 'VY [M/S]' YZER
TRAC 15 17 AXES 1.0 'V [M/S]' YZER
FIN
```

slid19.dgibi

```
opti echo 0;
opti donn 'px4cir2d.proc';
opti donn 'pxordpoi.proc';
opti echo 1;
opti dime 2 elem qua4;
opti trac psc ftra 'slid19_mesh.ps';
opti sauv form 'slid19.msh';
r = 2.0;
x0 = 3.0;
pc = x0 r;
n = 8;
tol = 0.001;
c1 ier = px4cir2d (x0 0) ((x0+r) r) pc n tol;
c2 = c1 tour 90 pc;
c3 = c2 tour 90 pc;
c4 = c3 tour 90 pc;
circ = c1 et c2 et c3 et c4;
elim tol circ;
p1 = x0 0;
p2 = (x0+r) r;
p3 = x0 (r+r);
p4 = (x0-r) r;
elim tol (circ et p1 et p2 et p3 et p4);
cc1 = cerc n p1 pc p2;
cc2 = cc1 tour 90 pc;
cc3 = cc2 tour 90 pc;
cc4 = cc3 tour 90 pc;
elim tol (circ et cc1 et cc2 et cc3 et cc4);
pc1 = pxordpoi (chan POI1 cc1) p1;
pc2 = pxordpoi (chan POI1 cc2) p2;
pc3 = pxordpoi (chan POI1 cc3) p3;
pc4 = pxordpoi (chan POI1 cc4) p4;
pm = pc plus (0 r);
elim tol (pm et circ);
mark = manu poi1 pm;
h = 3.0;
len = 10.0;
nh = enti (h / 1.0);
nb = enti (len / 1.0);
bas = (0 (0-h)) d nb (len (0-h));
base = bas tran nh (0 h);
bas2 = (len 0) d nb (0 0);
*list (nbno bas2);
elim tol (bas2 et base);
p5 = len 0;
elim tol (p5 et bas2);
pbas2 = chan POI1 bas2;
*list (nbno pbas2);
pb2 = pxordpoi pbas2 p5;
list (nbno pb2);
mesh = circ et base et pb2 et pc1 et pc2 et pc3 et pc4 et mark;
tass mesh noop;
sauv form mesh;
trac qual mesh;
fin;
```

slid19.epx

```
SLID19
ECHO
!CONV WIN
CAST mesh
LAGR DPLA
DIME GLIS 1 200 TERM
GEOM CAR4 circ base PMAT mark TERM
COMP EPAI 0.2 LECT mark TERM ! Only for visualization
     NGRO 3 'b1' LECT circ TERM COND NEAR POIN 3 0
            'm2' LECT circ TERM COND ENVE
            's2' LECT base TERM COND Y GT -0.1
     COUL TURQ LECT circ TERM
          VERT LECT base TERM
          ROUG LECT mark TERM
MATE LINE RO 7800. YOUN 2.E11 NU 0.
          LECT circ base TERM
     MASS 0.0 LECT mark TERM
!LINK COUP
LINK COUP
     BLOQ 12 LECT bas TERM
     SLID 2 SURF FROT MUST 0.25 MUDY 0.25 GAMM 0.1
                 EMAS LECT base TERM
                 NMAS LECT pb2 TERM
                 NSLA LECT pc1 pc2 pc3 pc4 TERM
            SURF FROT MUST 0.25 MUDY 0.25 GAMM 0.1
                 EMAS LECT circ TERM
                 NMAS LECT m2 TERM
                 NSLA LECT s2 TERM
CHAR 1 FACT 2
     FORC 1  6.E8 LECT pc TERM
     FORC 2 -6.E8 LECT pc TERM
     TABL 3 0. 0.  6.E-4 1.  6. 1.
ECRI DEPL VITE COOR FINT FEXT FLIA FREQ 10000
     FICH ALIC FREQ 5000
     FICH ALIC TEMP FREQ 1
          POIN LECT b1 pc mark TERM
OPTI PAS UTIL
     LOG 1
     LNKS STAT
CALC TINI 0 TFIN 60.E-3 PASF 2.E-6 NMAX 30000
PLAY
CAME   1 EYE   5.00000E+00  5.50000E-01  3.06645E+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 :  5.00000E+00  5.50000E-01  0.00000E+00
!RSPHERE:  6.13290E+00
!RADIUS :  3.06645E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.39183E+01
!FAR    :  4.29303E+01
SCEN GEOM NAVI FREE
          POIN SPHP
     VECT SCCO FIEL VITE SCAL USER PROG 100.0 PAS 100.0 1400.0 TERM
SLER CAM1 1 NFRA 1
FREQ 5000
TRAC OFFS FICH AVI NOCL NFTO 7 FPS 5 KFRE 5 COMP -1 REND
GOTR LOOP 5 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1. 'Time [s]'
COUR  1 'y_b1'   COOR COMP 2 NOEU LECT b1 TERM
COUR  5 'dy_mk'  DEPL COMP 2 NOEU LECT mark TERM
COUR  6 'dy_b1'  DEPL COMP 2 NOEU LECT b1 TERM
```

```
COUR  7 'dy_pc'  DEPL COMP 2 NOEU LECT pc TERM
COUR  8 'dx_mk'  DEPL COMP 1 NOEU LECT mark TERM
COUR  9 'dx_b1'  DEPL COMP 1 NOEU LECT b1 TERM
COUR 10 'dx_pc'  DEPL COMP 1 NOEU LECT pc TERM
COUR 11 'vy_b1'  VITE COMP 2 NOEU LECT b1 TERM
COUR 15 'vy_pc'  VITE COMP 2 NOEU LECT pc TERM
COUR 17 'vx_pc'  VITE COMP 1 NOEU LECT pc TERM
TRAC 1 AXES 1.0 'Y-COOR. [M]' YZER
TRAC 5 6 7 AXES 1.0 'DY [M]' YZER
TRAC 8 9 10 AXES 1.0 'DX [M]' YZER
TRAC 11 15 AXES 1.0 'VY [M/S]' YZER
TRAC 15 AXES 1.0 'VY [M/S]' YZER
TRAC 15 17 AXES 1.0 'V [M/S]' YZER
FIN
```

slid20.epx

```
SLID20
ECHO
!CONV win
DPLA LAGR
GEOM LIBR POIN 5 ED01 3 PMAT 1 TERM
 0 0  1 0   2 0  3 0
 1.5  0.1
 1 2
 2 3
 3 4
 5
COMP GROU 2 'targ' LECT 1 2 3 TERM
            'proj' LECT 4 TERM
     EPAI 0.1 LECT targ TERM
          0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 4 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 1 2 3 4 TERM
                 NSLA LECT 5 TERM
INIT VITE 2 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 20.E-3
PLAY
CAME   1 EYE   1.50000E+00 -3.46336E-02  7.53326E+00
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  1.50000E+00 -3.46336E-02  0.00000E+00
!RSPHERE:  1.50665E+00
!RADIUS :  7.53326E+00
!ASPECT :  1.00000E+00
!NEAR   :  5.87594E+00
!FAR    :  1.05466E+01
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 158 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 156 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR  2 'dy_5' DEPL COMP 2 NOEU LECT 5 TERM
COUR 11 'vy_3' VITE COMP 2 NOEU LECT 3 TERM
COUR 12 'vy_5' VITE COMP 2 NOEU LECT 5 TERM
COUR 21 'y_3'  COOR COMP 2 NOEU LECT 3 TERM
COUR 22 'y_5'  COOR COMP 2 NOEU LECT 5 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE  3.52988E-01 TOLE 1.E-2
     COUR 12 REFE  3.66121E+01 TOLE 1.E-2
     COUR 22 REFE  4.52988E-01 TOLE 1.E-2
FIN
```

slid21.epx

```
SLID21
ECHO
!CONV win
DPLA LAGR
GEOM LIBR POIN 5 Q42L 1 PMAT 1 TERM
 0 0  1 0
 0 1  1 1
 0.5 1.1
 1 2 4 3
 5
COMP EPAI 1.0 LECT tous TERM
     GROU 2 'targ' LECT 1 TERM
            'proj' LECT 2 TERM
     EPAI 1.0 LECT targ TERM
          0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 12 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 1 2 3 4 TERM
                 NSLA LECT 5 TERM
INIT VITE 2 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   5.00000E-01  5.50000E-01  3.75000E+00
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.50000E-01  0.00000E+00
!RSPHERE:  7.50000E-01
!RADIUS :  3.75000E+00
!ASPECT :  1.00000E+00
!NEAR   :  2.92500E+00
!FAR    :  5.25000E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 29 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 27 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR  2 'dy_5' DEPL COMP 2 NOEU LECT 5 TERM
COUR 11 'vy_3' VITE COMP 2 NOEU LECT 3 TERM
COUR 12 'vy_5' VITE COMP 2 NOEU LECT 5 TERM
COUR 21 'y_3'  COOR COMP 2 NOEU LECT 3 TERM
COUR 22 'y_5'  COOR COMP 2 NOEU LECT 5 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -7.51287E-02 TOLE 1.E-2
     COUR 12 REFE  1.48998E+01 TOLE 1.E-2
     COUR 22 REFE  1.02487E+00 TOLE 1.E-2
FIN
```

slid22.epx

```
SLID22
ECHO
!CONV win
DPLA LAGR
GEOM LIBR POIN 5 ED01 4 PMAT 1 TERM
 0 0  1 0   0 1  1 1
 0.5  1.1
 1 2
 2 4
 4 3
 3 1
 5
COMP GROU 2 'targ' LECT 1 2 3 4 TERM
            'proj' LECT 5 TERM
```

```
     EPAI 0.1 LECT targ TERM
          0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 1 2 3 4 TERM
                 NSLA LECT 5 TERM
INIT VITE 2 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   5.00000E-01  6.00000E-01  3.93700E+00
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  6.00000E-01  0.00000E+00
!RSPHERE:  7.87401E-01
!RADIUS :  3.93700E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.07086E+00
!FAR    :  5.51181E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 25 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 23 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR  2 'dy_5' DEPL COMP 2 NOEU LECT 5 TERM
COUR 11 'vy_3' VITE COMP 2 NOEU LECT 3 TERM
COUR 12 'vy_5' VITE COMP 2 NOEU LECT 5 TERM
COUR 21 'y_3'  COOR COMP 2 NOEU LECT 3 TERM
COUR 22 'y_5'  COOR COMP 2 NOEU LECT 5 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE  2.24618E-02 TOLE 1.E-2
     COUR 12 REFE  4.02579E+01 TOLE 1.E-2
     COUR 22 REFE  1.12246E+00 TOLE 1.E-2
FIN
```

slid23.epx

```
SLID23
ECHO
!CONV win
DPLA LAGR
GEOM LIBR POIN 6 ED01 4 PMAT 1 TERM
 0 0  1 0.2   2 0.4  3 0.2  4 0
 2  0.5
 1 2
 2 3
 3 4
 4 5
 6
COMP GROU 2 'targ' LECT 1 2 3 4 TERM
            'proj' LECT 5 TERM
     EPAI 0.1 LECT targ TERM
          0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 5 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 1 2 3 4 5 TERM
                 NSLA LECT 6 TERM
INIT VITE 2 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 20.E-3
PLAY
CAME   1 EYE   2.00000E+00  2.00000E-01  1.00623E+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 :  2.00000E+00  2.00000E-01  0.00000E+00
!RSPHERE:  2.01246E+00
!RADIUS :  1.00623E+01
!ASPECT :  1.00000E+00
!NEAR   :  7.84860E+00
!FAR    :  1.40872E+01
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 155 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 153 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR  2 'dy_6' DEPL COMP 2 NOEU LECT 6 TERM
COUR 11 'vy_3' VITE COMP 2 NOEU LECT 3 TERM
COUR 12 'vy_6' VITE COMP 2 NOEU LECT 6 TERM
COUR 21 'y_3'  COOR COMP 2 NOEU LECT 3 TERM
COUR 22 'y_6'  COOR COMP 2 NOEU LECT 6 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE  5.54306E-01 TOLE 1.E-2
     COUR 12 REFE  4.19314E+01 TOLE 1.E-2
     COUR 22 REFE  1.05431E+00 TOLE 1.E-2
FIN
```

slid24.epx

```
SLID24
ECHO
!CONV win
DPLA LAGR
GEOM LIBR POIN 6 ED01 4 PMAT 1 TERM
 0 0  1 0.2   2 0.4  3 0.2  4 0
 2  0.3
 1 2
 2 3
 3 4
 4 5
 6
COMP GROU 2 'targ' LECT 1 2 3 4 TERM
            'proj' LECT 5 TERM
     EPAI 0.1 LECT targ TERM
          0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 5 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 1 2 3 4 5 TERM
                 NSLA LECT 6 TERM
INIT VITE 2 100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 20.E-3
PLAY
CAME   1 EYE   2.00000E+00  2.00000E-01  1.00623E+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 :  2.00000E+00  2.00000E-01  0.00000E+00
```

```
!RSPHERE:  2.01246E+00
!RADIUS :  1.00623E+01
!ASPECT :  1.00000E+00
!NEAR   :  7.84860E+00
!FAR    :  1.40872E+01
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 155 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 153 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR  2 'dy_6' DEPL COMP 2 NOEU LECT 6 TERM
COUR 11 'vy_3' VITE COMP 2 NOEU LECT 3 TERM
COUR 12 'vy_6' VITE COMP 2 NOEU LECT 6 TERM
COUR 21 'y_3'  COOR COMP 2 NOEU LECT 3 TERM
COUR 22 'y_6'  COOR COMP 2 NOEU LECT 6 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -4.92365E-01 TOLE 1.E-2
     COUR 12 REFE -3.50800E+01 TOLE 1.E-2
     COUR 22 REFE -1.92365E-01 TOLE 1.E-2
FIN
```

slid25.epx

```
SLID25
ECHO
!CONV win
DPLA LAGR
GEOM LIBR POIN 4 ED01 2 PMAT 1 TERM
 0 0         2 0.4        4 0
 2  0.5
 1 2
 2 3
 4
COMP GROU 2 'targ' LECT 1 2 TERM
            'proj' LECT 3 TERM
     EPAI 0.1 LECT targ TERM
          0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 3 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 1 2 3 TERM
                 NSLA LECT 4 TERM
INIT VITE 2 -100 LECT proj TERM
ECRI COOR DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 20.E-3
PLAY
CAME   1 EYE   2.00000E+00  2.00000E-01  1.00623E+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 :  2.00000E+00  2.00000E-01  0.00000E+00
!RSPHERE:  2.01246E+00
!RADIUS :  1.00623E+01
!ASPECT :  1.00000E+00
!NEAR   :  7.84860E+00
!FAR    :  1.40872E+01
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 78 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 76 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dy_2' DEPL COMP 2 NOEU LECT 2 TERM
COUR  2 'dy_4' DEPL COMP 2 NOEU LECT 4 TERM
COUR 11 'vy_2' VITE COMP 2 NOEU LECT 2 TERM
COUR 12 'vy_4' VITE COMP 2 NOEU LECT 4 TERM
COUR 21 'y_2'  COOR COMP 2 NOEU LECT 2 TERM
COUR 22 'y_4'  COOR COMP 2 NOEU LECT 4 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE  4.77524E-01 TOLE 1.E-2
     COUR 12 REFE  3.85424E+01 TOLE 1.E-2
     COUR 22 REFE  9.77524E-01 TOLE 1.E-2
FIN
```

slid26.epx

```
SLID26
ECHO
!CONV win
DPLA LAGR
GEOM LIBR POIN 10 Q42L 3 TERM
           2 0  3 0  4 0
           2 1  3 1  4 1
           2 1  3 1
           2 2  3 2
 1 2 5 4
 2 3 6 5
 7 8 10 9
COMP EPAI 1.0 LECT tous TERM
     GROU 2 'targ' LECT 1 2 TERM
            'proj' LECT 3 TERM
     NGRO 3 'blox' LECT   2 3 TERM
            'bloy' LECT 1 2 3 TERM
            'symm' LECT 1 4 7 9 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VPJC RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 3.257E8 MXIT 500
          QR1 2.348E8 CR1 56.2 QR2 4.457E8 CR2 4.7
          PDOT 5.E-4 C 1.E-2 TQ 0.9 CP 452.0
          TM 1800.0 M 1.0 DC 1.0 WC 555.0E6
          resi 1
          LECT targ proj TERM
LINK COUP ! splt none
     BLOQ 1 LECT blox TERM
          2 LECT bloy TERM
     CONT SPLA NX 1 NY 0 LECT symm TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 4 5 6 TERM
                 NSLA LECT 7 8 TERM
INIT VITE 2 -50 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   2.00000E+00  1.00000E+00  1.11803E+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 :  2.00000E+00  1.00000E+00  0.00000E+00
!RSPHERE:  2.23607E+00
!RADIUS :  1.11803E+01
!ASPECT :  1.00000E+00
!NEAR   :  8.72067E+00
!FAR    :  1.56525E+01
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 29 FPS 15 KFRE 10 COMP -1
          REND
FREQ 0 TFRE 0.1E-3
GOTR LOOP 27 OFFS FICH AVI CONT NOCL
          REND
GO
TRAC OFFS FICH AVI CONT
          REND
FREQ 0
GO
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
```

```
COUR  1 'dy_4' DEPL COMP 2 NOEU LECT 4 TERM
COUR  2 'dy_7' DEPL COMP 2 NOEU LECT 7 TERM
COUR 11 'vy_4' VITE COMP 2 NOEU LECT 4 TERM
COUR 12 'vy_7' VITE COMP 2 NOEU LECT 7 TERM
COUR 21 'y_4'  COOR COMP 2 NOEU LECT 4 TERM
COUR 22 'y_7'  COOR COMP 2 NOEU LECT 7 TERM
RCOU 101 'dy_8' FICH 'slid13.pun' RENA 'dy_8_13'
RCOU 102 'dy_12' FICH 'slid13.pun' RENA 'dy_12_13'
RCOU 111 'vy_8' FICH 'slid13.pun' RENA 'vy_8_13'
RCOU 112 'vy_12' FICH 'slid13.pun' RENA 'vy_12_13'
RCOU 121 'y_8' FICH 'slid13.pun' RENA 'y_8_13'
RCOU 122 'y_12' FICH 'slid13.pun' RENA 'y_12_13'
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
TRAC  1  2 101 102 AXES 1.0 'DEPL. [M]' YZER
COLO NOIR NOIR ROUG ROUG
TRAC 11 12 111 112 AXES 1.0 'VITE. [M/S]' YZER
COLO NOIR NOIR ROUG ROUG
TRAC 21 22 121 122 AXES 1.0 'COOR. [M]' YZER
COLO NOIR NOIR ROUG ROUG
QUAL COUR  2 REFE  2.85945E-02 TOLE 1.E-2
     COUR 12 REFE  1.35695E+01 TOLE 1.E-2
     COUR 22 REFE  1.02859E+00 TOLE 1.E-2
FIN
```

slid27.epx

```
SLID27
ECHO
!CONV win
DPLA LAGR
GEOM LIBR POIN 4 ED01 2 PMAT 1 TERM
              2 0.4  3 0.2  4 0
 2  0.5
 1 2
 2 3
 4
COMP GROU 2 'targ' LECT 1 2 TERM
            'proj' LECT 3 TERM
     EPAI 0.1 LECT targ TERM
          0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 3 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 500. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     CONT SPLA NX 1 NY 0 LECT 1 4 TERM
     SLID 1 SURF EMAS LECT targ TERM
               NMAS LECT 1 2 3 TERM
               NSLA LECT 4 TERM
INIT VITE 2 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 20.E-3
PLAY
CAME   1 EYE   2.00000E+00  2.00000E-01  1.00623E+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 :  2.00000E+00  2.00000E-01  0.00000E+00
!RSPHERE:  2.01246E+00
!RADIUS :  1.00623E+01
!ASPECT :  1.00000E+00
!NEAR   :  7.84860E+00
!FAR    :  1.40872E+01
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 155 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 153 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM
COUR  2 'dy_4' DEPL COMP 2 NOEU LECT 4 TERM
COUR 11 'vy_1' VITE COMP 2 NOEU LECT 1 TERM
COUR 12 'vy_4' VITE COMP 2 NOEU LECT 4 TERM
COUR 21 'y_1'  COOR COMP 2 NOEU LECT 1 TERM
COUR 22 'y_4'  COOR COMP 2 NOEU LECT 4 TERM
RCOU 101 'dy_3' FICH 'slid23.pun' RENA 'dy_3_23'
RCOU 102 'dy_6' FICH 'slid23.pun' RENA 'dy_6_23'
RCOU 111 'vy_3' FICH 'slid23.pun' RENA 'vy_3_23'
RCOU 112 'vy_6' FICH 'slid23.pun' RENA 'vy_6_23'
RCOU 121 'y_3' FICH 'slid23.pun' RENA 'y_3_23'
RCOU 122 'y_6' FICH 'slid23.pun' RENA 'y_6_23'
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
TRAC  1  2 101 102 AXES 1.0 'DEPL. [M]' YZER
COLO NOIR NOIR ROUG ROUG
TRAC 11 12 111 112 AXES 1.0 'VITE. [M/S]' YZER
COLO NOIR NOIR ROUG ROUG
TRAC 21 22 121 122 AXES 1.0 'COOR. [M]' YZER
COLO NOIR NOIR ROUG ROUG
QUAL COUR  2 REFE  5.54306E-01 TOLE 5.E-2
     COUR 12 REFE  4.19314E+01 TOLE 5.E-2
     COUR 22 REFE  1.05431E+00 TOLE 5.E-2
FIN
```

slid28.epx

```
SLID28
ECHO
!CONV win
DPLA LAGR
GEOM LIBR POIN 4 ED01 2 PMAT 1 TERM
              2 0.4  3 0.2  4 0
 2  0.3
 1 2
 2 3
 4
COMP GROU 2 'targ' LECT 1 2 TERM
            'proj' LECT 3 TERM
     EPAI 0.1 LECT targ TERM
          0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 3 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 500. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     CONT SPLA NX 1 NY 0 LECT 1 4 TERM
     SLID 1 SURF EMAS LECT targ TERM
               NMAS LECT 1 2 3 TERM
               NSLA LECT 4 TERM
INIT VITE 2 100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 20.E-3
PLAY
CAME   1 EYE   2.00000E+00  2.00000E-01  1.00623E+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 :  2.00000E+00  2.00000E-01  0.00000E+00
!RSPHERE:  2.01246E+00
!RADIUS :  1.00623E+01
!ASPECT :  1.00000E+00
!NEAR   :  7.84860E+00
!FAR    :  1.40872E+01
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 155 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 153 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dy_1' DEPL COMP 2 NOEU LECT 1 TERM
COUR  2 'dy_4' DEPL COMP 2 NOEU LECT 4 TERM
COUR 11 'vy_1' VITE COMP 2 NOEU LECT 1 TERM
COUR 12 'vy_4' VITE COMP 2 NOEU LECT 4 TERM
COUR 21 'y_1'  COOR COMP 2 NOEU LECT 1 TERM
COUR 22 'y_4'  COOR COMP 2 NOEU LECT 4 TERM
RCOU 101 'dy_3' FICH 'slid24.pun' RENA 'dy_3_24'
RCOU 102 'dy_6' FICH 'slid24.pun' RENA 'dy_6_24'
RCOU 111 'vy_3' FICH 'slid24.pun' RENA 'vy_3_24'
```

```
RCOU 112 'vy_6' FICH 'slid24.pun' RENA 'vy_6_24'
RCOU 121 'y_3' FICH 'slid24.pun' RENA 'y_3_24'
RCOU 122 'y_6' FICH 'slid24.pun' RENA 'y_6_24'
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
TRAC  1  2 101 102 AXES 1.0 'DEPL. [M]' YZER
COLO NOIR NOIR ROUG ROUG
TRAC 11 12 111 112 AXES 1.0 'VITE. [M/S]' YZER
COLO NOIR NOIR ROUG ROUG
TRAC 21 22 121 122 AXES 1.0 'COOR. [M]' YZER
COLO NOIR NOIR ROUG ROUG
QUAL COUR  2 REFE -4.92365E-01 TOLE 5.E-2
     COUR 12 REFE -3.50800E+01 TOLE 5.E-2
     COUR 22 REFE -1.92365E-01 TOLE 5.E-2
FIN
```

slid29.epx

```
SLID29
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 9 PR6 2 PMAT 1 TERM
 0 0 0  1 0 0  0 1 0  1 1 0
 0 0 1  1 0 1  0 1 1  1 1 1
 0.5 0.5 1.1
 1 2 3 5 6 7
 2 4 3 6 8 7
 9
COMP GROU 2 'targ' LECT 1 2 TERM
            'proj' LECT 3 TERM
     EPAI 0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 3 4 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                NMAS LECT 5 6 7 8 TERM
                NSLA LECT 9 TERM
INIT VITE 3 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE  -2.45871E+00 -2.82129E+00  1.90960E+00
!        Q     7.53165E-01  5.55986E-01 -2.22849E-01 -2.71957E-01
         VIEW  6.38093E-01  7.16288E-01 -2.82435E-01
         RIGH  7.52756E-01 -6.57459E-01  3.32757E-02
         UP    1.61854E-01  2.33837E-01  9.58709E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 35 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 33 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_6' DEPL COMP 3 NOEU LECT 6 TERM
COUR  2 'dz_7' DEPL COMP 3 NOEU LECT 7 TERM
COUR  3 'dz_9' DEPL COMP 3 NOEU LECT 9 TERM
COUR 11 'vz_6' VITE COMP 3 NOEU LECT 6 TERM
COUR 12 'vz_7' VITE COMP 3 NOEU LECT 7 TERM
COUR 13 'vz_9' VITE COMP 3 NOEU LECT 9 TERM
COUR 21 'z_6'  COOR COMP 3 NOEU LECT 6 TERM
COUR 22 'z_7'  COOR COMP 3 NOEU LECT 7 TERM
COUR 23 'z_9'  COOR COMP 3 NOEU LECT 9 TERM
TRAC  1  2  3 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 13 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 23 AXES 1.0 'COOR. [M]' YZER
LIST  1  2  3 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 13 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 23 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE  2.97830E-04 TOLE 1.E-2
     COUR 12 REFE -1.83072E+01 TOLE 1.E-2
     COUR 22 REFE  1.00030E+00 TOLE 1.E-2
FIN
```

slid30.epx

```
SLID30
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 5 T3GS 2 PMAT 1 TERM
 0 0 1  1 0 1  0 1 1  1 1 1
 0.5 0.5 1.15
 1 2 3
 2 4 3
 5
COMP GROU 2 'targ' LECT 1 2 TERM
            'proj' LECT 3 TERM
     EPAI 0.2 LECT proj TERM
          0.1 LECT targ TERM
!    NGRO 1 'bloc' LECT 1 2 3 4 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
!    BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                NMAS LECT 1 2 3 4 TERM
                NSLA LECT 5 TERM
INIT VITE 3 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE  -2.45871E+00 -2.82129E+00  1.90960E+00
!        Q     7.53165E-01  5.55986E-01 -2.22849E-01 -2.71957E-01
         VIEW  6.38093E-01  7.16288E-01 -2.82435E-01
         RIGH  7.52756E-01 -6.57459E-01  3.32757E-02
         UP    1.61854E-01  2.33837E-01  9.58709E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 35 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 33 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_2' DEPL COMP 3 NOEU LECT 2 TERM
COUR  2 'dz_3' DEPL COMP 3 NOEU LECT 3 TERM
COUR  3 'dz_5' DEPL COMP 3 NOEU LECT 5 TERM
COUR 11 'vz_2' VITE COMP 3 NOEU LECT 2 TERM
COUR 12 'vz_3' VITE COMP 3 NOEU LECT 3 TERM
COUR 13 'vz_5' VITE COMP 3 NOEU LECT 5 TERM
COUR 21 'z_2'  COOR COMP 3 NOEU LECT 2 TERM
COUR 22 'z_3'  COOR COMP 3 NOEU LECT 3 TERM
COUR 23 'z_5'  COOR COMP 3 NOEU LECT 5 TERM
TRAC  1  2  3 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 13 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 23 AXES 1.0 'COOR. [M]' YZER
LIST  1  2  3 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 13 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 23 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -5.70652E-02 TOLE 1.E-2
     COUR 12 REFE  3.41691E+01 TOLE 1.E-2
     COUR 22 REFE  1.04293E+00 TOLE 1.E-2
FIN
```

slid31.epx

```
SLID31
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 11 PR6 4 PMAT 1 TERM
 0 0 0  1 0 0  0.5 0.5 0  0 1 0  1 1 0
```

```
 0 0 1  1 0 1  0.5 0.5 1  0 1 1  1 1 1
 0.5 0.5 1.1
 1 2 3 6 7 8
 2 5 3 7 10 8
 5 4 3 10 9 8
 4 1 3 9 6 8
 11
COMP GROU 2 'targ' LECT 1 2 3 4 TERM
            'proj' LECT 5 TERM
     EPAI 0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 3 4 5 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 6 7 8 9 10 TERM
                 NSLA LECT 11 TERM
INIT VITE 3 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   3.69529E+00 -2.60160E+00  1.89235E+00
!        Q     7.32692E-01  5.55831E-01  2.27362E-01  3.20189E-01
         VIEW -6.89114E-01  6.68908E-01 -2.78716E-01
         RIGH  6.91571E-01  7.21949E-01  2.27704E-02
         UP   -2.16450E-01  1.77061E-01  9.60103E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 49 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 47 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_6' DEPL COMP 3 NOEU LECT 6 TERM
COUR  2 'dz_7' DEPL COMP 3 NOEU LECT 7 TERM
COUR  3 'dz_11' DEPL COMP 3 NOEU LECT 11 TERM
COUR 11 'vz_6' VITE COMP 3 NOEU LECT 6 TERM
COUR 12 'vz_7' VITE COMP 3 NOEU LECT 7 TERM
COUR 13 'vz_11' VITE COMP 3 NOEU LECT 11 TERM
COUR 21 'z_6'  COOR COMP 3 NOEU LECT 6 TERM
COUR 22 'z_7'  COOR COMP 3 NOEU LECT 7 TERM
COUR 23 'z_11'  COOR COMP 3 NOEU LECT 11 TERM
TRAC  1  2  3 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 13 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 23 AXES 1.0 'COOR. [M]' YZER
LIST  1  2  3 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 13 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 23 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -3.60086E-03 TOLE 1.E-2
     COUR 12 REFE -1.67035E+00 TOLE 1.E-2
     COUR 22 REFE  9.96399E-01 TOLE 1.E-2
FIN
```

slid32.epx

```
SLID32
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 6 T3GS 4 PMAT 1 TERM
 0 0 1  1 0 1  0.5 0.5 1  0 1 1  1 1 1
 0.5 0.5 1.15
 1 2 3
 2 5 3
 5 4 3
 4 1 3
 6
COMP GROU 2 'targ' LECT 1 2 3 4 TERM
            'proj' LECT 5 TERM
     EPAI 0.2 LECT proj TERM
          0.1 LECT targ TERM
     NGRO 1 'bloc' LECT 1 2   4 5 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 1 2 3 4 5 TERM
                 NSLA LECT 6 TERM
INIT VITE 3 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   3.69529E+00 -2.60160E+00  1.89235E+00
!        Q     7.32692E-01  5.55831E-01  2.27362E-01  3.20189E-01
         VIEW -6.89114E-01  6.68908E-01 -2.78716E-01
         RIGH  6.91571E-01  7.21949E-01  2.27704E-02
         UP   -2.16450E-01  1.77061E-01  9.60103E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 48 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 46 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_3' DEPL COMP 3 NOEU LECT 3 TERM
COUR  2 'dz_6' DEPL COMP 3 NOEU LECT 6 TERM
COUR 11 'vz_3' VITE COMP 3 NOEU LECT 3 TERM
COUR 12 'vz_6' VITE COMP 3 NOEU LECT 6 TERM
COUR 21 'z_3'  COOR COMP 3 NOEU LECT 3 TERM
COUR 22 'z_6'  COOR COMP 3 NOEU LECT 6 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -1.61617E-01 TOLE 1.E-2
     COUR 12 REFE  4.20606E+01 TOLE 1.E-2
     COUR 22 REFE  9.88383E-01 TOLE 1.E-2
FIN
```

slid33.epx

```
SLID33
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 11 PR6 4 PMAT 1 TERM
 0 0 0  1 0 0  0.5 0.5 0    0 1 0  1 1 0
 0 0 1  1 0 1  0.5 0.5 0.9  0 1 1  1 1 1
 0.5 0.5 0.90001
 1 2 3 6 7 8
 2 5 3 7 10 8
 5 4 3 10 9 8
 4 1 3 9 6 8
 11
COMP GROU 2 'targ' LECT 1 2 3 4 TERM
            'proj' LECT 5 TERM
     EPAI 0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 3 4 5 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 6 7 8 9 10 TERM
                 NSLA LECT 11 TERM
INIT VITE 3 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
```

```
    LOG 1
    JAUM
    LMST
    LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   3.69529E+00 -2.60160E+00  1.89235E+00
!        Q     7.32692E-01  5.55831E-01  2.27362E-01  3.20189E-01
        VIEW -6.89114E-01  6.68908E-01 -2.78716E-01
        RIGH  6.91571E-01  7.21949E-01  2.27704E-02
        UP   -2.16450E-01  1.77061E-01  9.60103E-01
        FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
         REFE FRAM
         FACE SBAC
    LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 49 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 47 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_6' DEPL COMP 3 NOEU LECT 6 TERM
COUR  2 'dz_7' DEPL COMP 3 NOEU LECT 7 TERM
COUR  3 'dz_11' DEPL COMP 3 NOEU LECT 11 TERM
COUR 11 'vz_6' VITE COMP 3 NOEU LECT 6 TERM
COUR 12 'vz_7' VITE COMP 3 NOEU LECT 7 TERM
COUR 13 'vz_11' VITE COMP 3 NOEU LECT 11 TERM
COUR 21 'z_6'  COOR COMP 3 NOEU LECT 6 TERM
COUR 22 'z_7'  COOR COMP 3 NOEU LECT 7 TERM
COUR 23 'z_11'  COOR COMP 3 NOEU LECT 11 TERM
TRAC  1  2  3 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 13 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 23 AXES 1.0 'COOR. [M]' YZER
LIST  1  2  3 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 13 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 23 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -9.77052E-04 TOLE 1.E-2
    COUR 12 REFE  7.42964E+00 TOLE 1.E-2
    COUR 22 REFE  9.99023E-01 TOLE 1.E-2
FIN
```

slid34.epx

```
SLID34
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 11 PR6 4 PMAT 1 TERM
 0 0 0  1 0 0  0.5 0.5 0   0 1 0  1 1 0
 0 0 1  1 0 1  0.5 0.5 0.9  0 1 1  1 1 1
 0.5 0.5 0.90001
 3 1 2 8 6 7
 3 2 5 8 7 10
 3 5 4 8 10 9
 3 4 1 8 9 6
 11
COMP GROU 2 'targ' LECT 1 2 3 4 TERM
           'proj' LECT 5 TERM
    EPAI 0.2 LECT proj TERM
    NGRO 1 'bloc' LECT 1 2 3 4 5 TERM
    COUL TURQ LECT targ TERM
         ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
         TRAC 1 2.1E11 1.D0
         LECT targ TERM
    MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
    BLOQ 123 LECT bloc TERM
    SLID 1 SURF EMAS LECT targ TERM
               NMAS LECT 6 7 8 9 10 TERM
               NSLA LECT 11 TERM
INIT VITE 3 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
    FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
    LOG 1
    JAUM
    LMST
    LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   3.69529E+00 -2.60160E+00  1.89235E+00
!        Q     7.32692E-01  5.55831E-01  2.27362E-01  3.20189E-01
        VIEW -6.89114E-01  6.68908E-01 -2.78716E-01
        RIGH  6.91571E-01  7.21949E-01  2.27704E-02
        UP   -2.16450E-01  1.77061E-01  9.60103E-01
        FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
         REFE FRAM
         FACE SBAC
    LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 49 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 47 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_6' DEPL COMP 3 NOEU LECT 6 TERM
COUR  2 'dz_7' DEPL COMP 3 NOEU LECT 7 TERM
COUR  3 'dz_11' DEPL COMP 3 NOEU LECT 11 TERM
COUR 11 'vz_6' VITE COMP 3 NOEU LECT 6 TERM
COUR 12 'vz_7' VITE COMP 3 NOEU LECT 7 TERM
COUR 13 'vz_11' VITE COMP 3 NOEU LECT 11 TERM
COUR 21 'z_6'  COOR COMP 3 NOEU LECT 6 TERM
COUR 22 'z_7'  COOR COMP 3 NOEU LECT 7 TERM
COUR 23 'z_11'  COOR COMP 3 NOEU LECT 11 TERM
TRAC  1  2  3 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 13 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 23 AXES 1.0 'COOR. [M]' YZER
LIST  1  2  3 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 13 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 23 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -9.77052E-04 TOLE 1.E-2
    COUR 12 REFE  7.42964E+00 TOLE 1.E-2
    COUR 22 REFE  9.99023E-01 TOLE 1.E-2
FIN
```

slid35.epx

```
SLID35
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 11 PR6 4 PMAT 1 TERM
 0 0 0  1 0 0  0.5 0.5 0  0 1 0  1 1 0
 0 0 1  1 0 1  0.5 0.5 1.1  0 1 1  1 1 1
 0.5 0.5 1.10001
 1 2 3 6 7 8
 2 5 3 7 10 8
 5 4 3 10 9 8
 4 1 3 9 6 8
 11
COMP GROU 2 'targ' LECT 1 2 3 4 TERM
           'proj' LECT 5 TERM
    EPAI 0.2 LECT proj TERM
    NGRO 1 'bloc' LECT 1 2 3 4 5 TERM
    COUL TURQ LECT targ TERM
         ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
         TRAC 1 2.1E11 1.D0
         LECT targ TERM
    MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
    BLOQ 123 LECT bloc TERM
    SLID 1 SURF EMAS LECT targ TERM
               NMAS LECT 6 7 8 9 10 TERM
               NSLA LECT 11 TERM
INIT VITE 3 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
    FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
    LOG 1
    JAUM
    LMST
    LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   3.69529E+00 -2.60160E+00  1.89235E+00
!        Q     7.32692E-01  5.55831E-01  2.27362E-01  3.20189E-01
        VIEW -6.89114E-01  6.68908E-01 -2.78716E-01
        RIGH  6.91571E-01  7.21949E-01  2.27704E-02
        UP   -2.16450E-01  1.77061E-01  9.60103E-01
        FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
         REFE FRAM
         FACE SBAC
    LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 49 FPS 15 KFRE 10 COMP -1 REND
```

```
FREQ 1
GOTR LOOP 47 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_6' DEPL COMP 3 NOEU LECT 6 TERM
COUR  2 'dz_7' DEPL COMP 3 NOEU LECT 7 TERM
COUR  3 'dz_11' DEPL COMP 3 NOEU LECT 11 TERM
COUR 11 'vz_6' VITE COMP 3 NOEU LECT 6 TERM
COUR 12 'vz_7' VITE COMP 3 NOEU LECT 7 TERM
COUR 13 'vz_11' VITE COMP 3 NOEU LECT 11 TERM
COUR 21 'z_6'  COOR COMP 3 NOEU LECT 6 TERM
COUR 22 'z_7'  COOR COMP 3 NOEU LECT 7 TERM
COUR 23 'z_11'  COOR COMP 3 NOEU LECT 11 TERM
TRAC  1  2  3 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 13 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 23 AXES 1.0 'COOR. [M]' YZER
LIST  1  2  3 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 13 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 23 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -2.46647E-03 TOLE 1.E-2
     COUR 12 REFE -2.82929E+00 TOLE 1.E-2
     COUR 22 REFE  9.97534E-01 TOLE 1.E-2
FIN
```

slid36.epx

```
SLID36
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 6 T3GS 4 PMAT 1 TERM
 0 0 1  1 0 1  0.5 0.5 0.9  0 1 1  1 1 1
 0.5 0.5 0.951
 1 2 3
 2 5 3
 5 4 3
 4 1 3
 6
COMP GROU 2 'targ' LECT 1 2 3 4 TERM
            'proj' LECT 5 TERM
     EPAI 0.2 LECT proj TERM
          0.1 LECT targ TERM
     NGRO 1 'bloc' LECT 1 2   4 5 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 1 2 3 4 5 TERM
                 NSLA LECT 6 TERM
INIT VITE 3 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   3.69529E+00 -2.60160E+00  1.89235E+00
!        Q     7.32692E-01  5.55831E-01  2.27362E-01  3.20189E-01
         VIEW -6.89114E-01  6.68908E-01 -2.78716E-01
         RIGH  6.91571E-01  7.21949E-01  2.27704E-02
         UP   -2.16450E-01  1.77061E-01  9.60103E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 47 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 45 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_3' DEPL COMP 3 NOEU LECT 3 TERM
COUR  2 'dz_6' DEPL COMP 3 NOEU LECT 6 TERM
COUR 11 'vz_3' VITE COMP 3 NOEU LECT 3 TERM
COUR 12 'vz_6' VITE COMP 3 NOEU LECT 6 TERM
COUR 21 'z_3'  COOR COMP 3 NOEU LECT 3 TERM
COUR 22 'z_6'  COOR COMP 3 NOEU LECT 6 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE  1.07751E-01 TOLE 1.E-2
     COUR 12 REFE  7.86854E+01 TOLE 1.E-2
     COUR 22 REFE  1.05875E+00 TOLE 1.E-2
FIN
```

slid37.epx

```
SLID37
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 6 T3GS 4 PMAT 1 TERM
 0 0 1  1 0 1  0.5 0.5 1.1  0 1 1  1 1 1
 0.5 0.5 1.151
 1 2 3
 2 5 3
 5 4 3
 4 1 3
 6
COMP GROU 2 'targ' LECT 1 2 3 4 TERM
            'proj' LECT 5 TERM
     EPAI 0.2 LECT proj TERM
          0.1 LECT targ TERM
     NGRO 1 'bloc' LECT 1 2   4 5 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 1 2 3 4 5 TERM
                 NSLA LECT 6 TERM
INIT VITE 3 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   3.69529E+00 -2.60160E+00  1.89235E+00
!        Q     7.32692E-01  5.55831E-01  2.27362E-01  3.20189E-01
         VIEW -6.89114E-01  6.68908E-01 -2.78716E-01
         RIGH  6.91571E-01  7.21949E-01  2.27704E-02
         UP   -2.16450E-01  1.77061E-01  9.60103E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 48 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 46 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_3' DEPL COMP 3 NOEU LECT 3 TERM
COUR  2 'dz_6' DEPL COMP 3 NOEU LECT 6 TERM
COUR 11 'vz_3' VITE COMP 3 NOEU LECT 3 TERM
COUR 12 'vz_6' VITE COMP 3 NOEU LECT 6 TERM
COUR 21 'z_3'  COOR COMP 3 NOEU LECT 3 TERM
COUR 22 'z_6'  COOR COMP 3 NOEU LECT 6 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE  4.49888E-02 TOLE 1.E-2
     COUR 12 REFE  7.74032E+01 TOLE 1.E-2
     COUR 22 REFE  1.19599E+00 TOLE 1.E-2
FIN
```

slid38.dgibi

```
opti echo 0;
opti donn 'px4cir3d.proc';
opti donn 'pxhex2te.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'slid38_mesh.ps';
opti sauv form 'slid38.msh';
r = 2.0;
x0 = 3.0;
pc = x0 r 0;
pz = 0 0 1;
n = 8;
tol = 0.001;
ci1 ier = px4cir3d (x0 0 0) ((x0+r) r 0) pc (pc plus pz) n tol;
w = 2.0;
vzcir = 0 0 w;
nzc = 3;
c1 = ci1 volu tran nzc vzcir;
c2 = c1 tour 90 pc (pc plus pz);
c3 = c2 tour 90 pc (pc plus pz);
c4 = c3 tour 90 pc (pc plus pz);
circ8 = c1 et c2 et c3 et c4;
*
n = nbel circ8;
i = 0;
repe loop1 n;
  i = i + 1;
  ei = circ8 elem i;
  tetr = pxhex2te ei;
  si (ega i 1);
    circ = tetr;
  sinon;
    circ = circ et tetr;
  finsi;
fin loop1;
*
elim tol circ;
axe = pc d nzc (pc plus vzcir);
elim tol (circ et axe);
pm = pc plus (0 r w);
elim tol (pm et circ);
mark = manu poi1 pm;
trac cach qual (circ et mark);
*
h = 1.0;
len = 10.0;
a = 4.0;
nh = 2;
nb = enti (len / 1.0);
na = 6;
bas2d = (0 (0-h) -1.0) d nb (len (0-h) -1.0);
base2d = bas2d tran nh (0 h 0);
base8 = base2d volu tran na (0 0 a);
*
n = nbel base8;
i = 0;
repe loop1 n;
  i = i + 1;
  ei = base8 elem i;
  tetr = pxhex2te ei;
  si (ega i 1);
    base = tetr;
  sinon;
    base = base et tetr;
  finsi;
fin loop1;
*
trac cach qual base;
trac cach qual (base et circ et mark);
*
mesh = circ et base et mark;
tass mesh noop;
sauv form mesh;
trac cach qual mesh;
fin;
```

slid38.epx

```
SLID38
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM TETR circ base PMAT mark TERM
COMP NGRO 13 'bloc' LECT base TERM COND Y LT -0.99
             'f1a'  LECT axe TERM COND NEAR POIN 3 2 0
             'f1b'  LECT axe TERM COND NEAR POIN 3 2 2
             'f1'   LECT f1a f1b TERM
             'f2'   LECT axe DIFF f1 TERM
             'b1'   LECT circ TERM COND NEAR POIN 3 0 0
             'b2'   LECT circ TERM COND NEAR POIN 3 0 0.667
             'b3'   LECT circ TERM COND NEAR POIN 3 0 1.333
             'b4'   LECT circ TERM COND NEAR POIN 3 0 2
             'ns'   LECT base TERM COND Y GT -0.01
             'nm1'  LECT circ TERM COND CYLI
                               X1 3 Y1 2 Z1 0
                               X2 3 Y2 2 Z2 2 R 2.1
             'nm2'  LECT circ TERM COND CYLI
                               X1 3 Y1 2 Z1 0
                               X2 3 Y2 2 Z2 2 R 1.9
             'nm'   LECT nm1 DIFF nm2 TERM
     GROU 1  'em'   LECT circ TERM COND APPU LARG LECT nm TERM
     EPAI 0.2 LECT mark TERM ! Only for visualization
     COUL TURQ LECT circ TERM
          VERT LECT base TERM
          ROUG LECT mark TERM
MATE LINE RO 7800. YOUN 2.E11 NU 0.
          LECT circ base TERM
     MASS 0.0 LECT mark TERM
LINK COUP
     BLOQ 123 LECT bloc TERM
!    GLIS 1 ELIM
!         MAIT LECT circ TERM
!         ESCL LECT base TERM
     SLID 1 SURF EMAS LECT em TERM
                 NMAS LECT nm TERM
                 NSLA LECT ns TERM
CHAR 1 FACT 2
     FORC 1  3.33333E8 LECT f1 TERM
     FORC 1  6.66667E8 LECT f2 TERM
     FORC 2 -3.33333E8 LECT f1 TERM
     FORC 2 -6.66667E8 LECT f2 TERM
     TABL 3 0. 0.  12.E-4 1.  6. 1.
ECRI DEPL VITE COOR FINT FEXT FLIA FREQ 600
     FICH ALIC FREQ 100
     FICH ALIC TEMP FREQ 1
          POIN LECT b1 b2 b3 b4 f1 f2 mark TERM
OPTI PAS UTIL
     LOG 1
!    GLIS NORM ELEM
     LNKS STAT VISU
CALC TINI 0 TFIN 40.E-3 PASF 1.E-5 NMAX 4000
PLAY
CAME   1 EYE   1.84447E+01  1.93365E+01  2.07597E+01
!        Q     9.11780E-01 -3.31861E-01  2.41333E-01 -1.68756E-02
         VIEW -4.51285E-01 -5.97022E-01 -6.63254E-01
         RIGH  8.82948E-01 -1.90951E-01 -4.28884E-01
         UP   -1.29404E-01  7.79167E-01 -6.13313E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E+00  1.55000E+00  1.00000E+00
!RSPHERE:  5.95840E+00
!RADIUS :  2.97920E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.32377E+01
!FAR    :  4.17088E+01
SCEN GEOM NAVI FREE
          POIN SPHP
!         FACE HFRO
        ! LINE HEOU SSHA
        ! LNKS SHOW GLIS JOIN
!    VECT SCCO FIEL FLIA SCAL USER PROG 0.25E8 PAS 0.25E8 3.5E8 TERM
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 100
TRAC OFFS FICH AVI NOCL NFTO 41 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 39 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR  1 'y_b1'   COOR COMP 2 NOEU LECT b1 TERM
COUR  2 'y_b2'   COOR COMP 2 NOEU LECT b2 TERM
COUR  3 'y_b3'   COOR COMP 2 NOEU LECT b3 TERM
COUR  4 'y_b4'   COOR COMP 2 NOEU LECT b4 TERM
COUR  5 'dy_mk'  DEPL COMP 2 NOEU LECT mark TERM
COUR  6 'dy_b4'  DEPL COMP 2 NOEU LECT b4 TERM
COUR  7 'dy_f1b' DEPL COMP 2 NOEU LECT f1b TERM
COUR  8 'dx_mk'  DEPL COMP 1 NOEU LECT mark TERM
COUR  9 'dx_b4'  DEPL COMP 1 NOEU LECT b4 TERM
COUR 10 'dx_f1b' DEPL COMP 1 NOEU LECT f1b TERM
TRAC 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
TRAC 5 6 7 AXES 1.0 'DY [M]' YZER
TRAC 8 9 10 AXES 1.0 'DX [M]' YZER
LIST 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
LIST 5 6 7 AXES 1.0 'DY [M]' YZER
LIST 8 9 10 AXES 1.0 'DX [M]' YZER
QUAL COUR  8 REFE  7.59638E+00 TOLE 1.E-2
     COUR  9 REFE  7.80697E+00 TOLE 1.E-2
     COUR 10 REFE  7.70585E+00 TOLE 1.E-2
FIN
```

slid39.dgibi

```
opti echo 0;
opti donn 'px4cir3d.proc';
opti donn 'pxhex2t2.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'slid39_mesh.ps';
opti sauv form 'slid39.msh';
r = 2.0;
x0 = 3.0;
```

```
pc = x0 r 0;
pz = 0 0 1;
n = 8;
tol = 0.001;
ci1 ier = px4cir3d (x0 0 0) ((x0+r) r 0) pc (pc plus pz) n tol;
w = 2.0;
vzcir = 0 0 w;
nzc = 3;
c1 = ci1 volu tran nzc vzcir;
c2 = c1 tour 90 pc (pc plus pz);
c3 = c2 tour 90 pc (pc plus pz);
c4 = c3 tour 90 pc (pc plus pz);
circ8 = c1 et c2 et c3 et c4;
*
n = nbel circ8;
i = 0;
repe loop1 n;
  i = i + 1;
  ei = circ8 elem i;
  tetr = pxhex2t2 ei;
  si (ega i 1);
    circ = tetr;
  sinon;
    circ = circ et tetr;
  finsi;
fin loop1;
*
elim tol circ;
axe = pc d nzc (pc plus vzcir);
elim tol (circ et axe);
pm = pc plus (0 r w);
elim tol (pm et circ);
mark = manu poi1 pm;
trac cach qual (circ et mark);
*
h = 1.0;
len = 10.0;
a = 4.0;
nh = 2;
nb = enti (len / 1.0);
na = 6;
bas2d = (0 (0-h) -1.0) d nb (len (0-h) -1.0);
base2d = bas2d tran nh (0 h 0);
base8 = base2d volu tran na (0 0 a);
*
n = nbel base8;
i = 0;
repe loop1 n;
  i = i + 1;
  ei = base8 elem i;
  tetr = pxhex2t2 ei;
  si (ega i 1);
    base = tetr;
  sinon;
    base = base et tetr;
  finsi;
fin loop1;
*
trac cach qual base;
trac cach qual (base et circ et mark);
*
mesh = circ et base et mark;
tass mesh noop;
sauv form mesh;
trac cach qual mesh;
fin;
```

slid39.epx

```
SLID39
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM TETR circ base PMAT mark TERM
COMP NGRO 13 'bloc' LECT base TERM COND Y LT -0.99
             'f1a'  LECT axe TERM COND NEAR POIN 3 2 0
             'f1b'  LECT axe TERM COND NEAR POIN 3 2 2
             'f1'   LECT f1a f1b TERM
             'f2'   LECT axe DIFF f1 TERM
             'b1'   LECT circ TERM COND NEAR POIN 3 0 0
             'b2'   LECT circ TERM COND NEAR POIN 3 0 0.667
             'b3'   LECT circ TERM COND NEAR POIN 3 0 1.333
             'b4'   LECT circ TERM COND NEAR POIN 3 0 2
             'ns'   LECT base TERM COND Y GT -0.01
             'nm1'  LECT circ TERM COND CYLI
                                 X1 3 Y1 2 Z1 0
                                 X2 3 Y2 2 Z2 2 R 2.1
             'nm2'  LECT circ TERM COND CYLI
                                 X1 3 Y1 2 Z1 0
                                 X2 3 Y2 2 Z2 2 R 1.9
             'nm'   LECT nm1 DIFF nm2 TERM
     GROU 1  'em'   LECT circ TERM COND APPU LARG LECT nm TERM
     EPAI 0.2 LECT mark TERM ! Only for visualization
     COUL TURQ LECT circ TERM
          VERT LECT base TERM
          ROUG LECT mark TERM
MATE LINE RO 7800. YOUN 2.E11 NU 0.
         LECT circ base TERM
     MASS 0.0 LECT mark TERM
LINK COUP
     BLOQ 123 LECT bloc TERM
!    GLIS 1 ELIM
!         MAIT LECT circ TERM
!         ESCL LECT base TERM
     SLID 1 SURF EMAS LECT em TERM
                NMAS LECT nm TERM
                NSLA LECT ns TERM
CHAR 1 FACT 2
     FORC 1  3.33333E8 LECT f1 TERM
     FORC 1  6.66667E8 LECT f2 TERM
     FORC 2 -3.33333E8 LECT f1 TERM
     FORC 2 -6.66667E8 LECT f2 TERM
     TABL 3 0. 0.  12.E-4 1.  6. 1.
ECRI DEPL VITE COOR FINT FEXT FLIA FREQ 1000
     FICH ALIC FREQ 100
     FICH ALIC TEMP FREQ 1
          POIN LECT b1 b2 b3 b4 f1 f2 mark TERM
OPTI PAS UTIL
     LOG 1
!    GLIS NORM ELEM
     LNKS STAT VISU
CALC TINI 0 TFIN 40.E-3 PASF 5.E-6 NMAX 8000
PLAY
CAME   1 EYE   1.84447E+01  1.93365E+01  2.07597E+01
!        Q     9.11780E-01 -3.31861E-01  2.41333E-01 -1.68756E-02
         VIEW -4.51285E-01 -5.97022E-01 -6.63254E-01
         RIGH  8.82948E-01 -1.90951E-01 -4.28884E-01
         UP   -1.29404E-01  7.79167E-01 -6.13313E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E+00  1.55000E+00  1.00000E+00
!RSPHERE:  5.95840E+00
!RADIUS :  2.97920E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.32377E+01
!FAR    :  4.17088E+01
SCEN GEOM NAVI FREE
          POIN SPHP
!         FACE HFRO
        ! LINE HEOU SSHA
        ! LNKS SHOW GLIS JOIN
!    VECT SCCO FIEL FLIA SCAL USER PROG 0.25E8 PAS 0.25E8 3.5E8 TERM
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 200
TRAC OFFS FICH AVI NOCL NFTO 41 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 39 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR  1 'y_b1'   COOR COMP 2 NOEU LECT b1 TERM
COUR  2 'y_b2'   COOR COMP 2 NOEU LECT b2 TERM
COUR  3 'y_b3'   COOR COMP 2 NOEU LECT b3 TERM
COUR  4 'y_b4'   COOR COMP 2 NOEU LECT b4 TERM
COUR  5 'dy_mk'  DEPL COMP 2 NOEU LECT mark TERM
COUR  6 'dy_b4'  DEPL COMP 2 NOEU LECT b4 TERM
COUR  7 'dy_f1b' DEPL COMP 2 NOEU LECT f1b TERM
COUR  8 'dx_mk'  DEPL COMP 1 NOEU LECT mark TERM
COUR  9 'dx_b4'  DEPL COMP 1 NOEU LECT b4 TERM
COUR 10 'dx_f1b' DEPL COMP 1 NOEU LECT f1b TERM
TRAC 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
TRAC 5 6 7 AXES 1.0 'DY [M]' YZER
TRAC 8 9 10 AXES 1.0 'DX [M]' YZER
LIST 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
LIST 5 6 7 AXES 1.0 'DY [M]' YZER
LIST 8 9 10 AXES 1.0 'DX [M]' YZER
QUAL COUR  8 REFE  8.00100E+00 TOLE 1.E-2
     COUR  9 REFE  8.18614E+00 TOLE 1.E-2
     COUR 10 REFE  8.10118E+00 TOLE 1.E-2
FIN
```

slid40.epx

```
SLID40
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 7 PR6 1 PMAT 1 TERM
 0 0 0  1 0 0  0 1 0
 0 0 1  1 0 1  0 1 1
 0.33333 0.33333 1.1
 1 2 3 4 5 6
 7
COMP GROU 2 'targ' LECT 1 TERM
            'proj' LECT 2 TERM
     EPAI 0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 3 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
```

```
                NMAS LECT 4 5 6 TERM
                NSLA LECT 7 TERM
INIT VITE 3 -100 LECT proj TERM
         1 70.7107 LECT proj TERM
         2 70.7107 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE  -2.66700E+00 -2.66700E+00  1.80009E+00
!        Q     7.32963E-01  5.62422E-01 -2.32963E-01 -3.03603E-01
         VIEW  6.83013E-01  6.83013E-01 -2.58819E-01
         RIGH  7.07107E-01 -7.07107E-01 -5.55112E-17
         UP    1.83013E-01  1.83013E-01  9.65926E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
         REFE FRAM
         FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 35 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 33 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_4' DEPL COMP 3 NOEU LECT 4 TERM
COUR  2 'dz_7' DEPL COMP 3 NOEU LECT 7 TERM
COUR  3 'dx_7' DEPL COMP 1 NOEU LECT 7 TERM
COUR  4 'dy_7' DEPL COMP 2 NOEU LECT 7 TERM
COUR 11 'vz_4' VITE COMP 3 NOEU LECT 4 TERM
COUR 12 'vz_7' VITE COMP 3 NOEU LECT 7 TERM
COUR 13 'vx_7' VITE COMP 1 NOEU LECT 7 TERM
COUR 14 'vy_7' VITE COMP 2 NOEU LECT 7 TERM
COUR 21 'z_4'  COOR COMP 3 NOEU LECT 4 TERM
COUR 22 'z_7'  COOR COMP 3 NOEU LECT 7 TERM
COUR 23 'x_7'  COOR COMP 1 NOEU LECT 7 TERM
COUR 24 'y_7'  COOR COMP 2 NOEU LECT 7 TERM
TRAC  1  2  3  4 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 13 14 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 23 24 AXES 1.0 'COOR. [M]' YZER
LIST  1  2  3  4 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 13 14 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 23 24 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -5.75528E-02 TOLE 1.E-2
     COUR  3 REFE  2.13827E-01 TOLE 1.E-2
     COUR  4 REFE  2.13827E-01 TOLE 1.E-2
     COUR 12 REFE  3.41220E+01 TOLE 1.E-2
     COUR 13 REFE  7.08787E+01 TOLE 1.E-2
     COUR 14 REFE  7.08787E+01 TOLE 1.E-2
     COUR 22 REFE  1.04245E+00 TOLE 1.E-2
     COUR 23 REFE  5.47157E-01 TOLE 1.E-2
     COUR 24 REFE  5.47157E-01 TOLE 1.E-2
FIN
```

slid41.epx

```
SLID41
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 7 PR6 1 PMAT 1 TERM
 0 0 0  1 0 0  0 1 0
 0 0 1  1 0 1  0 1 1
 0.33333 0.33333 1.1
 1 2 3 4 5 6
 7
COMP GROU 2 'targ' LECT 1 TERM
            'proj' LECT 2 TERM
     EPAI 0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 3 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
         TRAC 1 2.1E11 1.D0
         LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF FROT MUST 0.25 MUDY 0.25 GAMM 0.1
                EMAS LECT targ TERM
                NMAS LECT 4 5 6 TERM
                NSLA LECT 7 TERM
INIT VITE 3 -100 LECT proj TERM
         1 70.7107 LECT proj TERM
         2 70.7107 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE  -2.66700E+00 -2.66700E+00  1.80009E+00
!        Q     7.32963E-01  5.62422E-01 -2.32963E-01 -3.03603E-01
         VIEW  6.83013E-01  6.83013E-01 -2.58819E-01
         RIGH  7.07107E-01 -7.07107E-01 -5.55112E-17
         UP    1.83013E-01  1.83013E-01  9.65926E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
         REFE FRAM
         FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 35 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 33 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_4' DEPL COMP 3 NOEU LECT 4 TERM
COUR  2 'dz_7' DEPL COMP 3 NOEU LECT 7 TERM
COUR  3 'dx_7' DEPL COMP 1 NOEU LECT 7 TERM
COUR  4 'dy_7' DEPL COMP 2 NOEU LECT 7 TERM
COUR 11 'vz_4' VITE COMP 3 NOEU LECT 4 TERM
COUR 12 'vz_7' VITE COMP 3 NOEU LECT 7 TERM
COUR 13 'vx_7' VITE COMP 1 NOEU LECT 7 TERM
COUR 14 'vy_7' VITE COMP 2 NOEU LECT 7 TERM
COUR 21 'z_4'  COOR COMP 3 NOEU LECT 4 TERM
COUR 22 'z_7'  COOR COMP 3 NOEU LECT 7 TERM
COUR 23 'x_7'  COOR COMP 1 NOEU LECT 7 TERM
COUR 24 'y_7'  COOR COMP 2 NOEU LECT 7 TERM
RCOU 101 'dz_4' FICH 'slid40.pun' RENA 'dz_4_40'
RCOU 102 'dz_7' FICH 'slid40.pun' RENA 'dz_7_40'
RCOU 103 'dx_7' FICH 'slid40.pun' RENA 'dx_7_40'
RCOU 104 'dy_7' FICH 'slid40.pun' RENA 'dy_7_40'
RCOU 111 'vz_4' FICH 'slid40.pun' RENA 'vz_4_40'
RCOU 112 'vz_7' FICH 'slid40.pun' RENA 'vz_7_40'
RCOU 113 'vx_7' FICH 'slid40.pun' RENA 'vx_7_40'
RCOU 114 'vy_7' FICH 'slid40.pun' RENA 'vy_7_40'
RCOU 121 'z_4' FICH 'slid40.pun' RENA 'z_4_40'
RCOU 122 'z_7' FICH 'slid40.pun' RENA 'z_7_40'
RCOU 123 'x_7' FICH 'slid40.pun' RENA 'x_7_40'
RCOU 124 'y_7' FICH 'slid40.pun' RENA 'y_7_40'
TRAC  1  2  3  4 101 102 103 104 AXES 1.0 'DEPL. [M]' YZER
COLO NOIR NOIR NOIR NOIR ROUG ROUG ROUG ROUG
TRAC 11 12 13 14 111 112 113 114 AXES 1.0 'VITE. [M/S]' YZER
COLO NOIR NOIR NOIR NOIR ROUG ROUG ROUG ROUG
TRAC 21 22 23 24 121 122 123 124 AXES 1.0 'COOR. [M]' YZER
COLO NOIR NOIR NOIR NOIR ROUG ROUG ROUG ROUG
LIST  1  2  3  4 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 13 14 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 23 24 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -6.17336E-02 TOLE 1.E-2
     COUR  3 REFE  1.71453E-01 TOLE 1.E-2
     COUR  4 REFE  1.71453E-01 TOLE 1.E-2
     COUR 12 REFE  3.17139E+01 TOLE 1.E-2
     COUR 13 REFE  4.76903E+01 TOLE 1.E-2
     COUR 14 REFE  4.76903E+01 TOLE 1.E-2
     COUR 22 REFE  1.03827E+00 TOLE 1.E-2
     COUR 23 REFE  5.04783E-01 TOLE 1.E-2
     COUR 24 REFE  5.04783E-01 TOLE 1.E-2
FIN
```

slid42.dgibi

```
opti echo 0;
opti donn 'px4cir3d.proc';
opti donn 'pxhex2te.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'slid42_mesh.ps';
opti sauv form 'slid42.msh';
r = 2.0;
x0 = 3.0;
pc = x0 r 0;
pz = 0 0 1;
n = 8;
tol = 0.001;
ci1 ier = px4cir3d (x0 0 0) ((x0+r) r 0) pc (pc plus pz) n tol;
w = 2.0;
vzcir = 0 0 w;
nzc = 3;
```

```
c1 = ci1 volu tran nzc vzcir;
c2 = c1 tour 90 pc (pc plus pz);
c3 = c2 tour 90 pc (pc plus pz);
c4 = c3 tour 90 pc (pc plus pz);
circ8 = c1 et c2 et c3 et c4;
*
n = nbel circ8;
i = 0;
repe loop1 n;
  i = i + 1;
  ei = circ8 elem i;
  tetr = pxhex2te ei;
  si (ega i 1);
    circ = tetr;
  sinon;
    circ = circ et tetr;
  finsi;
fin loop1;
*
elim tol circ;
axe = pc d nzc (pc plus vzcir);
elim tol (circ et axe);
pm = pc plus (0 r w);
elim tol (pm et circ);
mark = manu poi1 pm;
trac cach qual (circ et mark);
*
h = 1.0;
len = 10.0;
a = 4.0;
nh = 2;
nb = enti (len / 1.0);
na = 6;
bas2d = (0 (0-h) -1.0) d nb (len (0-h) -1.0);
base2d = bas2d tran nh (0 h 0);
base8 = base2d volu tran na (0 0 a);
*
n = nbel base8;
i = 0;
repe loop1 n;
  i = i + 1;
  ei = base8 elem i;
  tetr = pxhex2te ei;
  si (ega i 1);
    base = tetr;
  sinon;
    base = base et tetr;
  finsi;
fin loop1;
*
trac cach qual base;
trac cach qual (base et circ et mark);
*
mesh = circ et base et mark;
tass mesh noop;
sauv form mesh;
trac cach qual mesh;
fin;
```

slid42.epx

```
SLID42
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM TETR circ base PMAT mark TERM
COMP NGRO 13 'bloc' LECT base TERM COND Y LT -0.99
             'f1a'  LECT axe TERM COND NEAR POIN 3 2 0
             'f1b'  LECT axe TERM COND NEAR POIN 3 2 2
             'f1'   LECT f1a f1b TERM
             'f2'   LECT axe DIFF f1 TERM
             'b1'   LECT circ TERM COND NEAR POIN 3 0 0
             'b2'   LECT circ TERM COND NEAR POIN 3 0 0.667
             'b3'   LECT circ TERM COND NEAR POIN 3 0 1.333
             'b4'   LECT circ TERM COND NEAR POIN 3 0 2
             'ns'   LECT base TERM COND Y GT -0.01
             'nm1'  LECT circ TERM COND CYLI
                                  X1 3 Y1 2 Z1 0
                                  X2 3 Y2 2 Z2 2 R 2.1
             'nm2'  LECT circ TERM COND CYLI
                                  X1 3 Y1 2 Z1 0
                                  X2 3 Y2 2 Z2 2 R 1.9
             'nm'   LECT nm1 DIFF nm2 TERM
     GROU 1  'em'   LECT circ TERM COND APPU LARG LECT nm TERM
     EPAI 0.2 LECT mark TERM ! Only for visualization
     COUL TURQ LECT circ TERM
          VERT LECT base TERM
          ROUG LECT mark TERM
MATE LINE RO 7800. YOUN 2.E11 NU 0.
        LECT circ base TERM
     MASS 0.0 LECT mark TERM
LINK COUP
     BLOQ 123 LECT bloc TERM
!    GLIS 1 ELIM
!         MAIT LECT circ TERM
!         ESCL LECT base TERM
     SLID 1 SURF FROT MUST 0.25 MUDY 0.25 GAMM 0.1
                EMAS LECT em TERM
                NMAS LECT nm TERM
                NSLA LECT ns TERM
CHAR 1 FACT 2
     FORC 1  3.33333E8 LECT f1 TERM
     FORC 1  6.66667E8 LECT f2 TERM
     FORC 2 -3.33333E8 LECT f1 TERM
     FORC 2 -6.66667E8 LECT f2 TERM
     TABL 3 0. 0.  12.E-4 1.  6. 1.
ECRI DEPL VITE COOR FINT FEXT FLIA FREQ 600
     FICH ALIC FREQ 100
     FICH ALIC TEMP FREQ 1
          POIN LECT b1 b2 b3 b4 f1 f2 mark TERM
OPTI PAS UTIL
     LOG 1
!    GLIS NORM ELEM
     LNKS STAT VISU
CALC TINI 0 TFIN 40.E-3 PASF 1.E-5 NMAX 4000
PLAY
CAME   1 EYE   1.84447E+01  1.93365E+01  2.07597E+01
!        Q     9.11780E-01 -3.31861E-01  2.41333E-01 -1.68756E-02
         VIEW -4.51285E-01 -5.97022E-01 -6.63254E-01
         RIGH  8.82948E-01 -1.90951E-01 -4.28884E-01
         UP   -1.29404E-01  7.79167E-01 -6.13313E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E+00  1.55000E+00  1.00000E+00
!RSPHERE:  5.95840E+00
!RADIUS :  2.97920E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.32377E+01
!FAR    :  4.17088E+01
SCEN GEOM NAVI FREE
          POIN SPHP
!         FACE HFRO
        ! LINE HEOU SSHA
        ! LNKS SHOW GLIS JOIN
!    VECT SCCO FIEL FLIA SCAL USER PROG 0.25E8 PAS 0.25E8 3.5E8 TERM
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 100
TRAC OFFS FICH AVI NOCL NFTO 41 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 39 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR  1 'y_b1'   COOR COMP 2 NOEU LECT b1 TERM
COUR  2 'y_b2'   COOR COMP 2 NOEU LECT b2 TERM
COUR  3 'y_b3'   COOR COMP 2 NOEU LECT b3 TERM
COUR  4 'y_b4'   COOR COMP 2 NOEU LECT b4 TERM
COUR  5 'dy_mk'  DEPL COMP 2 NOEU LECT mark TERM
COUR  6 'dy_b4'  DEPL COMP 2 NOEU LECT b4 TERM
COUR  7 'dy_f1b' DEPL COMP 2 NOEU LECT f1b TERM
COUR  8 'dx_mk'  DEPL COMP 1 NOEU LECT mark TERM
COUR  9 'dx_b4'  DEPL COMP 1 NOEU LECT b4 TERM
COUR 10 'dx_f1b' DEPL COMP 1 NOEU LECT f1b TERM
TRAC 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
TRAC 5 6 7 AXES 1.0 'DY [M]' YZER
TRAC 8 9 10 AXES 1.0 'DX [M]' YZER
LIST 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
LIST 5 6 7 AXES 1.0 'DY [M]' YZER
LIST 8 9 10 AXES 1.0 'DX [M]' YZER
QUAL COUR  8 REFE  7.90074E+00 TOLE 1.E-2
     COUR  9 REFE  3.92802E+00 TOLE 1.E-2
     COUR 10 REFE  5.90767E+00 TOLE 1.E-2
FIN
```

slid43.dgibi

```
opti echo 0;
opti donn 'px4cir3d.proc';
opti donn 'pxhex2t2.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'slid43_mesh.ps';
opti sauv form 'slid43.msh';
r = 2.0;
x0 = 3.0;
pc = x0 r 0;
pz = 0 0 1;
n = 8;
tol = 0.001;
ci1 ier = px4cir3d (x0 0 0) ((x0+r) r 0) pc (pc plus pz) n tol;
w = 2.0;
vzcir = 0 0 w;
nzc = 3;
c1 = ci1 volu tran nzc vzcir;
c2 = c1 tour 90 pc (pc plus pz);
c3 = c2 tour 90 pc (pc plus pz);
c4 = c3 tour 90 pc (pc plus pz);
circ8 = c1 et c2 et c3 et c4;
*
n = nbel circ8;
i = 0;
repe loop1 n;
  i = i + 1;
  ei = circ8 elem i;
  tetr = pxhex2t2 ei;
  si (ega i 1);
    circ = tetr;
```

```
  sinon;
    circ = circ et tetr;
  finsi;
fin loop1;
*
elim tol circ;
axe = pc d nzc (pc plus vzcir);
elim tol (circ et axe);
pm = pc plus (0 r w);
elim tol (pm et circ);
mark = manu poi1 pm;
trac cach qual (circ et mark);
*
h = 1.0;
len = 10.0;
a = 4.0;
nh = 2;
nb = enti (len / 1.0);
na = 6;
bas2d = (0 (0-h) -1.0) d nb (len (0-h) -1.0);
base2d = bas2d tran nh (0 h 0);
base8 = base2d volu tran na (0 0 a);
*
n = nbel base8;
i = 0;
repe loop1 n;
  i = i + 1;
  ei = base8 elem i;
  tetr = pxhex2t2 ei;
  si (ega i 1);
    base = tetr;
  sinon;
    base = base et tetr;
  finsi;
fin loop1;
*
trac cach qual base;
trac cach qual (base et circ et mark);
*
mesh = circ et base et mark;
tass mesh noop;
sauv form mesh;
trac cach qual mesh;
fin;
```

slid43.epx

```
SLID43
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM TETR circ base PMAT mark TERM
COMP NGRO 13 'bloc' LECT base TERM COND Y LT -0.99
             'f1a'  LECT axe TERM COND NEAR POIN 3 2 0
             'f1b'  LECT axe TERM COND NEAR POIN 3 2 2
             'f1'   LECT f1a f1b TERM
             'f2'   LECT axe DIFF f1 TERM
             'b1'   LECT circ TERM COND NEAR POIN 3 0 0
             'b2'   LECT circ TERM COND NEAR POIN 3 0 0.667
             'b3'   LECT circ TERM COND NEAR POIN 3 0 1.333
             'b4'   LECT circ TERM COND NEAR POIN 3 0 2
             'ns'   LECT base TERM COND Y GT -0.01
             'nm1'  LECT circ TERM COND CYLI
                               X1 3 Y1 2 Z1 0
                               X2 3 Y2 2 Z2 2 R 2.1
             'nm2'  LECT circ TERM COND CYLI
                               X1 3 Y1 2 Z1 0
                               X2 3 Y2 2 Z2 2 R 1.9
             'nm'   LECT nm1 DIFF nm2 TERM
     GROU 1  'em'   LECT circ TERM COND APPU LARG LECT nm TERM
     EPAI 0.2 LECT mark TERM ! Only for visualization
     COUL TURQ LECT circ TERM
          VERT LECT base TERM
          ROUG LECT mark TERM
MATE LINE RO 7800. YOUN 2.E11 NU 0.
          LECT circ base TERM
     MASS 0.0 LECT mark TERM
LINK COUP
     BLOQ 123 LECT bloc TERM
!    GLIS 1 ELIM
!         MAIT LECT circ TERM
!         ESCL LECT base TERM
     SLID 1 SURF FROT MUST 0.25 MUDY 0.25 GAMM 0.1
                 EMAS LECT em TERM
                 NMAS LECT nm TERM
                 NSLA LECT ns TERM
CHAR 1 FACT 2
     FORC 1  3.33333E8 LECT f1 TERM
     FORC 1  6.66667E8 LECT f2 TERM
     FORC 2 -3.33333E8 LECT f1 TERM
     FORC 2 -6.66667E8 LECT f2 TERM
     TABL 3 0. 0.  12.E-4 1.  6. 1.
ECRI DEPL VITE COOR FINT FEXT FLIA FREQ 1000
     FICH ALIC FREQ 100
     FICH ALIC TEMP FREQ 1
          POIN LECT b1 b2 b3 b4 f1 f2 mark TERM
OPTI PAS UTIL
     LOG 1
!    GLIS NORM ELEM
     LNKS STAT VISU
CALC TINI 0 TFIN 40.E-3 PASF 5.E-6 NMAX 8000
PLAY
CAME   1 EYE   1.84447E+01  1.93365E+01  2.07597E+01
!        Q     9.11780E-01 -3.31861E-01  2.41333E-01 -1.68756E-02
         VIEW -4.51285E-01 -5.97022E-01 -6.63254E-01
         RIGH  8.82948E-01 -1.90951E-01 -4.28884E-01
         UP   -1.29404E-01  7.79167E-01 -6.13313E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E+00  1.55000E+00  1.00000E+00
!RSPHERE:  5.95840E+00
!RADIUS :  2.97920E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.32377E+01
!FAR    :  4.17088E+01
SCEN GEOM NAVI FREE
          POIN SPHP
!         FACE HFRO
        ! LINE HEOU SSHA
        ! LNKS SHOW GLIS JOIN
!    VECT SCCO FIEL FLIA SCAL USER PROG 0.25E8 PAS 0.25E8 3.5E8 TERM
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 200
TRAC OFFS FICH AVI NOCL NFTO 41 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 39 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR  1 'y_b1'   COOR COMP 2 NOEU LECT b1 TERM
COUR  2 'y_b2'   COOR COMP 2 NOEU LECT b2 TERM
COUR  3 'y_b3'   COOR COMP 2 NOEU LECT b3 TERM
COUR  4 'y_b4'   COOR COMP 2 NOEU LECT b4 TERM
COUR  5 'dy_mk'  DEPL COMP 2 NOEU LECT mark TERM
COUR  6 'dy_b4'  DEPL COMP 2 NOEU LECT b4 TERM
COUR  7 'dy_f1b' DEPL COMP 2 NOEU LECT f1b TERM
COUR  8 'dx_mk'  DEPL COMP 1 NOEU LECT mark TERM
COUR  9 'dx_b4'  DEPL COMP 1 NOEU LECT b4 TERM
COUR 10 'dx_f1b' DEPL COMP 1 NOEU LECT f1b TERM
TRAC 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
TRAC 5 6 7 AXES 1.0 'DY [M]' YZER
TRAC 8 9 10 AXES 1.0 'DX [M]' YZER
LIST 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
LIST 5 6 7 AXES 1.0 'DY [M]' YZER
LIST 8 9 10 AXES 1.0 'DX [M]' YZER
QUAL COUR  8 REFE  8.17753E+00 TOLE 1.E-2
     COUR  9 REFE  4.23055E+00 TOLE 1.E-2
     COUR 10 REFE  6.19470E+00 TOLE 1.E-2
FIN
```

slid46.epx

```
SLID46
ECHO
 CONV win
TRID LAGR
GEOM LIBR POIN 9 CUB8 1 PMAT 1 TERM
 0 0 1  1 0 1  1 0 0  0 0 0
 0 1 1  1 1 1  1 1 0  0 1 0
 0.5 1.1 0.5
 1 2 3 4 5 6 7 8
 9
COMP GROU 2 'targ' LECT 1 TERM
            'proj' LECT 2 TERM
     EPAI 0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 3 4 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 5 6 7 8 TERM
                 NSLA LECT 9 TERM
INIT VITE 2 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE  -5.24858E-01  2.86752E+00  4.41255E+00
!        Q     9.58252E-01 -2.46909E-01 -1.30902E-01 -6.04411E-02
         VIEW  2.21027E-01 -4.89025E-01 -8.43802E-01
         RIGH  9.58423E-01 -5.11942E-02  2.80720E-01
         UP    1.80477E-01  8.70766E-01 -4.57378E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  6.00000E-01  5.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
```

```
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 29 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 27 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dy_5' DEPL COMP 2 NOEU LECT 5 TERM
COUR  2 'dy_6' DEPL COMP 2 NOEU LECT 6 TERM
COUR  3 'dy_7' DEPL COMP 2 NOEU LECT 7 TERM
COUR  4 'dy_8' DEPL COMP 2 NOEU LECT 8 TERM
COUR  5 'dy_9' DEPL COMP 2 NOEU LECT 9 TERM
COUR 11 'vy_5' VITE COMP 2 NOEU LECT 5 TERM
COUR 12 'vy_6' VITE COMP 2 NOEU LECT 6 TERM
COUR 13 'vy_7' VITE COMP 2 NOEU LECT 7 TERM
COUR 14 'vy_8' VITE COMP 2 NOEU LECT 8 TERM
COUR 15 'vy_9' VITE COMP 2 NOEU LECT 9 TERM
COUR 21 'y_5'  COOR COMP 2 NOEU LECT 5 TERM
COUR 22 'y_6'  COOR COMP 2 NOEU LECT 6 TERM
COUR 23 'y_7'  COOR COMP 2 NOEU LECT 7 TERM
COUR 24 'y_8'  COOR COMP 2 NOEU LECT 8 TERM
COUR 25 'y_9'  COOR COMP 2 NOEU LECT 9 TERM
TRAC  1  2  3  4  5 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 13 14 15 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 23 24 25 AXES 1.0 'COOR. [M]' YZER
LIST  1  2  3  4  5 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 13 14 15 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 23 24 25 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  5 REFE -7.15670E-02 TOLE 1.E-2
     COUR 15 REFE  1.74854E+01 TOLE 1.E-2
     COUR 25 REFE  1.02843E+00 TOLE 1.E-2
FIN
```

slid47.epx

```
SLID47
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 19 CUB8 4 PMAT 1 TERM
 0 0 0  0.5 0 0  1 0 0
 0 0.5 0  0.5 0.5 0  1 0.5 0
 0 1 0  0.5 1 0  1 1 0
 0 0 1  0.5 0 1  1 0 1
 0 0.5 1  0.5 0.5 1  1 0.5 1
 0 1 1  0.5 1 1  1 1 1
 0.5 0.5 1.1
 1 2 5 4 10 11 14 13
 2 3 6 5 11 12 15 14
 4 5 8 7 13 14 17 16
 5 6 9 8 14 15 18 17
 19
COMP GROU 2 'targ' LECT 1 2 3 4 TERM
            'proj' LECT 5 TERM
     EPAI 0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 3 4 5 6 7 8 9 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 10 11 12 13 14 15 16 17 18 TERM
                 NSLA LECT 19 TERM
INIT VITE 3 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   3.69529E+00 -2.60160E+00  1.89235E+00
!        Q     7.32692E-01  5.55831E-01  2.27362E-01  3.20189E-01
         VIEW -6.89114E-01  6.68908E-01 -2.78716E-01
         RIGH  6.91571E-01  7.21949E-01  2.27704E-02
         UP   -2.16450E-01  1.77061E-01  9.60103E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
```

```
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 55 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 53 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_10' DEPL COMP 3 NOEU LECT 10 TERM
COUR  2 'dz_12' DEPL COMP 3 NOEU LECT 12 TERM
COUR  3 'dz_14' DEPL COMP 3 NOEU LECT 14 TERM
COUR  4 'dz_16' DEPL COMP 3 NOEU LECT 16 TERM
COUR  5 'dz_18' DEPL COMP 3 NOEU LECT 18 TERM
COUR  6 'dz_19' DEPL COMP 3 NOEU LECT 19 TERM
COUR 11 'vz_10' VITE COMP 3 NOEU LECT 10 TERM
COUR 12 'vz_12' VITE COMP 3 NOEU LECT 12 TERM
COUR 13 'vz_14' VITE COMP 3 NOEU LECT 14 TERM
COUR 14 'vz_16' VITE COMP 3 NOEU LECT 16 TERM
COUR 15 'vz_18' VITE COMP 3 NOEU LECT 18 TERM
COUR 16 'vz_19' VITE COMP 3 NOEU LECT 19 TERM
COUR 21 'z_10'  COOR COMP 3 NOEU LECT 10 TERM
COUR 22 'z_12'  COOR COMP 3 NOEU LECT 12 TERM
COUR 23 'z_14'  COOR COMP 3 NOEU LECT 14 TERM
COUR 24 'z_16'  COOR COMP 3 NOEU LECT 16 TERM
COUR 25 'z_18'  COOR COMP 3 NOEU LECT 18 TERM
COUR 26 'z_19'  COOR COMP 3 NOEU LECT 19 TERM
TRAC  1  2  3  4  5  6 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 13 14 15 16 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 23 24 25 26 AXES 1.0 'COOR. [M]' YZER
LIST  1  2  3  4  5  6 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 13 14 15 16 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 23 24 25 26 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -5.08867E-04 TOLE 1.E-2
     COUR 12 REFE -9.06008E+00 TOLE 1.E-2
     COUR 22 REFE  9.99491E-01 TOLE 1.E-2
FIN
```

slid48.epx

```
SLID48
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 10 Q4GS 4 PMAT 1 TERM
 0 0 1  0.5 0 1  1 0 1
 0 0.5 1  0.5 0.5 1  1 0.5 1
 0 1 1  0.5 1 1  1 1 1
 0.5 0.5 1.15
 1 2 5 4
 2 3 6 5
 4 5 8 7
 5 6 9 8
 10
COMP GROU 2 'targ' LECT 1 2 3 4 TERM
            'proj' LECT 5 TERM
     EPAI 0.2 LECT proj TERM
          0.1 LECT targ TERM
     NGRO 1 'bloc' LECT 1 2 3 4 6 7 8 9 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 1 2 3 4 5 6 7 8 9 TERM
                 NSLA LECT 10 TERM
INIT VITE 3 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   3.69529E+00 -2.60160E+00  1.89235E+00
!        Q     7.32692E-01  5.55831E-01  2.27362E-01  3.20189E-01
         VIEW -6.89114E-01  6.68908E-01 -2.78716E-01
         RIGH  6.91571E-01  7.21949E-01  2.27704E-02
         UP   -2.16450E-01  1.77061E-01  9.60103E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
```

```
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 48 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 46 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_5' DEPL COMP 3 NOEU LECT 5 TERM
COUR  2 'dz_10' DEPL COMP 3 NOEU LECT 10 TERM
COUR 11 'vz_5' VITE COMP 3 NOEU LECT 5 TERM
COUR 12 'vz_10' VITE COMP 3 NOEU LECT 10 TERM
COUR 21 'z_5'  COOR COMP 3 NOEU LECT 5 TERM
COUR 22 'z_10'  COOR COMP 3 NOEU LECT 10 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -1.53938E-01 TOLE 1.E-2
     COUR 12 REFE  4.80647E+01 TOLE 1.E-2
     COUR 22 REFE  9.96062E-01 TOLE 1.E-2
FIN
```

slid49.epx

```
SLID49
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 19 CUB8 4 PMAT 1 TERM
 0 0 0  0.5 0 0  1 0 0
 0 0.5 0  0.5 0.5 0  1 0.5 0
 0 1 0  0.5 1 0  1 1 0
 0 0 1  0.5 0 1  1 0 1
 0 0.5 1  0.5 0.5 1.05  1 0.5 1
 0 1 1  0.5 1 1  1 1 1
 0.5 0.5 1.15
 1 2 5 4 10 11 14 13
 2 3 6 5 11 12 15 14
 4 5 8 7 13 14 17 16
 5 6 9 8 14 15 18 17
 19
COMP GROU 2 'targ' LECT 1 2 3 4 TERM
            'proj' LECT 5 TERM
     EPAI 0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 3 4 5 6 7 8 9 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
               NMAS LECT 10 11 12 13 14 15 16 17 18 TERM
               NSLA LECT 19 TERM
INIT VITE 3 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   3.69529E+00 -2.60160E+00  1.89235E+00
!        Q     7.32692E-01  5.55831E-01  2.27362E-01  3.20189E-01
         VIEW -6.89114E-01  6.68908E-01 -2.78716E-01
         RIGH  6.91571E-01  7.21949E-01  2.27704E-02
         UP   -2.16450E-01  1.77061E-01  9.60103E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 55 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 53 OFFS FICH AVI CONT NOCL REND
GO
```

```
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_10' DEPL COMP 3 NOEU LECT 10 TERM
COUR  2 'dz_12' DEPL COMP 3 NOEU LECT 12 TERM
COUR  3 'dz_14' DEPL COMP 3 NOEU LECT 14 TERM
COUR  4 'dz_16' DEPL COMP 3 NOEU LECT 16 TERM
COUR  5 'dz_18' DEPL COMP 3 NOEU LECT 18 TERM
COUR  6 'dz_19' DEPL COMP 3 NOEU LECT 19 TERM
COUR 11 'vz_10' VITE COMP 3 NOEU LECT 10 TERM
COUR 12 'vz_12' VITE COMP 3 NOEU LECT 12 TERM
COUR 13 'vz_14' VITE COMP 3 NOEU LECT 14 TERM
COUR 14 'vz_16' VITE COMP 3 NOEU LECT 16 TERM
COUR 15 'vz_18' VITE COMP 3 NOEU LECT 18 TERM
COUR 16 'vz_19' VITE COMP 3 NOEU LECT 19 TERM
COUR 21 'z_10'  COOR COMP 3 NOEU LECT 10 TERM
COUR 22 'z_12'  COOR COMP 3 NOEU LECT 12 TERM
COUR 23 'z_14'  COOR COMP 3 NOEU LECT 14 TERM
COUR 24 'z_16'  COOR COMP 3 NOEU LECT 16 TERM
COUR 25 'z_18'  COOR COMP 3 NOEU LECT 18 TERM
COUR 26 'z_19'  COOR COMP 3 NOEU LECT 19 TERM
TRAC  1  2  3  4  5  6 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 13 14 15 16 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 23 24 25 26 AXES 1.0 'COOR. [M]' YZER
LIST  1  2  3  4  5  6 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 13 14 15 16 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 23 24 25 26 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -3.67240E-04 TOLE 1.E-2
     COUR 12 REFE -9.90738E+00 TOLE 1.E-2
     COUR 22 REFE  9.99633E-01 TOLE 1.E-2
FIN
```

slid50.epx

```
SLID50
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 19 CUB8 4 PMAT 1 TERM
 0 0 0  0.5 0 0  1 0 0
 0 0.5 0  0.5 0.5 0  1 0.5 0
 0 1 0  0.5 1 0  1 1 0
 0 0 1  0.5 0 1  1 0 1
 0 0.5 1  0.5 0.5 0.95  1 0.5 1
 0 1 1  0.5 1 1  1 1 1
 0.5 0.5 1.05
 1 2 5 4 10 11 14 13
 2 3 6 5 11 12 15 14
 4 5 8 7 13 14 17 16
 5 6 9 8 14 15 18 17
 19
COMP GROU 2 'targ' LECT 1 2 3 4 TERM
            'proj' LECT 5 TERM
     EPAI 0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 3 4 5 6 7 8 9 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
               NMAS LECT 10 11 12 13 14 15 16 17 18 TERM
               NSLA LECT 19 TERM
INIT VITE 3 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   3.69529E+00 -2.60160E+00  1.89235E+00
!        Q     7.32692E-01  5.55831E-01  2.27362E-01  3.20189E-01
         VIEW -6.89114E-01  6.68908E-01 -2.78716E-01
         RIGH  6.91571E-01  7.21949E-01  2.27704E-02
         UP   -2.16450E-01  1.77061E-01  9.60103E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 56 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 54 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
```

```
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_10' DEPL COMP 3 NOEU LECT 10 TERM
COUR  2 'dz_12' DEPL COMP 3 NOEU LECT 12 TERM
COUR  3 'dz_14' DEPL COMP 3 NOEU LECT 14 TERM
COUR  4 'dz_16' DEPL COMP 3 NOEU LECT 16 TERM
COUR  5 'dz_18' DEPL COMP 3 NOEU LECT 18 TERM
COUR  6 'dz_19' DEPL COMP 3 NOEU LECT 19 TERM
COUR 11 'vz_10' VITE COMP 3 NOEU LECT 10 TERM
COUR 12 'vz_12' VITE COMP 3 NOEU LECT 12 TERM
COUR 13 'vz_14' VITE COMP 3 NOEU LECT 14 TERM
COUR 14 'vz_16' VITE COMP 3 NOEU LECT 16 TERM
COUR 15 'vz_18' VITE COMP 3 NOEU LECT 18 TERM
COUR 16 'vz_19' VITE COMP 3 NOEU LECT 19 TERM
COUR 21 'z_10'  COOR COMP 3 NOEU LECT 10 TERM
COUR 22 'z_12'  COOR COMP 3 NOEU LECT 12 TERM
COUR 23 'z_14'  COOR COMP 3 NOEU LECT 14 TERM
COUR 24 'z_16'  COOR COMP 3 NOEU LECT 16 TERM
COUR 25 'z_18'  COOR COMP 3 NOEU LECT 18 TERM
COUR 26 'z_19'  COOR COMP 3 NOEU LECT 19 TERM
TRAC  1  2  3  4  5  6 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 13 14 15 16 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 23 24 25 26 AXES 1.0 'COOR. [M]' YZER
LIST  1  2  3  4  5  6 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 13 14 15 16 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 23 24 25 26 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -1.29703E-04 TOLE 1.E-2
     COUR 12 REFE -6.27760E+00 TOLE 1.E-2
     COUR 22 REFE  9.99870E-01 TOLE 1.E-2
FIN
```

slid51.epx

```
SLID51
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 10 Q4GS 4 PMAT 1 TERM
 0 0 1  0.5 0 1  1 0 1
 0 0.5 1  0.5 0.5 1.05  1 0.5 1
 0 1 1  0.5 1 1  1 1 1
 0.5 0.5 1.20
 1 2 5 4
 2 3 6 5
 4 5 8 7
 5 6 9 8
 10
COMP GROU 2 'targ' LECT 1 2 3 4 TERM
            'proj' LECT 5 TERM
     EPAI 0.2 LECT proj TERM
          0.1 LECT targ TERM
     NGRO 1 'bloc' LECT 1 2 3 4 6 7 8 9 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 1 2 3 4 5 6 7 8 9 TERM
                 NSLA LECT 10 TERM
INIT VITE 3 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   3.69529E+00 -2.60160E+00  1.89235E+00
!        Q     7.32692E-01  5.55831E-01  2.27362E-01  3.20189E-01
         VIEW -6.89114E-01  6.68908E-01 -2.78716E-01
         RIGH  6.91571E-01  7.21949E-01  2.27704E-02
         UP   -2.16450E-01  1.77061E-01  9.60103E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 48 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 46 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_5' DEPL COMP 3 NOEU LECT 5 TERM
COUR  2 'dz_10' DEPL COMP 3 NOEU LECT 10 TERM
COUR 11 'vz_5' VITE COMP 3 NOEU LECT 5 TERM
COUR 12 'vz_10' VITE COMP 3 NOEU LECT 10 TERM
COUR 21 'z_5'  COOR COMP 3 NOEU LECT 5 TERM
COUR 22 'z_10'  COOR COMP 3 NOEU LECT 10 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -1.68021E-01 TOLE 1.E-2
     COUR 12 REFE  2.73408E+01 TOLE 1.E-2
     COUR 22 REFE  1.03198E+00 TOLE 1.E-2
FIN
```

slid52.epx

```
SLID52
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 10 Q4GS 4 PMAT 1 TERM
 0 0 1  0.5 0 1  1 0 1
 0 0.5 1  0.5 0.5 0.95  1 0.5 1
 0 1 1  0.5 1 1  1 1 1
 0.5 0.5 1.10
 1 2 5 4
 2 3 6 5
 4 5 8 7
 5 6 9 8
 10
COMP GROU 2 'targ' LECT 1 2 3 4 TERM
            'proj' LECT 5 TERM
     EPAI 0.2 LECT proj TERM
          0.1 LECT targ TERM
     NGRO 1 'bloc' LECT 1 2 3 4 6 7 8 9 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 1 2 3 4 5 6 7 8 9 TERM
                 NSLA LECT 10 TERM
INIT VITE 3 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   3.69529E+00 -2.60160E+00  1.89235E+00
!        Q     7.32692E-01  5.55831E-01  2.27362E-01  3.20189E-01
         VIEW -6.89114E-01  6.68908E-01 -2.78716E-01
         RIGH  6.91571E-01  7.21949E-01  2.27704E-02
         UP   -2.16450E-01  1.77061E-01  9.60103E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 48 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 46 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_5' DEPL COMP 3 NOEU LECT 5 TERM
COUR  2 'dz_10' DEPL COMP 3 NOEU LECT 10 TERM
COUR 11 'vz_5' VITE COMP 3 NOEU LECT 5 TERM
COUR 12 'vz_10' VITE COMP 3 NOEU LECT 10 TERM
COUR 21 'z_5'  COOR COMP 3 NOEU LECT 5 TERM
COUR 22 'z_10'  COOR COMP 3 NOEU LECT 10 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
```

```
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -1.15972E-01 TOLE 1.E-2
     COUR 12 REFE  6.82937E+01 TOLE 1.E-2
     COUR 22 REFE  9.84028E-01 TOLE 1.E-2
FIN
```

slid53.epx

```
SLID53
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 13 CUB8 2 PMAT 1 TERM
 0 0 0  0.5 0 0
 0 0.5 0  0.5 0.5 0
 0 1 0  0.5 1 0
 0 0 1  0.5 0 1
 0 0.5 1  0.5 0.5 1
 0 1 1  0.5 1 1
 0.5 0.5 1.1
 1 2 4 3 7 8 10 9
 3 4 6 5 9 10 12 11
 13
COMP GROU 2 'targ' LECT 1 2 TERM
            'proj' LECT 3 TERM
     EPAI 0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 3 4 5 6 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 500. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
! Attention: the slave node (13) must also be subjected to the symmetry!
     CONT SPLA NX 1 NY 0 NZ 0 LECT 2 4 6 8 10 12 13 TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 7 8 9 10 11 12 TERM
                 NSLA LECT 13 TERM
INIT VITE 3 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   3.69529E+00 -2.60160E+00  1.89235E+00
!        Q     7.32692E-01  5.55831E-01  2.27362E-01  3.20189E-01
         VIEW -6.89114E-01  6.68908E-01 -2.78716E-01
         RIGH  6.91571E-01  7.21949E-01  2.27704E-02
         UP   -2.16450E-01  1.77061E-01  9.60103E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 55 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 53 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_7' DEPL COMP 3 NOEU LECT 7 TERM
COUR  2 'dz_10' DEPL COMP 3 NOEU LECT 10 TERM
COUR  3 'dz_11' DEPL COMP 3 NOEU LECT 11 TERM
COUR  4 'dz_13' DEPL COMP 3 NOEU LECT 13 TERM
COUR 11 'vz_7' VITE COMP 3 NOEU LECT 7 TERM
COUR 12 'vz_10' VITE COMP 3 NOEU LECT 10 TERM
COUR 13 'vz_11' VITE COMP 3 NOEU LECT 11 TERM
COUR 14 'vz_13' VITE COMP 3 NOEU LECT 13 TERM
COUR 21 'z_7'  COOR COMP 3 NOEU LECT 7 TERM
COUR 22 'z_10'  COOR COMP 3 NOEU LECT 10 TERM
COUR 23 'z_11'  COOR COMP 3 NOEU LECT 11 TERM
COUR 24 'z_13'  COOR COMP 3 NOEU LECT 13 TERM
TRAC  1  2  3  4 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 13 14 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 23 24 AXES 1.0 'COOR. [M]' YZER
LIST  1  2  3  4 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 13 14 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 23 24 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  1 REFE -5.08867E-04 TOLE 1.E-2
     COUR 11 REFE -9.06008E+00 TOLE 1.E-2
     COUR 21 REFE  9.99491E-01 TOLE 1.E-2
FIN
```

slid54.epx

```
SLID54
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 9 CUB8 1 PMAT 1 TERM
 0 0 0  0.5 0 0
 0 0.5 0  0.5 0.5 0
 0 0 1  0.5 0 1
 0 0.5 1  0.5 0.5 1
 0.5 0.5 1.1
 1 2 4 3 5 6 8 7
 9
COMP GROU 2 'targ' LECT 1 TERM
            'proj' LECT 2 TERM
     EPAI 0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 3 4 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 250. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
! Attention: the slave node (9) must also be subjected to the symmetries!
     CONT SPLA NX 1 NY 0 NZ 0 LECT 2 4 6 8 9 TERM
     CONT SPLA NX 0 NY 1 NZ 0 LECT 3 4 7 8 9 TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 5 6 7 8 TERM
                 NSLA LECT 9 TERM
INIT VITE 3 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   3.69529E+00 -2.60160E+00  1.89235E+00
!        Q     7.32692E-01  5.55831E-01  2.27362E-01  3.20189E-01
         VIEW -6.89114E-01  6.68908E-01 -2.78716E-01
         RIGH  6.91571E-01  7.21949E-01  2.27704E-02
         UP   -2.16450E-01  1.77061E-01  9.60103E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 55 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 53 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_5' DEPL COMP 3 NOEU LECT 5 TERM
COUR  2 'dz_8' DEPL COMP 3 NOEU LECT 8 TERM
COUR  3 'dz_9' DEPL COMP 3 NOEU LECT 9 TERM
COUR 11 'vz_5' VITE COMP 3 NOEU LECT 5 TERM
COUR 12 'vz_8' VITE COMP 3 NOEU LECT 8 TERM
COUR 13 'vz_9' VITE COMP 3 NOEU LECT 9 TERM
COUR 21 'z_5'  COOR COMP 3 NOEU LECT 5 TERM
COUR 22 'z_8'  COOR COMP 3 NOEU LECT 8 TERM
COUR 23 'z_9'  COOR COMP 3 NOEU LECT 9 TERM
TRAC  1  2  3 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 13 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 23 AXES 1.0 'COOR. [M]' YZER
LIST  1  2  3 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 13 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 23 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  1 REFE -5.08867E-04 TOLE 1.E-2
     COUR 11 REFE -9.06008E+00 TOLE 1.E-2
     COUR 21 REFE  9.99491E-01 TOLE 1.E-2
FIN
```

slid55.epx

```
SLID55
ECHO
```

```
!CONV win
TRID LAGR
GEOM LIBR POIN 7 Q4GS 2 PMAT 1 TERM
 0 0 1  0.5 0 1
 0 0.5 1  0.5 0.5 1
 0 1 1  0.5 1 1
 0.5 0.5 1.15
 1 2 4 3
 3 4 6 5
 7
COMP GROU 2 'targ' LECT 1 2 TERM
            'proj' LECT 3 TERM
     EPAI 0.2 LECT proj TERM
          0.1 LECT targ TERM
     NGRO 1 'bloc' LECT 1 2 3 5 6 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 500. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
! Attention: the slave node (7) must also be subjected to the symmetry!
     CONT SPLA NX 1 NY 0 NZ 0 LECT 2 4 6 7 TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 1 2 3 4 5 6 TERM
                 NSLA LECT 7 TERM
INIT VITE 3 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   3.69529E+00 -2.60160E+00  1.89235E+00
!        Q     7.32692E-01  5.55831E-01  2.27362E-01  3.20189E-01
         VIEW -6.89114E-01  6.68908E-01 -2.78716E-01
         RIGH  6.91571E-01  7.21949E-01  2.27704E-02
         UP   -2.16450E-01  1.77061E-01  9.60103E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 48 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 46 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_4' DEPL COMP 3 NOEU LECT 4 TERM
COUR  2 'dz_7' DEPL COMP 3 NOEU LECT 7 TERM
COUR 11 'vz_4' VITE COMP 3 NOEU LECT 4 TERM
COUR 12 'vz_7' VITE COMP 3 NOEU LECT 7 TERM
COUR 21 'z_4'  COOR COMP 3 NOEU LECT 4 TERM
COUR 22 'z_7'  COOR COMP 3 NOEU LECT 7 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -1.53938E-01 TOLE 1.E-2
     COUR 12 REFE  4.80647E+01 TOLE 1.E-2
     COUR 22 REFE  9.96062E-01 TOLE 1.E-2
FIN
```

slid56.epx

```
SLID56
ECHO
!CONV win
TRID LAGR
GEOM LIBR POIN 5 Q4GS 1 PMAT 1 TERM
 0 0 1  0.5 0 1
 0 0.5 1  0.5 0.5 1
 0.5 0.5 1.15
 1 2 4 3
 5
COMP GROU 2 'targ' LECT 1 TERM
            'proj' LECT 2 TERM
     EPAI 0.2 LECT proj TERM
          0.1 LECT targ TERM
     NGRO 1 'bloc' LECT 1 2 3 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 250. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 123 LECT bloc TERM
! Attention: the slave node (5) must also be subjected to the symmetries!
     CONT SPLA NX 1 NY 0 NZ 0 LECT 2 4 5 TERM
     CONT SPLA NX 0 NY 1 NZ 0 LECT 3 4 5 TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 1 2 3 4 TERM
                 NSLA LECT 5 TERM
INIT VITE 3 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   3.69529E+00 -2.60160E+00  1.89235E+00
!        Q     7.32692E-01  5.55831E-01  2.27362E-01  3.20189E-01
         VIEW -6.89114E-01  6.68908E-01 -2.78716E-01
         RIGH  6.91571E-01  7.21949E-01  2.27704E-02
         UP   -2.16450E-01  1.77061E-01  9.60103E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.00000E-01  6.00000E-01
!RSPHERE:  9.27362E-01
!RADIUS :  4.63681E+00
!ASPECT :  1.00000E+00
!NEAR   :  3.61671E+00
!FAR    :  6.49153E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 48 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 46 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dz_4' DEPL COMP 3 NOEU LECT 4 TERM
COUR  2 'dz_5' DEPL COMP 3 NOEU LECT 5 TERM
COUR 11 'vz_4' VITE COMP 3 NOEU LECT 4 TERM
COUR 12 'vz_5' VITE COMP 3 NOEU LECT 5 TERM
COUR 21 'z_4'  COOR COMP 3 NOEU LECT 4 TERM
COUR 22 'z_5'  COOR COMP 3 NOEU LECT 5 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -1.53938E-01 TOLE 1.E-2
     COUR 12 REFE  4.80647E+01 TOLE 1.E-2
     COUR 22 REFE  9.96062E-01 TOLE 1.E-2
FIN
```

slid59.dgibi

```
opti echo 0;
opti donn 'px4cir3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'slid59_mesh.ps';
opti sauv form 'slid59.msh';
r = 2.0;
x0 = 3.0;
pc = x0 r 0;
pz = 0 0 1;
n = 8;
tol = 0.001;
ci1 ier = px4cir3d (x0 0 0) ((x0+r) r 0) pc (pc plus pz) n tol;
w = 2.0;
vzcir = 0 0 w;
nzc = 3;
c1 = ci1 volu tran nzc vzcir;
c2 = c1 tour 90 pc (pc plus pz);
c3 = c2 tour 90 pc (pc plus pz);
c4 = c3 tour 90 pc (pc plus pz);
circ = c1 et c2 et c3 et c4;
elim tol circ;
axe = pc d nzc (pc plus vzcir);
elim tol (circ et axe);
pm = pc plus (0 r w);
elim tol (pm et circ);
mark = manu poi1 pm;
trac cach qual (circ et mark);
```

```
*
h = 1.0;
len = 10.0;
a = 4.0;
nh = 2;
nb = enti (len / 1.0);
na = 6;
bas2d = (0 (0-h) -1.0) d nb (len (0-h) -1.0);
base2d = bas2d tran nh (0 h 0);
base = base2d volu tran na (0 0 a);
trac cach qual base;
trac cach qual (base et circ et mark);
*
mesh = circ et base et mark;
tass mesh noop;
sauv form mesh;
trac cach qual mesh;
fin;
```

slid59.epx

```
SLID59
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM CUB8 circ base PMAT mark TERM
COMP NGRO 13 'bloc' LECT base TERM COND Y LT -0.99
             'f1a'  LECT axe TERM COND NEAR POIN 3 2 0
             'f1b'  LECT axe TERM COND NEAR POIN 3 2 2
             'f1'   LECT f1a f1b TERM
             'f2'   LECT axe DIFF f1 TERM
             'b1'   LECT circ TERM COND NEAR POIN 3 0 0
             'b2'   LECT circ TERM COND NEAR POIN 3 0 0.667
             'b3'   LECT circ TERM COND NEAR POIN 3 0 1.333
             'b4'   LECT circ TERM COND NEAR POIN 3 0 2
             'ns'   LECT base TERM COND Y GT -0.01
             'nm1'  LECT circ TERM COND CYLI
                                 X1 3 Y1 2 Z1 0
                                 X2 3 Y2 2 Z2 2 R 2.1
             'nm2'  LECT circ TERM COND CYLI
                                 X1 3 Y1 2 Z1 0
                                 X2 3 Y2 2 Z2 2 R 1.9
             'nm'   LECT nm1 DIFF nm2 TERM
     GROU 1  'em'   LECT circ TERM COND APPU LARG LECT nm TERM
     EPAI 0.2 LECT mark TERM ! Only for visualization
     COUL TURQ LECT circ TERM
          VERT LECT base TERM
          ROUG LECT mark TERM
MATE LINE RO 7800. YOUN 2.E11 NU 0.
          LECT circ base TERM
     MASS 0.0 LECT mark TERM
LINK COUP
     BLOQ 123 LECT bloc TERM
!    GLIS 1 ELIM
!         MAIT LECT circ TERM
!         ESCL LECT base TERM
     SLID 1 SURF EMAS LECT em TERM
                 NMAS LECT nm TERM
                 NSLA LECT ns TERM
CHAR 1 FACT 2
     FORC 1  3.33333E8 LECT f1 TERM
     FORC 1  6.66667E8 LECT f2 TERM
     FORC 2 -3.33333E8 LECT f1 TERM
     FORC 2 -6.66667E8 LECT f2 TERM
     TABL 3 0. 0.  12.E-4 1.  6. 1.
ECRI DEPL VITE COOR FINT FEXT FLIA FREQ 600
     FICH ALIC FREQ 100
     FICH ALIC TEMP FREQ 1
          POIN LECT b1 b2 b3 b4 f1 f2 mark TERM
OPTI PAS UTIL
     LOG 1
!    GLIS NORM ELEM
     LNKS STAT VISU
CALC TINI 0 TFIN 40.E-3 PASF 1.E-5 NMAX 4000
PLAY
CAME   1 EYE   1.84447E+01  1.93365E+01  2.07597E+01
!        Q     9.11780E-01 -3.31861E-01  2.41333E-01 -1.68756E-02
         VIEW -4.51285E-01 -5.97022E-01 -6.63254E-01
         RIGH  8.82948E-01 -1.90951E-01 -4.28884E-01
         UP   -1.29404E-01  7.79167E-01 -6.13313E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E+00  1.55000E+00  1.00000E+00
!RSPHERE:  5.95840E+00
!RADIUS :  2.97920E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.32377E+01
!FAR    :  4.17088E+01
SCEN GEOM NAVI FREE
          POIN SPHP
!         FACE HFRO
        ! LINE HEOU SSHA
        ! LNKS SHOW GLIS JOIN
!    VECT SCCO FIEL FLIA SCAL USER PROG 0.25E8 PAS 0.25E8 3.5E8 TERM
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 100
TRAC OFFS FICH AVI NOCL NFTO 41 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 39 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR  1 'y_b1'   COOR COMP 2 NOEU LECT b1 TERM
COUR  2 'y_b2'   COOR COMP 2 NOEU LECT b2 TERM
COUR  3 'y_b3'   COOR COMP 2 NOEU LECT b3 TERM
COUR  4 'y_b4'   COOR COMP 2 NOEU LECT b4 TERM
COUR  5 'dy_mk'  DEPL COMP 2 NOEU LECT mark TERM
COUR  6 'dy_b4'  DEPL COMP 2 NOEU LECT b4 TERM
COUR  7 'dy_f1b' DEPL COMP 2 NOEU LECT f1b TERM
COUR  8 'dx_mk'  DEPL COMP 1 NOEU LECT mark TERM
COUR  9 'dx_b4'  DEPL COMP 1 NOEU LECT b4 TERM
COUR 10 'dx_f1b' DEPL COMP 1 NOEU LECT f1b TERM
TRAC 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
TRAC 5 6 7 AXES 1.0 'DY [M]' YZER
TRAC 8 9 10 AXES 1.0 'DX [M]' YZER
LIST 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
LIST 5 6 7 AXES 1.0 'DY [M]' YZER
LIST 8 9 10 AXES 1.0 'DX [M]' YZER
QUAL COUR  8 REFE  7.33897E+00 TOLE 1.E-2
     COUR  9 REFE  7.64172E+00 TOLE 1.E-2
     COUR 10 REFE  7.49188E+00 TOLE 1.E-2
FIN
```

slid60.dgibi

```
opti echo 0;
opti donn 'px4cir3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'slid60_mesh.ps';
opti sauv form 'slid60.msh';
r = 2.0;
x0 = 3.0;
pc = x0 r 0;
pz = 0 0 1;
n = 8;
tol = 0.001;
ci1 ier = px4cir3d (x0 0 0) ((x0+r) r 0) pc (pc plus pz) n tol;
w = 2.0;
vzcir = 0 0 w;
nzc = 3;
c1 = ci1 volu tran nzc vzcir;
c2 = c1 tour 90 pc (pc plus pz);
c3 = c2 tour 90 pc (pc plus pz);
c4 = c3 tour 90 pc (pc plus pz);
circ = c1 et c2 et c3 et c4;
elim tol circ;
axe = pc d nzc (pc plus vzcir);
elim tol (circ et axe);
pm = pc plus (0 r w);
elim tol (pm et circ);
mark = manu poi1 pm;
trac cach qual (circ et mark);
*
h = 1.0;
len = 10.0;
a = 4.0;
nh = 2;
nb = enti (len / 1.0);
na = 6;
bas2d = (0 (0-h) -1.0) d nb (len (0-h) -1.0);
base2d = bas2d tran nh (0 h 0);
base = base2d volu tran na (0 0 a);
trac cach qual base;
trac cach qual (base et circ et mark);
*
mesh = circ et base et mark;
tass mesh noop;
sauv form mesh;
trac cach qual mesh;
fin;
```

slid60.epx

```
SLID60
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM CUB8 circ base PMAT mark TERM
COMP NGRO 13 'bloc' LECT base TERM COND Y LT -0.99
             'f1a'  LECT axe TERM COND NEAR POIN 3 2 0
             'f1b'  LECT axe TERM COND NEAR POIN 3 2 2
             'f1'   LECT f1a f1b TERM
             'f2'   LECT axe DIFF f1 TERM
             'b1'   LECT circ TERM COND NEAR POIN 3 0 0
             'b2'   LECT circ TERM COND NEAR POIN 3 0 0.667
             'b3'   LECT circ TERM COND NEAR POIN 3 0 1.333
             'b4'   LECT circ TERM COND NEAR POIN 3 0 2
             'ns'   LECT base TERM COND Y GT -0.01
             'nm1'  LECT circ TERM COND CYLI
                                 X1 3 Y1 2 Z1 0
                                 X2 3 Y2 2 Z2 2 R 2.1
             'nm2'  LECT circ TERM COND CYLI
```

```
                              X1 3 Y1 2 Z1 0
                              X2 3 Y2 2 Z2 2 R 1.9
           'nm'   LECT nm1 DIFF nm2 TERM
     GROU 1  'em'   LECT circ TERM COND APPU LARG LECT nm TERM
     EPAI 0.2 LECT mark TERM ! Only for visualization
     COUL TURQ LECT circ TERM
          VERT LECT base TERM
          ROUG LECT mark TERM
MATE LINE RO 7800. YOUN 2.E11 NU 0.
          LECT circ base TERM
     MASS 0.0 LECT mark TERM
LINK COUP
     BLOQ 123 LECT bloc TERM
!    GLIS 1 ELIM
!         MAIT LECT circ TERM
!         ESCL LECT base TERM
     SLID 1 SURF FROT MUST 0.25 MUDY 0.25 GAMM 0.1
               EMAS LECT em TERM
               NMAS LECT nm TERM
               NSLA LECT ns TERM
CHAR 1 FACT 2
     FORC 1  3.33333E8 LECT f1 TERM
     FORC 1  6.66667E8 LECT f2 TERM
     FORC 2 -3.33333E8 LECT f1 TERM
     FORC 2 -6.66667E8 LECT f2 TERM
     TABL 3 0. 0.  12.E-4 1.  6. 1.
ECRI DEPL VITE COOR FINT FEXT FLIA FREQ 600
     FICH ALIC FREQ 100
     FICH ALIC TEMP FREQ 1
          POIN LECT b1 b2 b3 b4 f1 f2 mark TERM
OPTI PAS UTIL
     LOG 1
!    GLIS NORM ELEM
     LNKS STAT VISU
CALC TINI 0 TFIN 40.E-3 PASF 1.E-5 NMAX 4000
PLAY
CAME   1 EYE   1.84447E+01  1.93365E+01  2.07597E+01
!        Q     9.11780E-01 -3.31861E-01  2.41333E-01 -1.68756E-02
         VIEW -4.51285E-01 -5.97022E-01 -6.63254E-01
         RIGH  8.82948E-01 -1.90951E-01 -4.28884E-01
         UP   -1.29404E-01  7.79167E-01 -6.13313E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E+00  1.55000E+00  1.00000E+00
!RSPHERE:  5.95840E+00
!RADIUS :  2.97920E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.32377E+01
!FAR    :  4.17088E+01
SCEN GEOM NAVI FREE
          POIN SPHP
!         FACE HFRO
        ! LINE HEOU SSHA
        ! LNKS SHOW GLIS JOIN
!    VECT SCCO FIEL FLIA SCAL USER PROG 0.25E8 PAS 0.25E8 3.5E8 TERM
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 100
TRAC OFFS FICH AVI NOCL NFTO 41 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 39 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR  1 'y_b1'   COOR COMP 2 NOEU LECT b1 TERM
COUR  2 'y_b2'   COOR COMP 2 NOEU LECT b2 TERM
COUR  3 'y_b3'   COOR COMP 2 NOEU LECT b3 TERM
COUR  4 'y_b4'   COOR COMP 2 NOEU LECT b4 TERM
COUR  5 'dy_mk'  DEPL COMP 2 NOEU LECT mark TERM
COUR  6 'dy_b4'  DEPL COMP 2 NOEU LECT b4 TERM
COUR  7 'dy_f1b' DEPL COMP 2 NOEU LECT f1b TERM
COUR  8 'dx_mk'  DEPL COMP 1 NOEU LECT mark TERM
COUR  9 'dx_b4'  DEPL COMP 1 NOEU LECT b4 TERM
COUR 10 'dx_f1b' DEPL COMP 1 NOEU LECT f1b TERM
TRAC 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
TRAC 5 6 7 AXES 1.0 'DY [M]' YZER
TRAC 8 9 10 AXES 1.0 'DX [M]' YZER
LIST 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
LIST 5 6 7 AXES 1.0 'DY [M]' YZER
LIST 8 9 10 AXES 1.0 'DX [M]' YZER
QUAL COUR  8 REFE  7.29716E+00 TOLE 1.E-2
     COUR  9 REFE  3.60438E+00 TOLE 1.E-2
     COUR 10 REFE  5.45414E+00 TOLE 1.E-2
FIN
```

slid61.dgibi

```
opti echo 0;
opti donn 'px4cir3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'slid61_mesh.ps';
opti sauv form 'slid61.msh';
r = 2.0;
x0 = 3.0;
pc = x0 r 0;
pz = 0 0 1;
n = 16;
tol = 0.001;
ci1 ier = px4cir3d (x0 0 0) ((x0+r) r 0) pc (pc plus pz) n tol;
w = 2.0;
vzcir = 0 0 w;
nzc = 6;
c1 = ci1 volu tran nzc vzcir;
c2 = c1 tour 90 pc (pc plus pz);
c3 = c2 tour 90 pc (pc plus pz);
c4 = c3 tour 90 pc (pc plus pz);
circ = c1 et c2 et c3 et c4;
elim tol circ;
axe = pc d nzc (pc plus vzcir);
elim tol (circ et axe);
pm = pc plus (0 r w);
elim tol (pm et circ);
mark = manu poi1 pm;
trac cach qual (circ et mark);
*
h = 1.0;
len = 10.0;
a = 4.0;
nh = 4;
nb = enti (len / 1.0);
na = 12;
bas2d = (0 (0-h) -1.0) d (nb+nb) (len (0-h) -1.0);
base2d = bas2d tran nh (0 h 0);
base = base2d volu tran na (0 0 a);
trac cach qual base;
trac cach qual (base et circ et mark);
*
mesh = circ et base et mark;
tass mesh noop;
sauv form mesh;
trac cach qual mesh;
fin;
```

slid61.epx

```
SLID61
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM CUB8 circ base PMAT mark TERM
COMP NGRO 13 'bloc' LECT base TERM COND Y LT -0.99
             'f1a'  LECT axe TERM COND NEAR POIN 3 2 0
             'f1b'  LECT axe TERM COND NEAR POIN 3 2 2
             'f1'   LECT f1a f1b TERM
             'f2'   LECT axe DIFF f1 TERM
             'b1'   LECT circ TERM COND NEAR POIN 3 0 0
             'b2'   LECT circ TERM COND NEAR POIN 3 0 0.667
             'b3'   LECT circ TERM COND NEAR POIN 3 0 1.333
             'b4'   LECT circ TERM COND NEAR POIN 3 0 2
             'ns'   LECT base TERM COND Y GT -0.01
             'nm1'  LECT circ TERM COND CYLI
                              X1 3 Y1 2 Z1 0
                              X2 3 Y2 2 Z2 2 R 2.1
             'nm2'  LECT circ TERM COND CYLI
                              X1 3 Y1 2 Z1 0
                              X2 3 Y2 2 Z2 2 R 1.9
             'nm'   LECT nm1 DIFF nm2 TERM
     GROU 1  'em'   LECT circ TERM COND APPU LARG LECT nm TERM
     EPAI 0.2 LECT mark TERM ! Only for visualization
     COUL TURQ LECT circ TERM
          VERT LECT base TERM
          ROUG LECT mark TERM
MATE LINE RO 7800. YOUN 2.E11 NU 0.
          LECT circ base TERM
     MASS 0.0 LECT mark TERM
LINK COUP
     BLOQ 123 LECT bloc TERM
!    GLIS 1 ELIM
!         MAIT LECT circ TERM
!         ESCL LECT base TERM
     SLID 1 SURF EMAS LECT em TERM
                 NMAS LECT nm TERM
                 NSLA LECT ns TERM
CHAR 1 FACT 2
!    FORC 1  3.33333E8 LECT f1 TERM
!    FORC 1  6.66667E8 LECT f2 TERM
!    FORC 2 -3.33333E8 LECT f1 TERM
!    FORC 2 -6.66667E8 LECT f2 TERM
     FORC 1  1.66667E8 LECT f1 TERM
     FORC 1  3.33333E8 LECT f2 TERM
     FORC 2 -1.66667E8 LECT f1 TERM
     FORC 2 -3.33333E8 LECT f2 TERM
     TABL 3 0. 0.  12.E-4 1.  6. 1.
ECRI DEPL VITE COOR FINT FEXT FLIA FREQ 600
     FICH ALIC FREQ 100
     FICH ALIC TEMP FREQ 1
          POIN LECT b1 b2 b3 b4 f1 f2 mark TERM
OPTI PAS UTIL
     LOG 1
!    GLIS NORM ELEM
     LNKS STAT VISU
CALC TINI 0 TFIN 40.E-3 PASF 5.E-6 NMAX 8000
PLAY
CAME   1 EYE   1.84447E+01  1.93365E+01  2.07597E+01
```

```
!        Q     9.11780E-01 -3.31861E-01  2.41333E-01 -1.68756E-02
         VIEW -4.51285E-01 -5.97022E-01 -6.63254E-01
         RIGH  8.82948E-01 -1.90951E-01 -4.28884E-01
         UP   -1.29404E-01  7.79167E-01 -6.13313E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E+00  1.55000E+00  1.00000E+00
!RSPHERE:  5.95840E+00
!RADIUS :  2.97920E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.32377E+01
!FAR    :  4.17088E+01
SCEN GEOM NAVI FREE
          POIN SPHP
!         FACE HFRO
        ! LINE HEOU SSHA
        ! LNKS SHOW GLIS JOIN
!    VECT SCCO FIEL FLIA SCAL USER PROG 0.25E8 PAS 0.25E8 3.5E8 TERM
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 200
TRAC OFFS FICH AVI NOCL NFTO 41 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 39 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR  1 'y_b1'   COOR COMP 2 NOEU LECT b1 TERM
COUR  2 'y_b2'   COOR COMP 2 NOEU LECT b2 TERM
COUR  3 'y_b3'   COOR COMP 2 NOEU LECT b3 TERM
COUR  4 'y_b4'   COOR COMP 2 NOEU LECT b4 TERM
COUR  5 'dy_mk'  DEPL COMP 2 NOEU LECT mark TERM
COUR  6 'dy_b4'  DEPL COMP 2 NOEU LECT b4 TERM
COUR  7 'dy_f1b' DEPL COMP 2 NOEU LECT f1b TERM
COUR  8 'dx_mk'  DEPL COMP 1 NOEU LECT mark TERM
COUR  9 'dx_b4'  DEPL COMP 1 NOEU LECT b4 TERM
COUR 10 'dx_f1b' DEPL COMP 1 NOEU LECT f1b TERM
TRAC 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
TRAC 5 6 7 AXES 1.0 'DY [M]' YZER
TRAC 8 9 10 AXES 1.0 'DX [M]' YZER
LIST 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
LIST 5 6 7 AXES 1.0 'DY [M]' YZER
LIST 8 9 10 AXES 1.0 'DX [M]' YZER
QUAL COUR  8 REFE  7.33897E+00 TOLE 1.E-2
     COUR  9 REFE  7.64172E+00 TOLE 1.E-2
     COUR 10 REFE  7.49188E+00 TOLE 1.E-2
FIN
```

slid62.dgibi

```
opti echo 0;
opti donn 'px4cir3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'slid62_mesh.ps';
opti sauv form 'slid62.msh';
r = 2.0;
x0 = 3.0;
pc = x0 r 0;
pz = 0 0 1;
n = 16;
tol = 0.001;
ci1 ier = px4cir3d (x0 0 0) ((x0+r) r 0) pc (pc plus pz) n tol;
w = 2.0;
vzcir = 0 0 w;
nzc = 6;
c1 = ci1 volu tran nzc vzcir;
c2 = c1 tour 90 pc (pc plus pz);
c3 = c2 tour 90 pc (pc plus pz);
c4 = c3 tour 90 pc (pc plus pz);
circ = c1 et c2 et c3 et c4;
elim tol circ;
axe = pc d nzc (pc plus vzcir);
elim tol (circ et axe);
pm = pc plus (0 r w);
elim tol (pm et circ);
mark = manu poi1 pm;
trac cach qual (circ et mark);
*
h = 1.0;
len = 10.0;
a = 4.0;
nh = 4;
nb = enti (len / 1.0);
na = 12;
bas2d = (0 (0-h) -1.0) d (nb+nb) (len (0-h) -1.0);
base2d = bas2d tran nh (0 h 0);
base = base2d volu tran na (0 0 a);
trac cach qual base;
trac cach qual (base et circ et mark);
*
mesh = circ et base et mark;
tass mesh noop;
sauv form mesh;
trac cach qual mesh;
fin;
```

slid62.epx

```
SLID62
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM CUB8 circ base PMAT mark TERM
COMP NGRO 13 'bloc' LECT base TERM COND Y LT -0.99
             'f1a'  LECT axe TERM COND NEAR POIN 3 2 0
             'f1b'  LECT axe TERM COND NEAR POIN 3 2 2
             'f1'   LECT f1a f1b TERM
             'f2'   LECT axe DIFF f1 TERM
             'b1'   LECT circ TERM COND NEAR POIN 3 0 0
             'b2'   LECT circ TERM COND NEAR POIN 3 0 0.667
             'b3'   LECT circ TERM COND NEAR POIN 3 0 1.333
             'b4'   LECT circ TERM COND NEAR POIN 3 0 2
             'ns'   LECT base TERM COND Y GT -0.01
             'nm1'  LECT circ TERM COND CYLI
                                   X1 3 Y1 2 Z1 0
                                   X2 3 Y2 2 Z2 2 R 2.1
             'nm2'  LECT circ TERM COND CYLI
                                   X1 3 Y1 2 Z1 0
                                   X2 3 Y2 2 Z2 2 R 1.9
             'nm'   LECT nm1 DIFF nm2 TERM
     GROU 1  'em'   LECT circ TERM COND APPU LARG LECT nm TERM
     EPAI 0.2 LECT mark TERM ! Only for visualization
     COUL TURQ LECT circ TERM
          VERT LECT base TERM
          ROUG LECT mark TERM
MATE LINE RO 7800. YOUN 2.E11 NU 0.
          LECT circ base TERM
     MASS 0.0 LECT mark TERM
LINK COUP
     BLOQ 123 LECT bloc TERM
!    GLIS 1 ELIM
!         MAIT LECT circ TERM
!         ESCL LECT base TERM
     SLID 1 SURF PHI 0.2
                EMAS LECT em TERM
                NMAS LECT nm TERM
                NSLA LECT ns TERM
CHAR 1 FACT 2
!    FORC 1  3.33333E8 LECT f1 TERM
!    FORC 1  6.66667E8 LECT f2 TERM
!    FORC 2 -3.33333E8 LECT f1 TERM
!    FORC 2 -6.66667E8 LECT f2 TERM
     FORC 1  1.66667E8 LECT f1 TERM
     FORC 1  3.33333E8 LECT f2 TERM
     FORC 2 -1.66667E8 LECT f1 TERM
     FORC 2 -3.33333E8 LECT f2 TERM
     TABL 3 0. 0.  12.E-4 1.  6. 1.
ECRI DEPL VITE COOR FINT FEXT FLIA FREQ 600
     FICH ALIC FREQ 100
     FICH ALIC TEMP FREQ 1
          POIN LECT b1 b2 b3 b4 f1 f2 mark TERM
OPTI PAS UTIL
     LOG 1
!    GLIS NORM ELEM
     LNKS STAT VISU
CALC TINI 0 TFIN 40.E-3 PASF 5.E-6 NMAX 8000
PLAY
CAME   1 EYE   1.84447E+01  1.93365E+01  2.07597E+01
!        Q     9.11780E-01 -3.31861E-01  2.41333E-01 -1.68756E-02
         VIEW -4.51285E-01 -5.97022E-01 -6.63254E-01
         RIGH  8.82948E-01 -1.90951E-01 -4.28884E-01
         UP   -1.29404E-01  7.79167E-01 -6.13313E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E+00  1.55000E+00  1.00000E+00
!RSPHERE:  5.95840E+00
!RADIUS :  2.97920E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.32377E+01
!FAR    :  4.17088E+01
SCEN GEOM NAVI FREE
          POIN SPHP
!         FACE HFRO
        ! LINE HEOU SSHA
        ! LNKS SHOW GLIS JOIN
!    VECT SCCO FIEL FLIA SCAL USER PROG 0.25E8 PAS 0.25E8 3.5E8 TERM
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 200
TRAC OFFS FICH AVI NOCL NFTO 41 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 39 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR  1 'y_b1'   COOR COMP 2 NOEU LECT b1 TERM
COUR  2 'y_b2'   COOR COMP 2 NOEU LECT b2 TERM
COUR  3 'y_b3'   COOR COMP 2 NOEU LECT b3 TERM
COUR  4 'y_b4'   COOR COMP 2 NOEU LECT b4 TERM
COUR  5 'dy_mk'  DEPL COMP 2 NOEU LECT mark TERM
COUR  6 'dy_b4'  DEPL COMP 2 NOEU LECT b4 TERM
```

```
COUR  7 'dy_f1b' DEPL COMP 2 NOEU LECT f1b TERM
COUR  8 'dx_mk'  DEPL COMP 1 NOEU LECT mark TERM
COUR  9 'dx_b4'  DEPL COMP 1 NOEU LECT b4 TERM
COUR 10 'dx_f1b' DEPL COMP 1 NOEU LECT f1b TERM
TRAC 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
TRAC 5 6 7 AXES 1.0 'DY [M]' YZER
TRAC 8 9 10 AXES 1.0 'DX [M]' YZER
LIST 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
LIST 5 6 7 AXES 1.0 'DY [M]' YZER
LIST 8 9 10 AXES 1.0 'DX [M]' YZER
QUAL COUR  8 REFE  7.33897E+00 TOLE 1.E-2
     COUR  9 REFE  7.64172E+00 TOLE 1.E-2
     COUR 10 REFE  7.49188E+00 TOLE 1.E-2
FIN
```

slid63.dgibi

```
opti echo 0;
opti donn 'px4cir3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'slid63_mesh.ps';
opti sauv form 'slid63.msh';
r = 2.0;
x0 = 3.0;
pc = x0 r 0;
pz = 0 0 1;
n = 8;
tol = 0.001;
ci1 ier = px4cir3d (x0 0 0) ((x0+r) r 0) pc (pc plus pz) n tol;
w = 2.0;
vzcir = 0 0 w;
nzc = 3;
c1 = ci1 volu tran nzc vzcir;
c2 = c1 tour 90 pc (pc plus pz);
c3 = c2 tour 90 pc (pc plus pz);
c4 = c3 tour 90 pc (pc plus pz);
circ = c1 et c2 et c3 et c4;
elim tol circ;
axe = pc d nzc (pc plus vzcir);
elim tol (circ et axe);
pm = pc plus (0 r w);
elim tol (pm et circ);
mark = manu poi1 pm;
trac cach qual (circ et mark);
*
h = 1.0;
len = 10.0;
a = 4.0;
nh = 2;
nb = enti (len / 1.0);
na = 6;
bas2d = (0 (0-h) -1.0) d nb (len (0-h) -1.0);
base2d = bas2d tran nh (0 h 0);
base = base2d volu tran na (0 0 a);
trac cach qual base;
trac cach qual (base et circ et mark);
*
mesh = circ et base et mark;
tass mesh noop;
sauv form mesh;
trac cach qual mesh;
fin;
```

slid63.epx

```
SLID63
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM CUB8 circ base PMAT mark TERM
COMP NGRO 13 'bloc' LECT base TERM COND Y LT -0.99
             'f1a'  LECT axe TERM COND NEAR POIN 3 2 0
             'f1b'  LECT axe TERM COND NEAR POIN 3 2 2
             'f1'   LECT f1a f1b TERM
             'f2'   LECT axe DIFF f1 TERM
             'b1'   LECT circ TERM COND NEAR POIN 3 0 0
             'b2'   LECT circ TERM COND NEAR POIN 3 0 0.667
             'b3'   LECT circ TERM COND NEAR POIN 3 0 1.333
             'b4'   LECT circ TERM COND NEAR POIN 3 0 2
             'nm'   LECT base TERM COND Y GT -0.01
             'ns1'  LECT circ TERM COND CYLI
                                 X1 3 Y1 2 Z1 0
                                 X2 3 Y2 2 Z2 2 R 2.1
             'ns2'  LECT circ TERM COND CYLI
                                 X1 3 Y1 2 Z1 0
                                 X2 3 Y2 2 Z2 2 R 1.9
             'ns'   LECT ns1 DIFF ns2 TERM
     GROU 1  'em'   LECT base TERM COND APPU LARG LECT nm TERM
     EPAI 0.2 LECT mark TERM ! Only for visualization
     COUL TURQ LECT circ TERM
          VERT LECT base TERM
          ROUG LECT mark TERM
MATE LINE RO 7800. YOUN 2.E11 NU 0.
          LECT circ base TERM
     MASS 0.0 LECT mark TERM
LINK COUP
     BLOQ 123 LECT bloc TERM
!    GLIS 1 ELIM
!         MAIT LECT circ TERM
!         ESCL LECT base TERM
     SLID 1 SURF EMAS LECT em TERM
                 NMAS LECT nm TERM
                 NSLA LECT ns TERM
CHAR 1 FACT 2
     FORC 1  3.33333E8 LECT f1 TERM
     FORC 1  6.66667E8 LECT f2 TERM
     FORC 2 -3.33333E8 LECT f1 TERM
     FORC 2 -6.66667E8 LECT f2 TERM
     TABL 3 0. 0.  12.E-4 1.  6. 1.
ECRI DEPL VITE COOR FINT FEXT FLIA FREQ 600
     FICH ALIC FREQ 100
     FICH ALIC TEMP FREQ 1
          POIN LECT b1 b2 b3 b4 f1 f2 mark TERM
OPTI PAS UTIL
     LOG 1
!    GLIS NORM ELEM
     LNKS STAT VISU
CALC TINI 0 TFIN 40.E-3 PASF 1.E-5 NMAX 4000
PLAY
CAME   1 EYE   1.84447E+01  1.93365E+01  2.07597E+01
!        Q     9.11780E-01 -3.31861E-01  2.41333E-01 -1.68756E-02
         VIEW -4.51285E-01 -5.97022E-01 -6.63254E-01
         RIGH  8.82948E-01 -1.90951E-01 -4.28884E-01
         UP   -1.29404E-01  7.79167E-01 -6.13313E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E+00  1.55000E+00  1.00000E+00
!RSPHERE:  5.95840E+00
!RADIUS :  2.97920E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.32377E+01
!FAR    :  4.17088E+01
SCEN GEOM NAVI FREE
          POIN SPHP
!         FACE HFRO
        ! LINE HEOU SSHA
        ! LNKS SHOW GLIS JOIN
!    VECT SCCO FIEL FLIA SCAL USER PROG 0.25E8 PAS 0.25E8 3.5E8 TERM
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 100
TRAC OFFS FICH AVI NOCL NFTO 41 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 39 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR  1 'y_b1'   COOR COMP 2 NOEU LECT b1 TERM
COUR  2 'y_b2'   COOR COMP 2 NOEU LECT b2 TERM
COUR  3 'y_b3'   COOR COMP 2 NOEU LECT b3 TERM
COUR  4 'y_b4'   COOR COMP 2 NOEU LECT b4 TERM
COUR  5 'dy_mk'  DEPL COMP 2 NOEU LECT mark TERM
COUR  6 'dy_b4'  DEPL COMP 2 NOEU LECT b4 TERM
COUR  7 'dy_f1b' DEPL COMP 2 NOEU LECT f1b TERM
COUR  8 'dx_mk'  DEPL COMP 1 NOEU LECT mark TERM
COUR  9 'dx_b4'  DEPL COMP 1 NOEU LECT b4 TERM
COUR 10 'dx_f1b' DEPL COMP 1 NOEU LECT f1b TERM
TRAC 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
TRAC 5 6 7 AXES 1.0 'DY [M]' YZER
TRAC 8 9 10 AXES 1.0 'DX [M]' YZER
LIST 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
LIST 5 6 7 AXES 1.0 'DY [M]' YZER
LIST 8 9 10 AXES 1.0 'DX [M]' YZER
QUAL COUR  8 REFE  8.10051E+00 TOLE 1.E-2
     COUR  9 REFE  7.81625E+00 TOLE 1.E-2
     COUR 10 REFE  7.96371E+00 TOLE 1.E-2
FIN
```

slid64.dgibi

```
opti echo 0;
opti donn 'px4cir3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'slid64_mesh.ps';
opti sauv form 'slid64.msh';
r = 2.0;
x0 = 3.0;
pc = x0 r 0;
pz = 0 0 1;
n = 8;
tol = 0.001;
ci1 ier = px4cir3d (x0 0 0) ((x0+r) r 0) pc (pc plus pz) n tol;
w = 2.0;
vzcir = 0 0 w;
nzc = 3;
c1 = ci1 volu tran nzc vzcir;
c2 = c1 tour 90 pc (pc plus pz);
c3 = c2 tour 90 pc (pc plus pz);
c4 = c3 tour 90 pc (pc plus pz);
circ = c1 et c2 et c3 et c4;
elim tol circ;
```

```
axe = pc d nzc (pc plus vzcir);
elim tol (circ et axe);
pm = pc plus (0 r w);
elim tol (pm et circ);
mark = manu poi1 pm;
trac cach qual (circ et mark);
*
h = 1.0;
len = 10.0;
a = 4.0;
nh = 2;
nb = enti (len / 1.0);
na = 6;
bas2d = (0 (0-h) -1.0) d nb (len (0-h) -1.0);
base2d = bas2d tran nh (0 h 0);
base = base2d volu tran na (0 0 a);
trac cach qual base;
trac cach qual (base et circ et mark);
*
mesh = circ et base et mark;
tass mesh noop;
sauv form mesh;
trac cach qual mesh;
fin;
```

slid64.epx

```
SLID64
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM CUB8 circ base PMAT mark TERM
COMP NGRO 13 'bloc' LECT base TERM COND Y LT -0.99
             'f1a'  LECT axe TERM COND NEAR POIN 3 2 0
             'f1b'  LECT axe TERM COND NEAR POIN 3 2 2
             'f1'   LECT f1a f1b TERM
             'f2'   LECT axe DIFF f1 TERM
             'b1'   LECT circ TERM COND NEAR POIN 3 0 0
             'b2'   LECT circ TERM COND NEAR POIN 3 0 0.667
             'b3'   LECT circ TERM COND NEAR POIN 3 0 1.333
             'b4'   LECT circ TERM COND NEAR POIN 3 0 2
             'nm'   LECT base TERM COND Y GT -0.01
             'ns1'  LECT circ TERM COND CYLI
                               X1 3 Y1 2 Z1 0
                               X2 3 Y2 2 Z2 2 R 2.1
             'ns2'  LECT circ TERM COND CYLI
                               X1 3 Y1 2 Z1 0
                               X2 3 Y2 2 Z2 2 R 1.9
             'ns'   LECT ns1 DIFF ns2 TERM
     GROU 1  'em'   LECT base TERM COND APPU LARG LECT nm TERM
     EPAI 0.2 LECT mark TERM ! Only for visualization
     COUL TURQ LECT circ TERM
          VERT LECT base TERM
          ROUG LECT mark TERM
MATE LINE RO 7800. YOUN 2.E11 NU 0.
          LECT circ base TERM
     MASS 0.0 LECT mark TERM
LINK COUP
     BLOQ 123 LECT bloc TERM
!    GLIS 1 ELIM
!         MAIT LECT circ TERM
!         ESCL LECT base TERM
     SLID 1 SURF FROT MUST 0.25 MUDY 0.25 GAMM 0.1
                EMAS LECT em TERM
                NMAS LECT nm TERM
                NSLA LECT ns TERM
CHAR 1 FACT 2
     FORC 1  3.33333E8 LECT f1 TERM
     FORC 1  6.66667E8 LECT f2 TERM
     FORC 2 -3.33333E8 LECT f1 TERM
     FORC 2 -6.66667E8 LECT f2 TERM
     TABL 3 0. 0.  12.E-4 1.  6. 1.
ECRI DEPL VITE COOR FINT FEXT FLIA FREQ 600
     FICH ALIC FREQ 100
     FICH ALIC TEMP FREQ 1
          POIN LECT b1 b2 b3 b4 f1 f2 mark TERM
OPTI PAS UTIL
     LOG 1
!    GLIS NORM ELEM
     LNKS STAT VISU
CALC TINI 0 TFIN 40.E-3 PASF 1.E-5 NMAX 4000
PLAY
CAME   1 EYE   1.84447E+01  1.93365E+01  2.07597E+01
!        Q     9.11780E-01 -3.31861E-01  2.41333E-01 -1.68756E-02
         VIEW -4.51285E-01 -5.97022E-01 -6.63254E-01
         RIGH  8.82948E-01 -1.90951E-01 -4.28884E-01
         UP   -1.29404E-01  7.79167E-01 -6.13313E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E+00  1.55000E+00  1.00000E+00
!RSPHERE:  5.95840E+00
!RADIUS :  2.97920E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.32377E+01
!FAR    :  4.17088E+01
SCEN GEOM NAVI FREE
          POIN SPHP
!         FACE HFRO
        ! LINE HEOU SSHA
        ! LNKS SHOW GLIS JOIN
!    VECT SCCO FIEL FLIA SCAL USER PROG 0.25E8 PAS 0.25E8 3.5E8 TERM
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 100
TRAC OFFS FICH AVI NOCL NFTO 41 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 39 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR  1 'y_b1'   COOR COMP 2 NOEU LECT b1 TERM
COUR  2 'y_b2'   COOR COMP 2 NOEU LECT b2 TERM
COUR  3 'y_b3'   COOR COMP 2 NOEU LECT b3 TERM
COUR  4 'y_b4'   COOR COMP 2 NOEU LECT b4 TERM
COUR  5 'dy_mk'  DEPL COMP 2 NOEU LECT mark TERM
COUR  6 'dy_b4'  DEPL COMP 2 NOEU LECT b4 TERM
COUR  7 'dy_f1b' DEPL COMP 2 NOEU LECT f1b TERM
COUR  8 'dx_mk'  DEPL COMP 1 NOEU LECT mark TERM
COUR  9 'dx_b4'  DEPL COMP 1 NOEU LECT b4 TERM
COUR 10 'dx_f1b' DEPL COMP 1 NOEU LECT f1b TERM
TRAC 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
TRAC 5 6 7 AXES 1.0 'DY [M]' YZER
TRAC 8 9 10 AXES 1.0 'DX [M]' YZER
LIST 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
LIST 5 6 7 AXES 1.0 'DY [M]' YZER
LIST 8 9 10 AXES 1.0 'DX [M]' YZER
QUAL COUR  8 REFE  7.81657E+00 TOLE 1.E-2
     COUR  9 REFE  4.11209E+00 TOLE 1.E-2
     COUR 10 REFE  5.96795E+00 TOLE 1.E-2
FIN
```

slid65.dgibi

```
opti echo 0;
opti donn 'px4cir3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'slid65_mesh.ps';
opti sauv form 'slid65.msh';
r = 2.0;
x0 = 3.0;
pc = x0 r 0;
pz = 0 0 1;
n = 16;
tol = 0.001;
ci1 ier = px4cir3d (x0 0 0) ((x0+r) r 0) pc (pc plus pz) n tol;
w = 2.0;
vzcir = 0 0 w;
nzc = 6;
c1 = ci1 volu tran nzc vzcir;
c2 = c1 tour 90 pc (pc plus pz);
c3 = c2 tour 90 pc (pc plus pz);
c4 = c3 tour 90 pc (pc plus pz);
circ = c1 et c2 et c3 et c4;
elim tol circ;
axe = pc d nzc (pc plus vzcir);
elim tol (circ et axe);
pm = pc plus (0 r w);
elim tol (pm et circ);
mark = manu poi1 pm;
trac cach qual (circ et mark);
*
h = 1.0;
len = 10.0;
a = 4.0;
nh = 4;
nb = enti (len / 1.0);
na = 12;
bas2d = (0 (0-h) -1.0) d (nb+nb) (len (0-h) -1.0);
base2d = bas2d tran nh (0 h 0);
base = base2d volu tran na (0 0 a);
trac cach qual base;
trac cach qual (base et circ et mark);
*
mesh = circ et base et mark;
tass mesh noop;
sauv form mesh;
trac cach qual mesh;
fin;
```

slid65.epx

```
SLID65
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM CUB8 circ base PMAT mark TERM
COMP NGRO 13 'bloc' LECT base TERM COND Y LT -0.99
             'f1a'  LECT axe TERM COND NEAR POIN 3 2 0
             'f1b'  LECT axe TERM COND NEAR POIN 3 2 2
             'f1'   LECT f1a f1b TERM
             'f2'   LECT axe DIFF f1 TERM
             'b1'   LECT circ TERM COND NEAR POIN 3 0 0
             'b2'   LECT circ TERM COND NEAR POIN 3 0 0.667
```

```
            'b3'   LECT circ TERM COND NEAR POIN 3 0 1.333
            'b4'   LECT circ TERM COND NEAR POIN 3 0 2
            'nm'   LECT base TERM COND Y GT -0.01
            'ns1'  LECT circ TERM COND CYLI
                              X1 3 Y1 2 Z1 0
                              X2 3 Y2 2 Z2 2 R 2.1
            'ns2'  LECT circ TERM COND CYLI
                              X1 3 Y1 2 Z1 0
                              X2 3 Y2 2 Z2 2 R 1.9
            'ns'   LECT ns1 DIFF ns2 TERM
     GROU 1  'em'   LECT base TERM COND APPU LARG LECT nm TERM
     EPAI 0.2 LECT mark TERM ! Only for visualization
     COUL TURQ LECT circ TERM
          VERT LECT base TERM
          ROUG LECT mark TERM
MATE LINE RO 7800. YOUN 2.E11 NU 0.
          LECT circ base TERM
     MASS 0.0 LECT mark TERM
LINK COUP
     BLOQ 123 LECT bloc TERM
!    GLIS 1 ELIM
!         MAIT LECT circ TERM
!         ESCL LECT base TERM
     SLID 1 SURF EMAS LECT em TERM
                 NMAS LECT nm TERM
                 NSLA LECT ns TERM
CHAR 1 FACT 2
!    FORC 1  3.33333E8 LECT f1 TERM
!    FORC 1  6.66667E8 LECT f2 TERM
!    FORC 2 -3.33333E8 LECT f1 TERM
!    FORC 2 -6.66667E8 LECT f2 TERM
     FORC 1  1.66667E8 LECT f1 TERM
     FORC 1  3.33333E8 LECT f2 TERM
     FORC 2 -1.66667E8 LECT f1 TERM
     FORC 2 -3.33333E8 LECT f2 TERM
     TABL 3 0. 0.  12.E-4 1.  6. 1.
ECRI DEPL VITE COOR FINT FEXT FLIA FREQ 600
     FICH ALIC FREQ 100
     FICH ALIC TEMP FREQ 1
          POIN LECT b1 b2 b3 b4 f1 f2 mark TERM
OPTI PAS UTIL
     LOG 1
!    GLIS NORM ELEM
     LNKS STAT VISU
CALC TINI 0 TFIN 40.E-3 PASF 5.E-6 NMAX 8000
PLAY
CAME   1 EYE   1.84447E+01  1.93365E+01  2.07597E+01
!        Q     9.11780E-01 -3.31861E-01  2.41333E-01 -1.68756E-02
         VIEW -4.51285E-01 -5.97022E-01 -6.63254E-01
         RIGH  8.82948E-01 -1.90951E-01 -4.28884E-01
         UP   -1.29404E-01  7.79167E-01 -6.13313E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E+00  1.55000E+00  1.00000E+00
!RSPHERE:  5.95840E+00
!RADIUS :  2.97920E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.32377E+01
!FAR    :  4.17088E+01
SCEN GEOM NAVI FREE
          POIN SPHP
!         FACE HFRO
        ! LINE HEOU SSHA
        ! LNKS SHOW GLIS JOIN
!    VECT SCCO FIEL FLIA SCAL USER PROG 0.25E8 PAS 0.25E8 3.5E8 TERM
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 200
TRAC OFFS FICH AVI NOCL NFTO 41 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 39 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR  1 'y_b1'   COOR COMP 2 NOEU LECT b1 TERM
COUR  2 'y_b2'   COOR COMP 2 NOEU LECT b2 TERM
COUR  3 'y_b3'   COOR COMP 2 NOEU LECT b3 TERM
COUR  4 'y_b4'   COOR COMP 2 NOEU LECT b4 TERM
COUR  5 'dy_mk'  DEPL COMP 2 NOEU LECT mark TERM
COUR  6 'dy_b4'  DEPL COMP 2 NOEU LECT b4 TERM
COUR  7 'dy_f1b' DEPL COMP 2 NOEU LECT f1b TERM
COUR  8 'dx_mk'  DEPL COMP 1 NOEU LECT mark TERM
COUR  9 'dx_b4'  DEPL COMP 1 NOEU LECT b4 TERM
COUR 10 'dx_f1b' DEPL COMP 1 NOEU LECT f1b TERM
TRAC 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
TRAC 5 6 7 AXES 1.0 'DY [M]' YZER
TRAC 8 9 10 AXES 1.0 'DX [M]' YZER
LIST 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
LIST 5 6 7 AXES 1.0 'DY [M]' YZER
LIST 8 9 10 AXES 1.0 'DX [M]' YZER
QUAL COUR  8 REFE  7.91231E+00 TOLE 1.E-2
     COUR  9 REFE  7.897781E+00 TOLE 1.E-2
     COUR 10 REFE  7.91091E+00 TOLE 1.E-2
FIN
```

slid66.dgibi

```
opti echo 0;
opti donn 'px4cir3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'slid66_mesh.ps';
opti sauv form 'slid66.msh';
r = 2.0;
x0 = 3.0;
pc = x0 r 0;
pz = 0 0 1;
n = 16;
tol = 0.001;
ci1 ier = px4cir3d (x0 0 0) ((x0+r) r 0) pc (pc plus pz) n tol;
w = 2.0;
vzcir = 0 0 w;
nzc = 6;
c1 = ci1 volu tran nzc vzcir;
c2 = c1 tour 90 pc (pc plus pz);
c3 = c2 tour 90 pc (pc plus pz);
c4 = c3 tour 90 pc (pc plus pz);
circ = c1 et c2 et c3 et c4;
elim tol circ;
axe = pc d nzc (pc plus vzcir);
elim tol (circ et axe);
pm = pc plus (0 r w);
elim tol (pm et circ);
mark = manu poi1 pm;
trac cach qual (circ et mark);
*
h = 1.0;
len = 10.0;
a = 4.0;
nh = 4;
nb = enti (len / 1.0);
na = 12;
bas2d = (0 (0-h) -1.0) d (nb+nb) (len (0-h) -1.0);
base2d = bas2d tran nh (0 h 0);
base = base2d volu tran na (0 0 a);
trac cach qual base;
trac cach qual (base et circ et mark);
*
mesh = circ et base et mark;
tass mesh noop;
sauv form mesh;
trac cach qual mesh;
fin;
```

slid66.epx

```
SLID66
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM CUB8 circ base PMAT mark TERM
COMP NGRO 13 'bloc' LECT base TERM COND Y LT -0.99
            'f1a'  LECT axe TERM COND NEAR POIN 3 2 0
            'f1b'  LECT axe TERM COND NEAR POIN 3 2 2
            'f1'   LECT f1a f1b TERM
            'f2'   LECT axe DIFF f1 TERM
            'b1'   LECT circ TERM COND NEAR POIN 3 0 0
            'b2'   LECT circ TERM COND NEAR POIN 3 0 0.667
            'b3'   LECT circ TERM COND NEAR POIN 3 0 1.333
            'b4'   LECT circ TERM COND NEAR POIN 3 0 2
            'nm'   LECT base TERM COND Y GT -0.01
            'ns1'  LECT circ TERM COND CYLI
                              X1 3 Y1 2 Z1 0
                              X2 3 Y2 2 Z2 2 R 2.1
            'ns2'  LECT circ TERM COND CYLI
                              X1 3 Y1 2 Z1 0
                              X2 3 Y2 2 Z2 2 R 1.9
            'ns'   LECT ns1 DIFF ns2 TERM
     GROU 1  'em'   LECT base TERM COND APPU LARG LECT nm TERM
     EPAI 0.2 LECT mark TERM ! Only for visualization
     COUL TURQ LECT circ TERM
          VERT LECT base TERM
          ROUG LECT mark TERM
MATE LINE RO 7800. YOUN 2.E11 NU 0.
          LECT circ base TERM
     MASS 0.0 LECT mark TERM
LINK COUP
     BLOQ 123 LECT bloc TERM
!    GLIS 1 ELIM
!         MAIT LECT circ TERM
!         ESCL LECT base TERM
     SLID 1 SURF FROT MUST 0.25 MUDY 0.25 GAMM 0.1
                 EMAS LECT em TERM
                 NMAS LECT nm TERM
                 NSLA LECT ns TERM
CHAR 1 FACT 2
!    FORC 1  3.33333E8 LECT f1 TERM
!    FORC 1  6.66667E8 LECT f2 TERM
!    FORC 2 -3.33333E8 LECT f1 TERM
!    FORC 2 -6.66667E8 LECT f2 TERM
     FORC 1  1.66667E8 LECT f1 TERM
     FORC 1  3.33333E8 LECT f2 TERM
     FORC 2 -1.66667E8 LECT f1 TERM
     FORC 2 -3.33333E8 LECT f2 TERM
     TABL 3 0. 0.  12.E-4 1.  6. 1.
ECRI DEPL VITE COOR FINT FEXT FLIA FREQ 600
     FICH ALIC FREQ 100
     FICH ALIC TEMP FREQ 1
```

```
        POIN LECT b1 b2 b3 b4 f1 f2 mark TERM
OPTI PAS UTIL
     LOG 1
!    GLIS NORM ELEM
     LNKS STAT VISU
CALC TINI 0 TFIN 40.E-3 PASF 5.E-6 NMAX 8000
PLAY
CAME   1 EYE   1.84447E+01  1.93365E+01  2.07597E+01
!        Q     9.11780E-01 -3.31861E-01  2.41333E-01 -1.68756E-02
         VIEW -4.51285E-01 -5.97022E-01 -6.63254E-01
         RIGH  8.82948E-01 -1.90951E-01 -4.28884E-01
         UP   -1.29404E-01  7.79167E-01 -6.13313E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E+00  1.55000E+00  1.00000E+00
!RSPHERE:  5.95840E+00
!RADIUS :  2.97920E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.32377E+01
!FAR    :  4.17088E+01
SCEN GEOM NAVI FREE
          POIN SPHP
!         FACE HFRO
        ! LINE HEOU SSHA
        ! LNKS SHOW GLIS JOIN
!    VECT SCCO FIEL FLIA SCAL USER PROG 0.25E8 PAS 0.25E8 3.5E8 TERM
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 200
TRAC OFFS FICH AVI NOCL NFTO 41 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 39 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR  1 'y_b1'   COOR COMP 2 NOEU LECT b1 TERM
COUR  2 'y_b2'   COOR COMP 2 NOEU LECT b2 TERM
COUR  3 'y_b3'   COOR COMP 2 NOEU LECT b3 TERM
COUR  4 'y_b4'   COOR COMP 2 NOEU LECT b4 TERM
COUR  5 'dy_mk'  DEPL COMP 2 NOEU LECT mark TERM
COUR  6 'dy_b4'  DEPL COMP 2 NOEU LECT b4 TERM
COUR  7 'dy_f1b' DEPL COMP 2 NOEU LECT f1b TERM
COUR  8 'dx_mk'  DEPL COMP 1 NOEU LECT mark TERM
COUR  9 'dx_b4'  DEPL COMP 1 NOEU LECT b4 TERM
COUR 10 'dx_f1b' DEPL COMP 1 NOEU LECT f1b TERM
TRAC 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
TRAC 5 6 7 AXES 1.0 'DY [M]' YZER
TRAC 8 9 10 AXES 1.0 'DX [M]' YZER
LIST 1 2 3 4 AXES 1.0 'Y-COOR. [M]' YZER
LIST 5 6 7 AXES 1.0 'DY [M]' YZER
LIST 8 9 10 AXES 1.0 'DX [M]' YZER
QUAL COUR  8 REFE  7.80381E+00 TOLE 1.E-2
     COUR  9 REFE  4.06469E+00 TOLE 1.E-2
     COUR 10 REFE  5.93983E+00 TOLE 1.E-2
FIN
```

slidl3.epx

```
SLIDL3
ECHO
!CONV win
DPLA LAGR
GEOM LIBR POIN 5 Q42L 1 PMAT 1 TERM
 0 0  1 0
 0 1  1 1
 0.5 1.1
 1 2 4 3
 5
COMP EPAI 1.0 LECT tous TERM
     GROU 2 'targ' LECT 1 TERM
            'proj' LECT 2 TERM
     EPAI 1.0 LECT targ TERM
          0.2 LECT proj TERM
     NGRO 1 'bloc' LECT 1 2 TERM
     COUL TURQ LECT targ TERM
          ROUG LECT proj TERM
MATE VM23 RO 7850.0 YOUN 2.1E11 NU 0.33 ELAS 2.1E11
          TRAC 1 2.1E11 1.D0
          LECT targ TERM
     MASS 1000. LECT proj TERM
LINK COUP ! SPLT NONE
     BLOQ 12 LECT bloc TERM
     SLID 1 SURF EMAS LECT targ TERM
                 NMAS LECT 3 4 TERM
                 NSLA LECT 5 TERM
INIT VITE 2 -100 LECT proj TERM
ECRI DEPL VITE ACCE FLIA FREQ 1
     FICH ALIC FREQ 1
OPTI NOTE CSTA 0.7
     LOG 1
     JAUM
     LMST
     LNKS STAT VISU
     LIAJ ALPH 0.0
CALC TINI 0 TEND 3.E-3
PLAY
CAME   1 EYE   5.00000E-01  5.50000E-01  3.75000E+00
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  5.50000E-01  0.00000E+00
!RSPHERE:  7.50000E-01
!RADIUS :  3.75000E+00
!ASPECT :  1.00000E+00
!NEAR   :  2.92500E+00
!FAR    :  5.25000E+00
SCEN GEOM NAVI FREE
          REFE FRAM
          FACE SBAC
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 29 FPS 15 KFRE 10 COMP -1 REND
FREQ 1
GOTR LOOP 27 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
COUR  1 'dy_3' DEPL COMP 2 NOEU LECT 3 TERM
COUR  2 'dy_5' DEPL COMP 2 NOEU LECT 5 TERM
COUR 11 'vy_3' VITE COMP 2 NOEU LECT 3 TERM
COUR 12 'vy_5' VITE COMP 2 NOEU LECT 5 TERM
COUR 21 'y_3'  COOR COMP 2 NOEU LECT 3 TERM
COUR 22 'y_5'  COOR COMP 2 NOEU LECT 5 TERM
TRAC  1  2 AXES 1.0 'DEPL. [M]' YZER
TRAC 11 12 AXES 1.0 'VITE. [M/S]' YZER
TRAC 21 22 AXES 1.0 'COOR. [M]' YZER
LIST  1  2 AXES 1.0 'DEPL. [M]' YZER
LIST 11 12 AXES 1.0 'VITE. [M/S]' YZER
LIST 21 22 AXES 1.0 'COOR. [M]' YZER
QUAL COUR  2 REFE -7.51287E-02 TOLE 1.E-2
     COUR 12 REFE  1.48998E+01 TOLE 1.E-2
     COUR 22 REFE  1.02487E+00 TOLE 1.E-2
FIN
```

squas9.epx

```
SQUAS9
*
 ECHO
!CONV WIN
*--------------------------------------------------------Type of problem
CAST mesh
 TRID
 AMOR
*--------------------------------------------------------Geometry (Mesh)
GEOM
 DST3 sh3
 Q4GS sh4
TERM
*-------------------------------------------Additional geometrical data
COMP
 GROU 1 'e_alit' LECT 1 TERM
 COUL roug LECT piece  TERM
      turq LECT die    TERM
      rose LECT punch  TERM
      vert LECT holder TERM
NGRO 6 ! 17
        'n_forcz'  LECT holder TERM COND NEAR POIN 0.15 0.15 0.005
        'n_ali1'   LECT holder TERM COND NEAR POIN 0.1225 0.1025 0.005
        'n_ali2'   LECT punch  TERM COND NEAR POIN 0 0 0.005
        'n_alit'   LECT n_ali1 n_ali2 TERM
        'symx'     LECT piece die punch holder TERM COND X LT 0.001
        'symy'     LECT piece die punch holder TERM COND Y LT 0.001
 EPAI 0.8E-03 LECT piece TERM
 EPAI 1.0E-03 LECT die punch holder TERM
*--------------------------------------------------------------Materials
MATE
 VMIS ISOT RO 2.767E+03 YOUN 7.0E+10 NU 3.E-01 ELAS 2.93E+08
      TRAC  12  2.93000E+08               4.18571E-03
                3.09400E+08               6.10600E-03
                3.16350E+08               7.12129E-03
                3.24380E+08               8.46700E-03
                3.33800E+08               1.03196E-02
                3.45120E+08               1.29853E-02
                3.59060E+08               1.70604E-02
                3.76870E+08               2.38049E-02
                4.00710E+08               3.62904E-02
                4.34740E+08               6.35266E-02
                4.87940E+08               1.40321E-01
                1.09500E+09               1.01564E+00
       LECT piece TERM
 LINE RO 7.8E+03 YOUN  2.E+11 NU 3.E-01
       LECT die punch holder TERM
*--------------------------------------------------------------Couplings
LINK COUP SPLT NONE SOLV SPLI
 BLOQ 123456 LECT die DIFF symx symy TERM
       12456 LECT punch holder DIFF symx symy TERM
 CONT SPLA NX 1 NY 0 NZ 0 LECT symx TERM
      SPLA NX 0 NY 1 NZ 0 LECT symy TERM
 DEPL 3 0.1E+01 FONC 1 LECT punch TERM
!!GLIS 3
```

```
!!  FROT MUST 0.25 MUDY 0.25 GAMM 1
!!  CMAI LECT piece  TERM EXTE LECT n_ext1 TERM
!!  CESC LECT punch  TERM
!!  FROT MUST 0.125 MUDY 0.125 GAMM 1
!!  CMAI LECT piece  TERM EXTE LECT n_ext2 TERM
!!  CESC LECT die    TERM
!!  CMAI LECT piece  TERM EXTE LECT n_ext3 TERM
!!  CESC LECT holder TERM
 SLID 3
   SURF FROT MUST 0.25 MUDY 0.25 GAMM 1
        EMAS LECT piece  TERM
        NMAS LECT piece  TERM
        NSLA LECT punch  TERM
   SURF FROT MUST 0.125 MUDY 0.125 GAMM 1
        EMAS LECT piece  TERM
        NMAS LECT piece  TERM
        NSLA LECT die    TERM
   SURF EMAS LECT piece  TERM
        NMAS LECT piece  TERM
        NSLA LECT holder TERM
 FONC 1 TABL 2
        0.000E+00  0.000E+00
        0.101E-01 -0.500E-01
*-------------------------------------------------------Factorized loads
CHAR 1 FACT 2
 FORC 3 0.1E+01 LECT n_forcz TERM
        TABL 3
        0.000E+00  0.000E+00
        0.100E-02 -0.200E+05
        0.100E-00 -0.200E+05
*----------------------------------------------------Initial conditions
INIT VITE 3 -4.95050 LECT punch TERM
*---------------------------------------------------------------Storage
ECRI
  DEPL VITE TFRE 1.0E-3 ! POIN LECT n_alit TERM
  FICH ALIC      TFRE 1.0E-04
  FICH ALIC TEMP TFRE 1.0E-05
                 POIN LECT n_alit TERM
                 ELEM LECT e_alit TERM
*---------------------------------------------------------------Options
OPTI LOG 1
     step io
     GLIS SYME
*------------------------------------------------------------Time Steps
CALC TINI 0.E+00 TFIN 10.E-03
*======================================================================
SUIT
Post-treatment (time curves from alice temps file)
ECHO
*
RESU ALIC TEMP GARD PSCR
*
SORT GRAP
*
AXTE 1000.0 'Time [ms]'
*
COUR  1 'dz_1' DEPL COMP 3 NOEU LECT n_ali1 TERM
COUR  2 'dz_2' DEPL COMP 3 NOEU LECT n_ali2 TERM
COUR  3 'vz_1' VITE COMP 3 NOEU LECT n_ali1 TERM
COUR  4 'vz_2' VITE COMP 3 NOEU LECT n_ali2 TERM
*
trac 1 2 axes 1.0 'DISPL. [M]'
trac 3 4 axes 1.0 'VELOC. [M/S]'
*
QUAL DEPL COMP 3 LECT n_ali2 TERM REFE -4.95050E-2 TOLE 5.E-3
*======================================================================
FIN
```

squas9e.epx

```
SQUA - 01E
*
ECHO
*
RESU ALIC 'squas9.ali' GARD PSCR
*
COMP
 GROU 6 'masses' LECT    1 PAS 1    3 TERM
        'piece'  LECT   37 PAS 1 1480 TERM
        'die'    LECT   23 PAS 1   36 4769 PAS 1 7013 TERM
        'punch'  LECT   22 3082 PAS 1 4768 TERM
        'holder' LECT    4 PAS 1   21 1481 PAS 1 3081 TERM
        'e_alit' LECT    1             TERM
 COUL jaun LECT masses TERM
      roug LECT piece  TERM
      turq LECT die    TERM
      rose LECT punch  TERM
      vert LECT holder TERM
 NGRO 15 'n_masses' LECT masses TERM
         'n_piece'  LECT piece  TERM
         'n_die'    LECT die    TERM
         'n_punch'  LECT punch  TERM
         'n_holder' LECT holder TERM
         'n_ext1'   LECT 7342   TERM
         'n_ext2'   LECT 7343   TERM
         'n_ext3'   LECT 7344   TERM
         'n_pibloq' LECT 39     TERM
         'n_bl156'  LECT 1 PAS 1 38 TERM
         'n_bl246'  LECT 78 116 PAS 1 152 TERM
         'n_forcz'  LECT 2673 TERM
         'n_ali1'   LECT 1522 TERM
         'n_ali2'   LECT 3439 TERM
         'n_alit'   LECT n_ali1 n_ali2 TERM
*
OPTI PRIN
*
SORT VISU NSTO 1
*=============================================================
PLAY
CAME   1 EYE  -5.23690E-01 -5.46688E-01  4.75014E-01
!        Q     7.79402E-01  5.00912E-01 -1.99864E-01 -3.18865E-01
         VIEW  6.30994E-01  6.53365E-01 -4.18283E-01
         RIGH  7.16760E-01 -6.97276E-01 -7.89860E-03
         UP    2.96819E-01  2.94824E-01  9.08282E-01
         FOV   2.28819E+01
SCEN OBJE SELM LECT piece TERM
     DHAS CGLA
     GEOM NAVI FREE
          FACE SBAC
          LINE HEOU SFRE
          poin sphe 1
     colo pape
     lima on
          sele gol2 appl mesh

sler cam1 1        nfra 1
trac offs fich avi      nocl nfto 101 fps 10 kfre 10 comp -1
                                                             rend
FREQ 1
GOTR LOOP  99 offs fich avi cont nocl
                                                             rend
GO
TRAC offs fich avi cont
                                                             rend
ENDPLAY
*=============================================================
FIN
```

squas9h.epx

```
SQUA - 01H
*
ECHO
*
RESU ALIC 'squas9.ali' GARD PSCR
*
COMP
 GROU 6 'masses' LECT    1 PAS 1    3 TERM
        'piece'  LECT   37 PAS 1 1480 TERM
        'die'    LECT   23 PAS 1   36 4769 PAS 1 7013 TERM
        'punch'  LECT   22 3082 PAS 1 4768 TERM
        'holder' LECT    4 PAS 1   21 1481 PAS 1 3081 TERM
        'e_alit' LECT    1             TERM
 COUL jaun LECT masses TERM
      roug LECT piece  TERM
      turq LECT die    TERM
      rose LECT punch  TERM
      vert LECT holder TERM
 NGRO 15 'n_masses' LECT masses TERM
         'n_piece'  LECT piece  TERM
         'n_die'    LECT die    TERM
         'n_punch'  LECT punch  TERM
         'n_holder' LECT holder TERM
         'n_ext1'   LECT 7342   TERM
         'n_ext2'   LECT 7343   TERM
         'n_ext3'   LECT 7344   TERM
         'n_pibloq' LECT 39     TERM
         'n_bl156'  LECT 1 PAS 1 38 TERM
         'n_bl246'  LECT 78 116 PAS 1 152 TERM
         'n_forcz'  LECT 2673 TERM
         'n_ali1'   LECT 1522 TERM
         'n_ali2'   LECT 3439 TERM
         'n_alit'   LECT n_ali1 n_ali2 TERM
*
OPTI PRIN
*
SORT VISU NSTO 1
*=============================================================
PLAY
CAME   1 EYE  -5.23690E-01 -5.46688E-01  4.75014E-01
!        Q     7.92247E-01  4.80338E-01 -1.91448E-01 -3.23987E-01
         VIEW  6.14595E-01  6.37040E-01 -4.65245E-01
         RIGH  7.16760E-01 -6.97275E-01 -7.89894E-03
         UP    3.29436E-01  3.28614E-01  8.85147E-01
         FOV   2.28819E+01
CAME   2 EYE  -5.23690E-01 -5.46688E-01  4.75014E-01
!        Q     7.92247E-01  4.80338E-01 -1.91448E-01 -3.23987E-01
         VIEW  6.14595E-01  6.37040E-01 -4.65245E-01
         RIGH  7.16760E-01 -6.97275E-01 -7.89894E-03
         UP    3.29436E-01  3.28614E-01  8.85147E-01
         FOV   1.16819E+01
SCEN OBJE SELM LECT piece TERM
     DHAS CGLA
     GEOM NAVI FREE
          FACE SBAC
          LINE HEOU SFRE
          poin sphe 1
     iso  fill fiel ecro 3 scal user prog 1.e-2 pas 1.e-2 14.e-2 term
                        supp lect piece term
     text isca
     colo pape
```

```
     lima on

sler cam1 1 cam2 2 nfra 40
trac offs fich avi      nocl nfto 181 fps 10 kfre 10 comp -1
                                                            rend

sler cam1 2        nfra 1
TRAC offs fich avi cont nocl
                                                            rend
FREQ 1
GOTR LOOP  99 offs fich avi cont nocl
                                                            rend
GO
TRAC offs fich avi cont nocl
                                                            rend
sler cam1 2 cam2 1 nfra 40
TRAC offs fich avi cont
                                                            rend
ENDPLAY
*==================================================================
FIN
```

squas9m.epx

```
SQUAS9M
*
ECHO
CONV WIN
*
OPTI PRIN
RESU ALIC '..\squas9.ali' GARD PSCR
SORT VISU NSTO 1
FIN
```

squas9z.epx

```
SQUAS9Z
*
ECHO
CONV WIN
*
OPTI PRIN
RESU ALIC '..\squas9.ali' GARD PSCR
SORT VISU NSTO 42
FIN
```

List of input files